

ASME BPVC.II.A-2021

SECTION II
MATERIALS

2021

ASME Boiler and
Pressure Vessel Code
An International Code

Part A
Ferrous Material Specifications
(Beginning to SA-450)


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AN INTERNATIONAL CODE

2021 ASME Boiler & Pressure Vessel Code

2021 Edition

July 1, 2021

II MATERIALS

Part A

Ferrous Material Specifications (Beginning to SA-450)

ASME Boiler and Pressure Vessel Committee
on Materials



The American Society of
Mechanical Engineers

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INTERPRETATIONS

Interpretations are issued in real time in ASME's Interpretations Database at <http://go.asme.org/Interpretations>. Historical BPVC interpretations may also be found in the Database.

CODE CASES

The Boiler and Pressure Vessel Code committees meet regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases that have been adopted will appear in the appropriate 2021 Code Cases book: "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books up to the publication of the 2023 Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. Code Case users can check the current status of any Code Case at <http://go.asme.org/BPVCCDatabase>. Code Case users can also view an index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases at <http://go.asme.org/BPVCC>.

FOREWORD*

(21)

In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

- (a) Committee on Power Boilers (I)
- (b) Committee on Materials (II)
- (c) Committee on Construction of Nuclear Facility Components (III)
- (d) Committee on Heating Boilers (IV)
- (e) Committee on Nondestructive Examination (V)
- (f) Committee on Pressure Vessels (VIII)
- (g) Committee on Welding, Brazing, and Fusing (IX)
- (h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
- (i) Committee on Nuclear Inservice Inspection (XI)
- (j) Committee on Transport Tanks (XII)
- (k) Committee on Overpressure Protection (XIII)
- (l) Technical Oversight Management Committee (TOMC)

Where reference is made to “the Committee” in this Foreword, each of these committees is included individually and collectively.

The Committee’s function is to establish rules of safety relating only to pressure integrity, which govern the construction* of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the

* The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI’s requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

** *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at <http://go.asme.org/BPVCPublicReview> to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in this Section, the singular shall be interpreted as the plural, and vice versa, and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

The words "shall," "should," and "may" are used in this Standard as follows:

- *Shall* is used to denote a requirement.
- *Should* is used to denote a recommendation.
- *May* is used to denote permission, neither a requirement nor a recommendation.

STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not “approve,” “certify,” “rate,” or “endorse” any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities “are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code,” or “meet the requirements of the ASME Boiler and Pressure Vessel Code.” An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as “ASME,” “ASME Standard,” or any other marking including “ASME” or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

(21) **SUBMITTAL OF TECHNICAL INQUIRIES TO THE BOILER AND PRESSURE VESSEL STANDARDS COMMITTEES**

1 INTRODUCTION

(a) The following information provides guidance to Code users for submitting technical inquiries to the applicable Boiler and Pressure Vessel (BPV) Standards Committee (hereinafter referred to as the Committee). See the guidelines on approval of new materials under the ASME Boiler and Pressure Vessel Code in Section II, Part D for requirements for requests that involve adding new materials to the Code. See the guidelines on approval of new welding and brazing materials in Section II, Part C for requirements for requests that involve adding new welding and brazing materials (“consumables”) to the Code.

Technical inquiries can include requests for revisions or additions to the Code requirements, requests for Code Cases, or requests for Code Interpretations, as described below:

(1) *Code Revisions.* Code revisions are considered to accommodate technological developments, to address administrative requirements, to incorporate Code Cases, or to clarify Code intent.

(2) *Code Cases.* Code Cases represent alternatives or additions to existing Code requirements. Code Cases are written as a Question and Reply, and are usually intended to be incorporated into the Code at a later date. When used, Code Cases prescribe mandatory requirements in the same sense as the text of the Code. However, users are cautioned that not all regulators, jurisdictions, or Owners automatically accept Code Cases. The most common applications for Code Cases are as follows:

(-a) to permit early implementation of an approved Code revision based on an urgent need

(-b) to permit use of a new material for Code construction

(-c) to gain experience with new materials or alternative requirements prior to incorporation directly into the Code

(3) *Code Interpretations*

(-a) Code Interpretations provide clarification of the meaning of existing requirements in the Code and are presented in Inquiry and Reply format. Interpretations do not introduce new requirements.

(-b) Interpretations will be issued only if existing Code text is ambiguous or conveys conflicting requirements. If a revision of the requirements is required to support the Interpretation, an Intent Interpretation will be issued in parallel with a revision to the Code.

(b) Code requirements, Code Cases, and Code Interpretations established by the Committee are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or Owners to choose any method of design or any form of construction that conforms to the Code requirements.

(c) Inquiries that do not comply with the following guidance or that do not provide sufficient information for the Committee’s full understanding may result in the request being returned to the Inquirer with no action.

2 INQUIRY FORMAT

Submittals to the Committee should include the following information:

(a) *Purpose.* Specify one of the following:

(1) request for revision of present Code requirements

(2) request for new or additional Code requirements

(3) request for Code Case

(4) request for Code Interpretation

(b) *Background.* The Inquirer should provide the information needed for the Committee’s understanding of the Inquiry, being sure to include reference to the applicable Code Section, Division, Edition, Addenda (if applicable), paragraphs, figures, and tables. This information should include a statement indicating why the included paragraphs, figures, or tables are ambiguous or convey conflicting requirements. Preferably, the Inquirer should provide a copy of, or relevant extracts from, the specific referenced portions of the Code.

(c) *Presentations.* The Inquirer may desire to attend or be asked to attend a meeting of the Committee to make a formal presentation or to answer questions from the Committee members with regard to the Inquiry. Attendance at a BPV Standards Committee meeting shall be at the expense of the Inquirer. The Inquirer's attendance or lack of attendance at a meeting will not be used by the Committee as a basis for acceptance or rejection of the Inquiry by the Committee. However, if the Inquirer's request is unclear, attendance by the Inquirer or a representative may be necessary for the Committee to understand the request sufficiently to be able to provide an Interpretation. If the Inquirer desires to make a presentation at a Committee meeting, the Inquirer should provide advance notice to the Committee Secretary, to ensure time will be allotted for the presentation in the meeting agenda. The Inquirer should consider the need for additional audiovisual equipment that might not otherwise be provided by the Committee. With sufficient advance notice to the Committee Secretary, such equipment may be made available.

3 CODE REVISIONS OR ADDITIONS

Requests for Code revisions or additions should include the following information:

(a) *Requested Revisions or Additions.* For requested revisions, the Inquirer should identify those requirements of the Code that they believe should be revised, and should submit a copy of, or relevant extracts from, the appropriate requirements as they appear in the Code, marked up with the requested revision. For requested additions to the Code, the Inquirer should provide the recommended wording and should clearly indicate where they believe the additions should be located in the Code requirements.

(b) *Statement of Need.* The Inquirer should provide a brief explanation of the need for the revision or addition.

(c) *Background Information.* The Inquirer should provide background information to support the revision or addition, including any data or changes in technology that form the basis for the request, that will allow the Committee to adequately evaluate the requested revision or addition. Sketches, tables, figures, and graphs should be submitted, as appropriate. The Inquirer should identify any pertinent portions of the Code that would be affected by the revision or addition and any portions of the Code that reference the requested revised or added paragraphs.

4 CODE CASES

Requests for Code Cases should be accompanied by a statement of need and background information similar to that described in 3(b) and 3(c), respectively, for Code revisions or additions. The urgency of the Code Case (e.g., project underway or imminent, new procedure) should be described. In addition, it is important that the request is in connection with equipment that will bear the ASME Single Certification Mark, with the exception of Section XI applications. The proposed Code Case should identify the Code Section and Division, and should be written as a Question and a Reply, in the same format as existing Code Cases. Requests for Code Cases should also indicate the applicable Code Editions and Addenda (if applicable) to which the requested Code Case applies.

5 CODE INTERPRETATIONS

(a) Requests for Code Interpretations should be accompanied by the following information:

(1) *Inquiry.* The Inquirer should propose a condensed and precise Inquiry, omitting superfluous background information and, when possible, composing the Inquiry in such a way that a "yes" or a "no" Reply, with brief limitations or conditions, if needed, can be provided by the Committee. The proposed question should be technically and editorially correct.

(2) *Reply.* The Inquirer should propose a Reply that clearly and concisely answers the proposed Inquiry question. Preferably, the Reply should be "yes" or "no," with brief limitations or conditions, if needed.

(3) *Background Information.* The Inquirer should include a statement indicating why the included paragraphs, figures, or tables are ambiguous or convey conflicting requirements. The Inquirer should provide any need or background information, such as described in 3(b) and 3(c), respectively, for Code revisions or additions, that will assist the Committee in understanding the proposed Inquiry and Reply.

If the Inquirer believes a revision of the Code requirements would be helpful to support the Interpretation, the Inquirer may propose such a revision for consideration by the Committee. In most cases, such a proposal is not necessary.

(b) Requests for Code Interpretations should be limited to an Interpretation of a particular requirement in the Code or in a Code Case. Except with regard to interpreting a specific Code requirement, the Committee is not permitted to consider consulting-type requests such as the following:

(1) a review of calculations, design drawings, welding qualifications, or descriptions of equipment or parts to determine compliance with Code requirements

- (2) a request for assistance in performing any Code-prescribed functions relating to, but not limited to, material selection, designs, calculations, fabrication, inspection, pressure testing, or installation
- (3) a request seeking the rationale for Code requirements

6 SUBMITTALS

(a) *Submittal.* Requests for Code Interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at <http://go.asme.org/InterpretationRequest>. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt. If the Inquirer is unable to use the online form, the Inquirer may mail the request to the following address:

Secretary
ASME Boiler and Pressure Vessel Committee
Two Park Avenue
New York, NY 10016-5990

All other Inquiries should be mailed to the Secretary of the BPV Committee at the address above. Inquiries are unlikely to receive a response if they are not written in clear, legible English. They must also include the name of the Inquirer and the company they represent or are employed by, if applicable, and the Inquirer's address, telephone number, fax number, and e-mail address, if available.

(b) *Response.* The Secretary of the appropriate Committee will provide a written response, via letter or e-mail, as appropriate, to the Inquirer, upon completion of the requested action by the Committee. Inquirers may track the status of their Interpretation Request at <http://go.asme.org/Interpretations>.

PERSONNEL

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January 1, 2021

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PREFACE

The American Society of Mechanical Engineers (ASME) and the American Society for Testing and Materials (ASTM) have cooperated for more than fifty years in the preparation of material specifications adequate for safety in the field of pressure equipment for ferrous and nonferrous materials, contained in Section II (Part A — Ferrous and Part B — Nonferrous) of the ASME Boiler and Pressure Vessel Code.

The evolution of this cooperative effort is contained in Professor A. M. Greene's "History of the ASME Boiler Code," which was published as a series of articles in *Mechanical Engineering* from July 1952 through August 1953 and is now available from ASME in a special bound edition. The following quotations from this history, which was based upon the minutes of the ASME Boiler and Pressure Vessel Committee, will help focus on the cooperative nature of the specifications found in Section II, Material Specifications.

"General discussion of material specifications comprising Paragraphs 1 to 112 of Part 2 and the advisability of having them agree with ASTM specifications," (1914).

"ASME Subcommittee appointed to confer with ASTM," (1916).

"Because of this cooperation the specifications of the 1918 Edition of the ASME Boiler Code were more nearly in agreement with ASTM specifications. In the 1924 Edition of the Code, 10 specifications were in complete agreement with ASTM specifications, 4 in substantial agreement and 2 covered materials for which ASTM had no corresponding specifications."

"In Section II, Material Specifications, the paragraphs were given new numbers beginning with S-1 and extending to S-213," (1925).

"Section II was brought into agreement with changes made in the latest ASTM specifications since 1921," (1932).

"The Subcommittee on Material Specifications arranged for the introduction of the revisions of many of the specifications so that they would agree with the latest form of the earlier ASTM specifications...," (1935).

From the preceding, it is evident that many of the material specifications were prepared by the Boiler and Pressure Vessel Code Committees, then subsequently, by cooperative action, modified and identified as ASTM specifications. Section II, Parts A and B, currently contain many material specifications that are identical with the corresponding ASTM specifications and some that have been modified for Code usage. Many of these specifications are published in dual format. That is, they contain both U.S. Customary units and SI units. The metrication protocols followed in the specifications are those adopted by ASTM, and are usually to the rules of IEEE/ASTM SI 10-1997, Standard for the Use of the International System of Units (SI): The Modern Metric System.

In 1969, the American Welding Society began publication of specifications for welding rods, electrodes, and filler metals, hitherto issued by ASTM. The Boiler and Pressure Vessel Committee has recognized this new arrangement, and is now working with AWS on these specifications. Section II, Part C, contains the welding material specifications approved for Code use.

In 1992, the ASME Board of Pressure Technology Codes and Standards endorsed the use of non-ASTM material for Boiler and Pressure Vessel Code applications. It is the intent to follow the procedures and practices currently in use to implement the adoption of non-ASTM materials.

All identical specifications are indicated by the ASME/originating organization symbols. The specifications prepared and copyrighted by ASTM, AWS, and other originating organizations are reproduced in the Code with the permission of the respective Society. The ASME Boiler and Pressure Vessel Committee has given careful consideration to each new and revised specification, and has made such changes as they deemed necessary to make the specification adaptable for Code usage. In addition, ASME has furnished ASTM with the basic requirements that should govern many proposed new specifications. Joint action will continue an effort to make the ASTM, AWS, and ASME specifications identical.

To assure that there will be a clear understanding on the part of the users of Section II, ASME publishes both the identical specifications and those amended for Code usage every 2 years.

The ASME Boiler and Pressure Vessel Code has been adopted into law by 50 states and many municipalities in the United States and by all of the Canadian provinces.

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SA-524	Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures	891
SA-530/SA-530M	Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe . . .	901
SA-587	Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry	1045
SA-660	Specification for Centrifugally Cast Carbon Steel Pipe for High-Temperature Service . . .	1093
SA-671/SA-671M	Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	1119
SA-672/SA-672M	Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures	1127
SA-691/SA-691M	Specification for Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	1151
SA-727/SA-727M	Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness	1217
SA-731/SA-731M	Specification for Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe	1223
SA-790/SA-790M	Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe	1329
SA-813/SA-813M	Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe	1347
SA-814/SA-814M	Specification for Cold-Worked Welded Austenitic Stainless Steel Pipe	1359
SA-941	Specification for Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys	1413
SA-961/SA-961M	Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications	1437
SA-999/SA-999M	Specification for General Requirements for Alloy and Stainless Steel Pipe	1521

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SA-568/SA-568M	Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for	995
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SA-20/SA-20M	Specification for General Requirements for Steel Plates for Pressure Vessels	65
SA-203/SA-203M	Specification for Pressure Vessel Plates, Alloy Steel, Nickel	267
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SA-225/SA-225M	Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel	319
SA-240/SA-240M	Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications	345
SA-263	Specification for Stainless Chromium Steel-Clad Plate	377
SA-264	Specification for Stainless Chromium-Nickel Steel-Clad Plate	383
SA-265	Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate	389
SA-285/SA-285M	Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength	433
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SA-414/SA-414M	Specification for Steel, Sheet, Carbon, for Pressure Vessels	705
SA-455/SA-455M	Specification for Pressure Vessel Plates, Carbon Steel, High-Strength Manganese	769
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SA-515/SA-515M	Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher- Temperature Service	873
SA-516/SA-516M	Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower- Temperature Service	877
SA-517/SA-517M	Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered	881
SA-533/SA-533M	Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	911
SA-537/SA-537M	Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel	915
SA-542/SA-542M	Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium	937
SA-543/SA-543M	Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Nickel- Chromium-Molybdenum	943
SA-553/SA-553M	Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 7, 8, and 9% Nickel	947
SA-562/SA-562M	Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings	967
SA-612/SA-612M	Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service	1069
SA-645/SA-645M	Specification for Pressure Vessel Plates, 5% and 5 ¹ / ₂ % Nickel Alloy Steels, Specially Heat Treated	1079
SA-662/SA-662M	Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	1099
SA-666	Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar	1103
SA-693	Specification for Precipitation-Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip	1159
SA-724/SA-724M	Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, Quenched and Tempered, for Welded Pressure Vessels	1211
SA-736/SA-736M	Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper- Chromium-Molybdenum-Columbium (Niobium) Alloy Steel	1229
SA-737/SA-737M	Specification for Pressure Vessel Plates, High-Strength Low-Alloy Steel	1233
SA-738/SA-738M	Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	1237
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SA-832/SA-832M	Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium	1377

SA-841/SA-841M	Specification for Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Control Process (TMCP)	1393
SA-1010/SA-1010M	Specification for Higher-Strength Martensitic Stainless Steel Plate, Sheet, and Strip	1543
SA-1017/SA-1017M	Specification for Pressure Vessel Plates, Alloy-Steel, Chromium-Molybdenum-Tungsten	1569
SA/AS 1548	Specification for Fine Grained, Weldable Steel Plates for Pressure Equipment	1585
SA/EN 10028-2	Specification for Flat Products Made of Steels for Pressure Purposes Part 2: Non-Alloy and Alloy Steels With Specified Elevated Temperature Properties	1591
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SA/EN 10028-7	Specification for Flat Products Made of Steels for Pressure Purposes Part 7: Stainless Steels	1601
SA/GB 713	Specification for Steel Plates for Boilers and Pressure Vessels	1615
SA/JIS G3118	Specification for Carbon Steel Plates for Pressure Vessels for Intermediate and Moderate Temperature Service	1619

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SA-192/SA-192M	Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service	237
SA-209/SA-209M	Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	275
SA-210/SA-210M	Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes	279
SA-213/SA-213M	Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes	285
SA-214/SA-214M	Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	301
SA-249/SA-249M	Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes	361
SA-250/SA-250M	Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes	371
SA-268/SA-268M	Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	403
SA-334/SA-334M	Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service	499
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SA-450/SA-450M	Specification for General Requirements for Carbon and Low Alloy Steel Tubes	743
SA-513	Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing	847
SA-556/SA-556M	Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	951
SA-557/SA-557M	Specification for Electric-Resistance-Welded Carbon Steel Feedwater Heater Tubes	959
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SA-803/SA-803M	Specification for Seamless and Welded Ferritic Stainless Steel Feedwater Heater Tubes	1339
SA-941	Specification for Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys	1413
SA-1016/SA-1016M	Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes	1557
SA/EN 10216-2	Specification for Seamless Steel Tubes for Pressure Purposes Part 2: Technical Delivery Conditions for Non-Alloy and Alloy Steel Tubes With Specified Elevated Temperature Properties	1609

SA/EN 10217-1	Specification for Welded Steel Tubes for Pressure Purposes Part 1: Technical Delivery Conditions for Electric Welded and Submerged Arc Welded Non-Alloy Steel Tubes With Specified Room Temperature Properties	1611
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Structural Steel

SA-6/SA-6M	Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling	1
SA-36/SA-36M	Specification for Carbon Structural Steel	127
SA-283/SA-283M	Specification for Low and Intermediate Tensile Strength Carbon Steel Plates	429
SA-572/SA-572M	Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel	1031
SA-656/SA-656M	Specification for Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate With Improved Formability	1089
SA-1008/SA-1008M	Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy With Improved Formability	1533
SA-1011/SA-1011M	Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy With Improved Formability, and Ultra-High-Strength	1547
SA/CSA-G40.21	Specification for Structural Quality Steels	1587
SA/EN 10025-2	Specification for Hot Rolled Products of Structural Steels Part 2: Technical Delivery Conditions for Non-Alloy Structural Steels	1589
SA/IS 2062	Specification for Hot Rolled Medium and High Tensile Structural Steel	1617

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SA-47/SA-47M	Specification for Ferritic Malleable Iron Castings	131
SA-278/SA-278M	Specification for Gray Iron Castings for Pressure Containing Parts for Temperatures up to 650°F (350°C)	423
SA-395/SA-395M	Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures	673
SA-476/SA-476M	Specification for Ductile Iron Castings for Paper Mill Dryer Rolls	773
SA-748/SA-748M	Specification for Statically Cast Chilled White Iron-Gray Iron Dual Metal Rolls for Pressure Vessel Use	1253
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SPECIFICATION REMOVAL

From time to time, it becomes necessary to remove specifications from this Part of Section II. This occurs because the sponsoring society (e.g., ASTM, AWS, CEN) has notified ASME that the specification has either been replaced with another specification, or that there is no known use and production of a material. Removal of a specification from this Section also results in concurrent removal of the same specification from Section IX and from all of the ASME Boiler and Pressure Vessel Construction Codes that reference the material. This action effectively prohibits further use of the material in ASME Boiler and Pressure Vessel construction.

The following specifications will be dropped from this Section in the next Edition, unless information concerning current production and use of the material is received before December 1 of this year:

SA/NF A 36-215

If you are currently using and purchasing new material to this specification for ASME Boiler and Pressure Vessel Code construction, and if discontinuance of this specification would present a hardship, please notify the Secretary of the ASME Boiler and Pressure Vessel Committee, at the address shown below:

Secretary
ASME Boiler and Pressure Vessel Committee
Two Park Avenue
New York, NY 10016-5990

SUMMARY OF CHANGES

Errata to the BPV Code may be posted on the ASME website to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in the BPV Code. Such Errata shall be used on the date posted.

Information regarding Special Notices and Errata is published by ASME at <http://go.asme.org/BPVCerrata>.

Changes given below are identified on the pages by a margin note, **(21)**, placed next to the affected area.

<i>Page</i>	<i>Location</i>	<i>Change</i>
xi	List of Sections	(1) Listing for Section III updated (2) Section XIII added (3) Code Case information updated
xiii	Foreword	(1) Subparagraph (k) added and subsequent subparagraph redesignated (2) Second footnote revised (3) Last paragraph added
xvi	Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees	Paragraphs 1(a)(3)(-b), 2(b), and 5(a)(3) revised
xix	Personnel	Updated
xl	ASTM Personnel	Updated
131	SA-47/SA-47M	Reapproved
169	SA-105/SA-105M	In Table 1, added "[Note (1)]" reference to vanadium
189	SA-134/SA-134M	Revised in its entirety
195	SA-135/SA-135M	Revised in its entirety
211	SA-179/SA-179M	Reapproved
221	SA-182/SA-182M	In Table 3, increased minimum yield strength for Grade F60 to "70 [485]"
275	SA-209/SA-209M	Reapproved
285	SA-213/SA-213M	Revised in its entirety
335	SA-234/SA-234M	Revised in its entirety
361	SA-249/SA-249M	Revised title to Supplementary Requirement S9
371	SA-250/SA-250M	Reapproved
377	SA-263	Reapproved
383	SA-264	Reapproved
389	SA-265	Reapproved
423	SA-278/SA-278M	Reapproved
429	SA-283/SA-283M	Reapproved
451	SA-311/SA-311M	Reapproved
457	SA-312/SA-312M	Revised in its entirety

<i>Page</i>	<i>Location</i>	<i>Change</i>
499	SA-334/SA-334M	Reapproved
553	SA-352/SA-352M	Reapproved
647	SA-372/SA-372M	Reapproved
673	SA-395/SA-395M	Reapproved
711	SA-420/SA-420M	Revised in its entirety
719	SA-423/SA-423M	Reapproved
755	SA-451/SA-451M	Reapproved
769	SA-455/SA-455M	Reapproved
773	SA-476/SA-476M	Reapproved
831	SA-487/SA-487M	Reapproved
915	SA-537/SA-537M	Revised in its entirety
927	SA-541/SA-541M	Reapproved
943	SA-543/SA-543M	Reapproved
951	SA-556/SA-556M	Reapproved
971	SA-563	Reapproved
983	SA-564/SA-564M	Reapproved
1045	SA-587	Reapproved
1051	SA-592/SA-592M	Reapproved
1055	SA-609/SA-609M	Reapproved
1069	SA-612/SA-612M	Reapproved
1073	SA-638/SA-638M	Reapproved
1079	SA-645/SA-645M	Reapproved
1093	SA-660	Reapproved
1115	SA-667/SA-667M	Reapproved
1119	SA-671/SA-671M	Revised in its entirety
1127	SA-672/SA-672M	Revised in its entirety
1135	SA-675/SA-675M	Reapproved
1169	SA-696	Reapproved
1195	SA-705/SA-705M	Reapproved
1205	SA-723/SA-723M	Reapproved
1211	SA-724/SA-724M	Reapproved
1217	SA-727/SA-727M	Reapproved
1243	SA-739	Reapproved
1253	SA-748/SA-748M	Reapproved
1257	SA-749/SA-749M	Reapproved
1269	SA-751	Reapproved

<i>Page</i>	<i>Location</i>	<i>Change</i>
1277	SA-765/SA-765M	Reapproved
1283	SA-770/SA-770M	Reapproved
1323	SA-789/SA-789M	Revised in its entirety
1329	SA-790/SA-790M	Revised in its entirety
1347	SA-813/SA-813M	Reapproved
1383	SA-834	Reapproved
1389	SA-836/SA-836M	Reapproved
1403	SA-874/SA-874M	Reapproved
1491	SA-988/SA-988M	Added
1505	SA-989/SA-989M	Added
1515	SA-995	Reapproved
1543	SA-1010/SA-1010M	Reapproved
1585	SA/AS 1548	Para. 1.2 corrected by errata to state "Marking"
1587	SA/CSA-G40.21	Revised
1589	SA/EN 10025-2	Revised
1591	SA/EN 10028-2	Para. 1.1 corrected by errata to state "Marking"
1595	SA/EN 10028-3	Para. 1.1 corrected by errata to state "Marking"
1611	SA/EN 10217-1	Revised
1615	SA/GB 713	Reapproved
1617	SA/IS 2062	Revised
1625	SA/NF A 36-215	Deleted
1627	II-200	Revised
1629	Table II-200-1	(1) Updated (2) For SA-182/SA-182M, (b) revised to reference "S32205"
1638	Table II-200-2	Updated
1646	Table IV-800-1	Revised
1647	IV-1400	Revised

LIST OF CHANGES IN RECORD NUMBER ORDER

DELETED

CROSS-REFERENCING AND STYLISTIC CHANGES IN THE BOILER AND PRESSURE VESSEL CODE

There have been structural and stylistic changes to BPVC, starting with the 2011 Addenda, that should be noted to aid navigating the contents. The following is an overview of the changes:

Subparagraph Breakdowns/Nested Lists Hierarchy

- First-level breakdowns are designated as (a), (b), (c), etc., as in the past.
- Second-level breakdowns are designated as (1), (2), (3), etc., as in the past.
- Third-level breakdowns are now designated as (-a), (-b), (-c), etc.
- Fourth-level breakdowns are now designated as (-1), (-2), (-3), etc.
- Fifth-level breakdowns are now designated as (+a), (+b), (+c), etc.
- Sixth-level breakdowns are now designated as (+1), (+2), etc.

Footnotes

With the exception of those included in the front matter (roman-numbered pages), all footnotes are treated as endnotes. The endnotes are referenced in numeric order and appear at the end of each BPVC section/subsection.

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees has been moved to the front matter. This information now appears in all Boiler Code Sections (except for Code Case books).

Cross-References

It is our intention to establish cross-reference link functionality in the current edition and moving forward. To facilitate this, cross-reference style has changed. Cross-references within a subsection or subarticle will not include the designator/identifier of that subsection/subarticle. Examples follow:

- *(Sub-)Paragraph Cross-References.* The cross-references to subparagraph breakdowns will follow the hierarchy of the designators under which the breakdown appears.
 - If subparagraph (-a) appears in X.1(c)(1) and is referenced in X.1(c)(1), it will be referenced as (-a).
 - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(c)(2), it will be referenced as (1)(-a).
 - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).
 - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).
- *Equation Cross-References.* The cross-references to equations will follow the same logic. For example, if eq. (1) appears in X.1(a)(1) but is referenced in X.1(b), it will be referenced as eq. (a)(1)(1). If eq. (1) appears in X.1(a)(1) but is referenced in a different subsection/subarticle/paragraph, it will be referenced as eq. X.1(a)(1)(1).

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SPECIFICATION FOR GENERAL REQUIREMENTS FOR ROLLED STRUCTURAL STEEL BARS, PLATES, SHAPES, AND SHEET PILING



SA-6/SA-6M



(Identical with ASTM Specification A6/A6M-17a.)

Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

1. Scope

1.1 This general requirements specification covers a group of common requirements that, unless otherwise specified in the applicable product specification, apply to rolled structural steel bars, plates, shapes, and sheet piling covered by each of the following product specifications issued by ASTM:

ASTM Designation	Title of Specification
A36/A36M	Carbon Structural Steel
A131/A131M	Structural Steel for Ships
A242/A242M	High-Strength Low-Alloy Structural Steel
A283/A283M	Low and Intermediate Tensile Strength Carbon Steel Plates
A328/A328M	Steel Sheet Piling
A514/A514M	High-Yield Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
A529/A529M	High-Strength Carbon-Manganese Steel of Structural Quality
A572/A572M	High-Strength Low-Alloy Columbium-Vanadium Steel
A573/A573M	Structural Carbon Steel Plates of Improved Toughness
A588/A588M	High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance
A633/A633M	Normalized High-Strength Low-Alloy Structural Steel Plates
A656/A656M	Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate with Improved Formability
A690/A690M	High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments
A709/A709M	Structural Steel for Bridges
A710/A710M	Precipitation-Strengthened Low-Carbon Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Structural Steel Plates
A769/A769M	Carbon and High-Strength Electric Resistance Forge-Welded Steel Structural Shapes
A786/A786M	Hot-Rolled Carbon, Low-Alloy, High-Strength Low-Alloy, and Alloy Steel Floor Plates
A827/A827M	Plates, Carbon Steel, for Forging and Similar Applications

A829/A829M	Alloy Structural Steel Plates
A830/A830M	Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements
A857/A857M	Steel Sheet Piling, Cold Formed, Light Gage
A871/A871M	High-Strength Low-Alloy Structural Steel Plate With Atmospheric Corrosion Resistance
A913/A913M	High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)
A945/A945M	High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness
A950/A950M	Fusion-Bonded Epoxy-Coated Structural Steel H-Piles and Sheet Piling
A992/A992M	Structural Steel Shapes
A1043/A1043M	Structural Steel with Low Yield to Tensile Ratio for Use in Buildings
A1066/A1066M	High-Strength Low-Alloy Structural Steel Plate Produced by Thermo-Mechanical Controlled Process (TMCP)

1.2 Annex A1 lists permitted variations in dimensions and mass (Note 1) in SI units. The values listed are not exact conversions of the values in Tables 1 to 31 inclusive but are, instead, rounded or rationalized values. Conformance to Annex A1 is mandatory when the “M” specification designation is used.

NOTE 1—The term “weight” is used when inch-pound units are the standard; however, under SI, the preferred term is “mass.”

1.3 Annex A2 lists the dimensions of some shape profiles.

1.4 Appendix X1 provides information on coil as a source of structural products.

1.5 Appendix X2 provides information on the variability of tensile properties in plates and structural shapes.

1.6 Appendix X3 provides information on weldability.

1.7 Appendix X4 provides information on cold bending of plates, including suggested minimum inside radii for cold bending.

1.8 This general requirements specification also covers a group of supplementary requirements that are applicable to several of the above product specifications as indicated therein. Such requirements are provided for use where additional testing or additional restrictions are required by the purchaser, and apply only where specified individually in the purchase order.

1.9 In case of any conflict in requirements, the requirements of the applicable product specification prevail over those of this general requirements specification.

1.10 Additional requirements that are specified in the purchase order and accepted by the supplier are permitted, provided that such requirements do not negate any of the requirements of this general requirements specification or the applicable product specification.

1.11 For purposes of determining conformance with this general requirements specification and the applicable product specification, values are to be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E29.

1.12 The text of this general requirements specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.13 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.14 This general requirements specification and the applicable product specification are expressed in both inch-pound units and SI units; however, unless the order specifies the applicable “M” specification designation (SI units), the structural product is furnished to inch-pound units.

1.15 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.16 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A131/A131M Specification for Structural Steel for Ships
 A370 Test Methods and Definitions for Mechanical Testing of Steel Products
 A673/A673M Specification for Sampling Procedure for Impact Testing of Structural Steel
 A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
 A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
 A829/A829M Specification for Alloy Structural Steel Plates
 A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
 E29 Practice for Using Significant Digits in Test Data to

Determine Conformance with Specifications
 E112 Test Methods for Determining Average Grain Size
 E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

2.2 American Welding Society Standards:

A5.1/A5.1M Mild Steel Covered Arc-Welding Electrodes
 A5.5/A5.5M Low-Alloy Steel Covered Arc-Welding Electrodes
 A5.17/A5.17M Specification For Carbon Steel Electrodes And Fluxes For Submerged Arc Welding
 A5.18/A5.18M Specification For Carbon Steel Electrodes And Rods For Gas Shielded Arc Welding
 A5.20/A5.20M Carbon Steel Electrodes For Flux Cored Arc Welding
 A5.23/A5.23M Low Alloy Steel Electrodes And Fluxes For Submerged Arc Welding
 A5.28/A5.28M Specification For Low-Alloy Steel Electrodes And Rods For Gas Shielded Arc Welding
 A5.29/A5.29M Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding
 D1.1/D1.1M Structural Welding Code Steel

2.3 U.S. Military Standards:

MIL-STD-129 Marking for Shipment and Storage
 MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.4 U.S. Federal Standard:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

2.5 American Society of Mechanical Engineers Code:

ASME Boiler and Pressure Vessel Code, Section IX

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *Plates (other than floor plates)*—Flat, hot-rolled steel, ordered to thickness or weight [mass] and typically width and length, commonly classified as follows:

3.1.1.1 When Ordered to Thickness:

(1) Over 8 in. [200 mm] in width and 0.230 in. [6 mm] or over in thickness.

(2) Over 48 in. [1200 mm] in width and 0.180 in. [4.5 mm] or over in thickness.

3.1.1.2 When Ordered to Weight [Mass]:

(1) Over 8 in. [200 mm] in width and 9.392 lb/ft² [47.10 kg/m²] or heavier.

(2) Over 48 in. [1200 mm] in width and 7.350 lb/ft² [35.32 kg/m²] or heavier.

3.1.1.3 *Discussion*—Steel products are available in various thickness, width, and length combinations depending upon equipment and processing capabilities of various manufacturers and processors. Historic limitations of a product based upon dimensions (thickness, width, and length) do not take into

account current production and processing capabilities. To qualify any product to a particular product specification requires all appropriate and necessary tests be performed and that the results meet the limits prescribed in that product specification. If the necessary tests required by a product specification cannot be conducted, the product cannot be qualified to that specification. This general requirement standard contains permitted variations for the commonly available sizes. Permitted variations for other sizes are subject to agreement between the customer and the manufacturer or processor, whichever is applicable.

3.1.1.4 Slabs, sheet bars, and skelp, though frequently falling in the foregoing size ranges, are not classed as plates.

3.1.1.5 Coils are excluded from qualification to the applicable product specification until they are decoiled, leveled or straightened, formed (if applicable), cut to length, and, if required, properly tested by the processor in accordance with ASTM specification requirements (see Sections 9 – 15, 18, and 19 and the applicable product specification).

3.1.2 *Shapes (Flanged Sections):*

3.1.2.1 *structural-size shapes*—rolled flanged sections having at least one dimension of the cross section 3 in. [75 mm] or greater.

3.1.2.2 *bar-size shapes*—rolled flanged sections having a maximum dimension of the cross section less than 3 in. [75 mm].

3.1.2.3 “W” *shapes*—doubly-symmetric, wide-flange shapes with inside flange surfaces that are substantially parallel.

3.1.2.4 “HP” *shapes*—are wide-flange shapes generally used as bearing piles whose flanges and webs are of the same nominal thickness and whose depth and width are essentially the same.

3.1.2.5 “S” *shapes*—doubly-symmetric beam shapes with inside flange surfaces that have a slope of approximately 16 $\frac{2}{3}$ %.

3.1.2.6 “M” *shapes*—doubly-symmetric shapes that cannot be classified as “W,” “S,” or “HP” shapes.

3.1.2.7 “C” *shapes*—channels with inside flange surfaces that have a slope of approximately 16 $\frac{2}{3}$ %.

3.1.2.8 “MC” *shapes*—channels that cannot be classified as “C” shapes.

3.1.2.9 “L” *shapes*—shapes having equal-leg and unequal-leg angles.

3.1.3 *sheet piling*—rolled steel sections that are capable of being interlocked, forming a continuous wall when individual pieces are driven side by side.

3.1.4 *bars*—rounds, squares, and hexagons, of all sizes; flats $\frac{13}{64}$ in. (0.203 in.) and over [over 5 mm] in specified thickness, not over 6 in. [150 mm] in specified width; and flats 0.230 in. and over [over 6 mm] in specified thickness, over 6 to 8 in. [150 to 200 mm] inclusive, in specified width.

3.1.5 *exclusive*—when used in relation to ranges, as for ranges of thickness in the tables of permissible variations in dimensions, is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 1800 mm] exclusive includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].

3.1.6 *rimmed steel*—steel containing sufficient oxygen to give a continuous evolution of carbon monoxide during solidification, resulting in a case or rim of metal virtually free of voids.

3.1.7 *semi-killed steel*—incompletely deoxidized steel containing sufficient oxygen to form enough carbon monoxide during solidification to offset solidification shrinkage.

3.1.8 *capped steel*—rimmed steel in which the rimming action is limited by an early capping operation. Capping is carried out mechanically by using a heavy metal cap on a bottle-top mold or chemically by an addition of aluminum or ferrosilicon to the top of the molten steel in an open-top mold.

3.1.9 *killed steel*—steel deoxidized, either by addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

3.1.10 *mill edge*—the normal edge produced by rolling between horizontal finishing rolls. A mill edge does not conform to any definite contour. Mill edge plates have two mill edges and two trimmed edges.

3.1.11 *universal mill edge*—the normal edge produced by rolling between horizontal and vertical finishing rolls. Universal mill plates, sometimes designated UM Plates, have two universal mill edges and two trimmed edges.

3.1.12 *sheared edge*—the normal edge produced by shearing. Sheared edge plates are trimmed on all edges.

3.1.13 *gas cut edge*—the edge produced by gas flame cutting.

3.1.14 *special cut edge*—usually the edge produced by gas flame cutting involving special practices such as pre-heating or post-heating, or both, in order to minimize stresses, avoid thermal cracking and reduce the hardness of the gas cut edge. In special instances, special cut edge is used to designate an edge produced by machining.

3.1.15 *sketch*—when used to describe a form of plate, denotes a plate other than rectangular, circular, or semi-circular.

3.1.16 *normalizing*—a heat treating process in which a steel plate is reheated to a uniform temperature above the upper critical temperature and then cooled in air to below the transformation range.

3.1.17 *plate-as-rolled*—when used in relation to the location and number of tests, the term refers to the unit plate rolled from a slab or directly from an ingot. It does not refer to the condition of the plate.

3.1.18 *fine grain practice*—a steelmaking practice that is intended to produce a killed steel that is capable of meeting the requirements for fine austenitic grain size.

3.1.18.1 *Discussion*—It normally involves the addition of one or more austenitic grain refining elements in amounts that have been established by the steel producer as being sufficient. Austenitic grain refining elements include, but are not limited to, aluminum, columbium (niobium), titanium, and vanadium.

3.1.19 *structural product*—a hot-rolled steel plate, shape, sheet piling, or bar.

3.1.20 *coil*—hot-rolled steel in coiled form that is intended to be processed into a finished structural product.

3.1.21 *manufacturer*—the organization that directly controls the conversion of steel ingots, slabs, blooms, or billets, by hot-rolling, into an as-rolled structural product or into coil; and for structural products produced from as-rolled structural products, the organization that directly controls, or is responsible for, the operations involved in finishing the structural product.

3.1.21.1 *Discussion*—Such finishing operations include leveling or straightening, hot forming or cold forming (if applicable), welding (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.22 *processor*—the organization that directly controls, or is responsible for, the operations involved in the processing of coil into a finished structural product. Such processing operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), welding (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.22.1 *Discussion*—The processing operations need not be done by the organization that did the hot rolling of the coil. If only one organization is involved in the hot rolling and processing operations, that organization is termed the *manufacturer* for the hot rolling operation and the *processor* for the processing operations. If more than one organization is involved in the hot rolling and processing operations, the organization that did the hot rolling is termed the *manufacturer* and an organization that does one or more processing operations is termed a *processor*.

3.2 Refer to Terminology A941 for additional definitions of terms used in this standard.

4. Ordering Information

4.1 Information items to be considered, if appropriate, for inclusion in purchase orders are as follows:

4.1.1 ASTM product specification designation (see 1.1) and year-date;

4.1.2 Name of structural product (plate, shape, bar, or sheet piling);

4.1.3 Shape designation, or size and thickness or diameter;

4.1.4 Grade, class, and type designation, if applicable;

4.1.5 Condition (see Section 6), if other than as-rolled;

4.1.6 Quantity (weight [mass] or number of pieces);

4.1.7 Length;

4.1.8 Exclusion of either structural product produced from coil or structural product produced from an as-rolled structural product (see 5.4 and Appendix X1), if applicable;

4.1.9 Heat treatment requirements (see 6.2 and 6.3), if any;

4.1.10 Testing for fine austenitic grain size (see 8.3.2);

4.1.11 Mechanical property test report requirements (see Section 14), if any;

4.1.12 Special packaging, marking, and loading for shipment requirements (see Section 19), if any;

4.1.13 Supplementary requirements, if any, including any additional requirements called for in the supplementary requirements;

4.1.14 End use, if there are any end-use-specific requirements (see 18.1, 11.3.4, Table 22 or Table A1.22, and Table 24 or Table A1.24);

4.1.15 Special requirements (see 1.10), if any; and

4.1.16 Repair welding requirements (see 9.5), if any.

5. Materials and Manufacture

5.1 The steel shall be made in a basic-oxygen or electric-arc furnace, possibly followed by additional refining in a ladle metallurgy furnace (LMF) or secondary melting by vacuum-arc remelting (VAR) or electroslag remelting (ESR).

5.2 The steel shall be killed.

5.3 The steel shall be strand cast or cast in stationary molds.

5.3.1 *Strand Cast:*

5.3.1.1 When heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product need not be changed until all of the steel in the cast product is from the following heat.

5.3.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by an established procedure that positively separates the grades.

5.4 Structural products shall be produced from an as-rolled structural product or from coil.

5.5 Where part of a heat is rolled into an as-rolled structural product and the balance of the heat is rolled into coil, each part shall be tested separately.

5.6 Structural products produced from coil shall not contain splice welds, unless previously approved by the purchaser.

6. Heat Treatment

6.1 Where the structural product is required to be heat treated, such heat treatment shall be performed by the manufacturer, the processor, or the fabricator, unless otherwise specified in the applicable product specification.

NOTE 2—When no heat treatment is required, the manufacturer or processor has the option of heat treating the structural product by normalizing, stress relieving, or normalizing then stress relieving to meet the applicable product specification.

6.2 Where the heat treatment is to be performed by other than the manufacturer, the order shall so state.

6.2.1 Where the heat treatment is to be performed by other than the manufacturer, the structural products shall be accepted on the basis of tests made on test specimens taken from full thickness test coupons heat treated in accordance with the requirements specified in the applicable product specification or in the purchase order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the test coupons under conditions the manufacturer or processor considers appropriate, provided that the purchaser is informed of the procedure followed in heat treating the test coupons.

6.3 Where the heat treatment is to be performed by the manufacturer or the processor, the structural product shall be

heat treated as specified in the applicable product specification, or as specified in the purchase order, provided that the heat treatment specified by the purchaser is not in conflict with the requirements of the applicable product specification.

6.4 Where normalizing is to be performed by the fabricator, the structural product shall be either normalized or heated uniformly for hot forming, provided that the temperature to which the structural product is heated for hot forming does not significantly exceed the normalizing temperature.

6.5 The use of cooling rates that are faster than those obtained by cooling in air to improve the toughness shall be subject to approval by the purchaser, and structural products so treated shall be tempered subsequently in the range from 1100 to 1300°F [595 to 705°C].

7. Chemical Analysis

7.1 Heat Analysis:

7.1.1 Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

7.1.2 For each heat, the heat analysis shall include determination of the content of carbon, manganese, phosphorus, sulfur, silicon, nickel, chromium, molybdenum, copper, vanadium, columbium (niobium); any other element that is specified or restricted by the applicable product specification for the applicable grade, class, and type; and any austenitic grain refining element whose content is to be used in place of austenitic grain size testing of the heat (see 8.3.2). Boron shall be reported if intentionally added.

NOTE 3—For steels that do not have intentional boron additions for hardenability, the boron content will not normally exceed 0.0008 %.

7.1.3 Except as allowed by 7.1.4 for primary heats, heat analyses shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type.

7.1.4 Where vacuum-arc remelting or electroslag remelting is used, a remelted heat is defined as all ingots remelted from a single primary heat. If the heat analysis of the primary heat conforms to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type, the heat analysis for the remelted heat shall be determined from one test sample taken from one remelted ingot, or the product of one remelted ingot, from the primary heat. If the heat analysis of the primary heat does not conform to the heat analysis requirements of the applicable product specification for the applicable grade, type, and class, the heat analysis for the remelted heat shall be determined from one test sample taken from each remelted ingot, or the product of each remelted ingot, from the primary heat.

7.2 *Product Analysis*—For each heat, the purchaser shall have the option of analyzing representative samples taken from the finished structural product. Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A751. The product

analyses so determined shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type, subject to the permitted variations in product analysis given in Table A. If a range is specified, the determinations of any element in a heat shall not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur. Therefore, the limitations for these elements shall not be applicable unless misapplication is clearly indicated.

7.3 *Referee Analysis*—For referee purposes, Test Methods, Practices, and Terminology A751 shall be used.

7.4 *Grade Substitution*—Alloy steel grades that meet the chemical requirements of Table 1 of Specification A829/A829M shall not be substituted for carbon steel grades.

8. Metallurgical Structure

8.1 Where austenitic grain size testing is required, such testing shall be in accordance with Test Methods E112 and at least 70 % of the grains in the area examined shall meet the specified grain size requirement.

8.1.1 *Discussion—Austenitic Grain Size*—All requirements for austenitic grain size control in Section 8, Metallurgical Structure, refer to a size of austenite grains that form when and if the structural product is reheated to a temperature at or above the transformation temperature, A_{c3} , after the product has experienced the complete rolling operation and has cooled to ambient temperature. The requirements for austenitic grain size control in Section 8, including the results of the referenced testing methods, do not measure or control the prior austenitic grain size or the ferritic grain size of the structural product in the as-rolled condition.

8.2 *Coarse Austenitic Grain Size*—Where coarse austenitic grain size is specified, one austenitic grain size test per heat shall be made and the austenitic grain size number so determined shall be in the range of 1 to 5 inclusive.

8.3 Fine Austenitic Grain Size:

8.3.1 Where fine austenitic grain size is specified, except as allowed in 8.3.2, one austenitic grain size test per heat shall be made and the austenitic grain size number so determined shall be 5 or higher.

NOTE 4—Such austenitic grain size numbers may be achieved with lower contents of austenitic grain refining elements than 8.3.2 requires for austenitic grain size testing to be waived.

8.3.2 Unless testing for fine austenitic grain size is specified in the purchase order, an austenitic grain size test need not be made for any heat that has, by heat analysis, one or more of the following:

8.3.2.1 A total aluminum content of 0.020 % or more.

8.3.2.2 An acid soluble aluminum content of 0.015 % or more.

8.3.2.3 A content for an austenitic grain refining element that exceeds the minimum value agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived, or

TABLE A Permitted Variations in Product Analysis

NOTE 1—Where “...” appears in this table, there is no requirement.

Element	Upper Limit, or Maximum Specified Value, %	Permitted Variations, %	
		Under Minimum Limit	Over Maximum Limit
Carbon	to 0.15 incl	0.02	0.03
	over 0.15 to 0.40 incl	0.03	0.04
	over 0.40 to 0.75 incl	0.04	0.05
	over 0.75	0.04	0.06
Manganese ^A	to 0.60 incl	0.05	0.06
	over 0.60 to 0.90 incl	0.06	0.08
	over 0.90 to 1.20 incl	0.08	0.10
	over 1.20 to 1.35 incl	0.09	0.11
	over 1.35 to 1.65 incl	0.09	0.12
	over 1.65 to 1.95 incl	0.11	0.14
Phosphorus	to 0.04 incl	...	0.010 ^B
	over 0.04 to 0.15 incl	...	...
Sulfur	to 0.06 incl	...	0.010 ^B
	over 0.06	...	...
Silicon	to 0.30 incl	0.02	0.03
	over 0.30 to 0.40 incl	0.05	0.05
	over 0.40 to 2.20 incl	0.06	0.06
Nickel	to 1.00 incl	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05
	over 2.00 to 3.75 incl	0.07	0.07
	over 3.75 to 5.30 incl	0.08	0.08
	over 5.30	0.10	0.10
Chromium	to 0.90 incl	0.04	0.04
	over 0.90 to 2.00 incl	0.06	0.06
	over 2.00 to 10.00 incl	0.10	0.10
	over 10.00 to 15.00 incl	0.15	0.15
Molybdenum	to 0.20 incl	0.01	0.01
	over 0.20 to 0.40 incl	0.03	0.03
	over 0.40 to 1.15 incl	0.04	0.04
Copper	0.20 minimum only	0.02	...
	to 1.00 incl	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05
Titanium	to 0.15 incl	0.01 ^C	0.01
Vanadium	to 0.10 incl	0.01 ^C	0.01
	over 0.10 to 0.25 incl	0.02	0.02
	over 0.25	0.02	0.03
	minimum only specified	0.01	...
Boron	any	^B	^B
Columbium (Niobium) ^D	to 0.10 incl	0.01 ^C	0.01
Zirconium	to 0.15 incl	0.03	0.03
Nitrogen	to 0.030 incl	0.005	0.005

^A Permitted variations in manganese content for bars and bar size shapes shall be: to 0.90 incl ± 0.03 ; over 0.90 to 2.20 incl ± 0.06 .

^B Product analysis not applicable.

^C 0.005, if the minimum of the range is 0.01 %.

^D Columbium and niobium are interchangeable names for the same element.

Index to Tables of Permitted Variations

Dimension	Table	
	Inch-Pound Units	SI Units
Camber		
Plates, Carbon Steel; Sheared and Gas-Cut	12	A1.12
Plates, Carbon Steel; Universal Mill	11	A1.11
Plates, Other than Carbon Steel; Sheared, Gas-Cut and Universal Mill	11	A1.11
Shapes, Rolled; S, M, C, MC, and L	21	A1.21
Shapes, Rolled; W and HP	24	A1.24
Shapes, Split; L and T	25	A1.25
Cross Section of Shapes and Bars		
Flats	26	A1.26
Hexagons	28	A1.28
Rounds and Squares	27	A1.27
Shapes, Rolled; L, Bulb Angles, and Z	17	A1.17
Shapes, Rolled; W, HP, S, M, C, and MC	16	A1.16
Shapes, Rolled; T	18	A1.18
Shapes, Split; L and T	25	A1.25
Diameter		
Plates, Sheared	6	A1.6
Plates, Other than Alloy Steel, Gas-Cut	7	A1.7
Plates, Alloy Steel, Gas-Cut	10	A1.10
Rounds	27	A1.27
End Out-of-Square		
Shapes, Other than W	20	A1.20
Shapes, W	22	A1.22
Shapes, Milled, Other than W	23	A1.23
Flatness		
Plates, Carbon Steel	13	A1.13
Plates, Other than Carbon Steel	14	A1.14
Plates, Restrictive—Carbon Steel	S27.1	S27.2
Plates, Restrictive—Other than Carbon Steel	S27.3	S27.4
Length		
Bars	30	A1.30
Bars, Recut	31	A1.31
Plates, Sheared and Universal Mill	3	A1.3
Plates, Other than Alloy Steel, Gas-Cut	9	A1.9
Plates, Alloy Steel, Gas-Cut	8	A1.8
Plates, Mill Edge	4	A1.4
Shapes, Rolled; Other than W	19	A1.19
Shapes, Rolled; W and HP	22	A1.22
Shapes, Split; L and T	25	A1.25
Shapes, Milled	23	A1.23
Straightness		
Bars	29	A1.29
Shapes, Other than W	21	A1.21
Sweep		
Shapes, W and HP	24	A1.24
Thickness		
Flats	26	A1.26
Plates, Ordered to Thickness	1	A1.1
Waviness		
Plates	15	A1.15
Weight [Mass]		
Plates, Ordered to Weight [Mass]	2	A1.2
Width		
Flats	26	A1.26
Plates, Sheared	3	A1.3
Plates, Universal Mill	5	A1.5
Plates, Other than Alloy Steel, Gas-Cut	9	A1.9
Plates, Alloy Steel, Gas-Cut	8	A1.8
Plates, Mill Edge	4	A1.4

8.3.2.4 Contents for the combination of two or more austenitic grain refining elements that exceed the applicable minimum values agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived.

9. Quality

9.1 *General*—Structural products shall be free of injurious defects and shall have a workmanlike finish.

NOTE 5—Unless otherwise specified, structural products are normally furnished in the as-rolled condition and are subjected to visual inspection by the manufacturer or processor. Non-injurious surface or internal imperfections, or both, may be present in the structural product as delivered and the structural product may require conditioning by the purchaser to improve its appearance or in preparation for welding, coating, or other further operations.

More restrictive requirements may be specified by invoking supplementary requirements or by agreement between the purchaser and the supplier.

Structural products that exhibit injurious defects during subsequent fabrication are deemed not to comply with the applicable product specification. (See 17.2.) Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge during the fabrication process; this is not considered to be a fault of the steel but is rather a function of the induced cold-work or the heat-affected zone.

The conditioning requirements in 9.2, 9.3, and 9.4 limit the conditioning allowed to be performed by the manufacturer or processor. Conditioning of imperfections beyond the limits of 9.2, 9.3, and 9.4 may be performed by parties other than the manufacturer or processor at the discretion of the purchaser.

9.2 Plate Conditioning:

9.2.1 The grinding of plates by the manufacturer or processor to remove imperfections on the top or bottom surface shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the grinding does not reduce the thickness of the plate by (1) more than 7 % under the nominal thickness for plates ordered to weight per square foot or mass per square metre, but in no case more than 1/8 in. [3 mm]; or (2) below the permissible minimum thickness for plates ordered to thickness in inches or millimetres.

9.2.2 The deposition of weld metal (see 9.5) following the removal of imperfections on the top or bottom surface of plates by chipping, grinding, or arc-air gouging shall be subject to the following limiting conditions:

9.2.2.1 The chipped, ground, or gouged area shall not exceed 2 % of the area of the surface being conditioned.

9.2.2.2 After removal of any imperfections preparatory to welding, the thickness of the plate at any location shall not be reduced by more than 30 % of the nominal thickness of the plate. (Specification A131/A131M restricts the reduction in thickness to 20 % maximum.)

9.2.3 The deposition of weld metal (see 9.5) following the removal of injurious imperfections on the edges of plates by grinding, chipping, or arc-air gouging by the manufacturer or processor shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the plate edge inward, is not more than the thickness of the plate or 1 in. [25 mm], whichever is the lesser.

9.3 Structural Size Shapes, Bar Size Shapes, and Sheet Piling Conditioning:

9.3.1 The grinding, or chipping and grinding, of structural size shapes, bar size shapes, and sheet piling by the manufacturer or processor to remove imperfections shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the depression does not extend below the rolled surface by more than (1) 1/32 in. [1 mm], for material less than 3/8 in. [10 mm] in thickness; (2) 1/16 in. [2 mm], for material 3/8 to 2 in. [10 to 50 mm] inclusive in thickness; or (3) 1/8 in. [3 mm], for material over 2 in. [50 mm] in thickness.

9.3.2 The deposition of weld metal (see 9.5) following removal of imperfections that are greater in depth than the limits listed in 9.3.1 shall be subject to the following limiting conditions:

9.3.2.1 The total area of the chipped or ground surface of any piece prior to welding shall not exceed 2 % of the total surface area of that piece.

9.3.2.2 The reduction of thickness of the material resulting from removal of imperfections prior to welding shall not exceed 30 % of the nominal thickness at the location of the imperfection, nor shall the depth of depression prior to welding exceed 1/4 in. [32 mm] in any case except as noted in 9.3.2.3.

9.3.2.3 The deposition of weld metal (see 9.5) following grinding, chipping, or arc-air gouging of the toes of angles, beams, channels, and zees and the stems and toes of tees shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the toe inward, is not more than the thickness of the material at the base of the depression or 1/2 in. [12.5 mm], whichever is the lesser.

9.3.2.4 The deposition of weld metal (see 9.5) and grinding to correct or build up the interlock of any sheet piling section at any location shall be subject to the limitation that the total surface area of the weld not exceed 2 % of the total surface area of the piece.

9.4 Bar Conditioning:

9.4.1 The conditioning of bars by the manufacturer or processor to remove imperfections by grinding, chipping, or some other means shall be subject to the limitations that the conditioned area is well faired and the affected sectional area is not reduced by more than the applicable permitted variations (see Section 12).

9.4.2 The deposition of weld metal (see 9.5) following chipping or grinding to remove imperfections that are greater in depth than the limits listed in 9.4.1 shall be subject to the following conditions:

9.4.2.1 The total area of the chipped or ground surface of any piece, prior to welding, shall not exceed 2 % of the total surface area of the piece.

9.4.2.2 The reduction of sectional dimension of a round, square, or hexagon bar, or the reduction in thickness of a flat bar, resulting from removal of an imperfection, prior to welding, shall not exceed 5 % of the nominal dimension or thickness at the location of the imperfection.

9.4.2.3 For the edges of flat bars, the depth of the conditioning depression prior to welding shall be measured from the edge inward and shall be limited to a maximum depth equal to the thickness of the flat bar or 1/2 in. [12.5 mm], whichever is less.

9.5 Repair by Welding:

9.5.1 General Requirements:

9.5.1.1 Repair by welding shall be in accordance with a welding procedure specification (WPS) using shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), or submerged arc welding (SAW) processes. Shielding gases used shall be of welding quality.

9.5.1.2 Electrodes and electrode-flux combinations shall be in accordance with the requirements of AWS Specifications A5.1/A5.1M, A5.5/A5.5M, A5.17/A5.17M, A5.18/A5.18M,

A5.20/A5.20M, A5.23/A5.23M, A5.28/A5.28M, or A5.29/A5.29M, whichever is applicable. For SMAW, low hydrogen electrodes shall be used.

9.5.1.3 Electrodes and electrode-flux combinations shall be selected so that the tensile strength of the deposited weld metal (after any required heat treatment) is consistent with the tensile strength specified for the base metal being repaired.

9.5.1.4 Welding electrodes and flux materials shall be dry and protected from moisture during storage and use.

9.5.1.5 Prior to repair welding, the surface to be welded shall be inspected to verify that the imperfections intended to be removed have been removed completely. Surfaces to be welded and surfaces adjacent to the weld shall be dry and free of scale, slag, rust, moisture, grease, and other foreign material that would prevent proper welding.

9.5.1.6 Welders and welding operators shall be qualified in accordance with the requirements of AWS D1.1/D1.1M or ASME Boiler and Pressure Vessel Code, Section IX, except that any complete joint penetration groove weld qualification also qualifies the welder or welding operator to do repair welding.

9.5.1.7 Repair welding of structural products shall be in accordance with a welding procedure specification (WPS) that is in accordance with the requirements of AWS D1.1/D1.1M or ASME Boiler and Pressure Vessel Code, Section IX, with the following exceptions or clarifications:

(1) The WPS shall be qualified by testing a complete joint penetration groove weld or a surface groove weld.

(2) The geometry of the surface groove weld need not be described in other than a general way.

(3) An AWS D1.1/D1.1M prequalified complete joint penetration groove weld WPS is acceptable.

(4) Any material not listed in the prequalified base metal-filler metal combinations of AWS D1.1/D1.1M also is considered to be prequalified if its chemical composition and mechanical properties are comparable to those for one of the prequalified base metals listed in AWS D1.1/D1.1M.

(5) Any material not listed in ASME Boiler and Pressure Vessel Code, Section IX, also is considered to be a material with an S-number in Section IX if its chemical composition and its mechanical properties are comparable to those for one of the materials listed in Section IX with an S-number.

9.5.1.8 When so specified in the purchase order, the WPS shall include qualification by Charpy V-notch testing, with the test locations, test conditions, and the acceptance criteria meeting the requirements specified for repair welding in the purchase order.

9.5.1.9 When so specified in the purchase order, the welding procedure specification shall be subject to approval by the purchaser prior to repair welding.

9.5.2 *Structural Products with a Specified Minimum Tensile Strength of 100 ksi [690 MPa] or Higher*—Repair welding of structural products with a specified minimum tensile strength of 100 ksi [690 MPa] or higher shall be subject to the following additional requirements:

9.5.2.1 When so specified in the purchase order, prior approval for repair by welding shall be obtained from the purchaser.

9.5.2.2 The surface to be welded shall be inspected using a magnetic particle method or a liquid penetrant method to verify that the imperfections intended to be removed have been completely removed. When magnetic particle inspection is employed, the surface shall be inspected both parallel and perpendicular to the length of the area to be repaired.

9.5.2.3 When weld repairs are to be post-weld heat-treated, special care shall be exercised in the selection of electrodes to avoid those compositions that embrittle as a result of such heat treatment.

9.5.2.4 Repairs on structural products that are subsequently heat-treated at the mill shall be inspected after heat treatment; repairs on structural products that are not subsequently heat-treated at the mill shall be inspected no sooner than 48 h after welding. Such inspection shall use a magnetic particle method or a liquid penetrant method; where magnetic particle inspection is involved, such inspection shall be both parallel to and perpendicular to the length of the repair.

9.5.2.5 The location of the weld repairs shall be marked on the finished piece.

9.5.3 *Repair Quality*—The welds and adjacent heat-affected zone shall be sound and free of cracks, the weld metal being thoroughly fused to all surfaces and edges without undercutting or overlap. Any visible cracks, porosity, lack of fusion, or undercut in any layer shall be removed prior to deposition of the succeeding layer. Weld metal shall project at least $\frac{1}{16}$ in. (2 mm) above the rolled surface after welding, and the projecting metal shall be removed by chipping or grinding, or both, to make it flush with the rolled surface, and to produce a workmanlike finish.

9.5.4 *Inspection of Repair*—The manufacturer or processor shall maintain an inspection program to inspect the work to see that:

9.5.4.1 Imperfections have been completely removed.

9.5.4.2 The limitations specified above have not been exceeded.

9.5.4.3 Established welding procedures have been followed, and

9.5.4.4 Any weld deposit is of acceptable quality as defined above.

10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A370.

10.2 Yield strength shall be determined either by the 0.2 % offset method or by the 0.5 % extension under load method, unless otherwise stated in the material specification.

10.3 *Rounding Procedures*—For purposes of determining conformance with the specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] tensile and yield strength, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding method given in Practice E29.

10.4 For full-section test specimens of angles, the cross-sectional area used for calculating the yield and tensile strengths shall be a theoretical area calculated on the basis of the weight of the test specimen (see 12.1).

11. Tension Tests

11.1 *Condition*—Test specimens for non-heat-treated structural products shall be taken from test coupons that are representative of the structural products in their delivered condition. Test specimens for heat-treated structural products shall be taken from test coupons that are representative of the structural products in their delivered condition, or from separate pieces of full thickness or full section from the same heat similarly heat treated.

11.1.1 Where the plate is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.1.1.1 The gage length of the tension test specimen shall be taken at least $1T$ from any as-heat treated edge where T is the thickness of the plate and shall be at least $\frac{1}{2}$ in. [12.5 mm] from flame cut or heat-affected-zone surfaces.

11.1.1.2 A steel thermal buffer pad, $1T$ by $1T$ by at least $3T$, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.1.1.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.1.1.2.

11.1.1.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than $3T$ by $3T$ by T and each tension specimen cut from it shall meet the requirements of 11.1.1.1.

11.1.1.5 The heat treatment of test specimens separately in the device shall be subject to the limitations that (1) cooling rate data for the plate are available; (2) cooling rate control devices for the test specimens are available; and, (3) the method has received prior approval by the purchaser.

11.2 *Orientation*—For plates wider than 24 in. [600 mm], test specimens shall be taken such that the longitudinal axis of the test specimen is transverse to the final direction of rolling of the plate. Test specimens for all other structural products shall be taken such that the longitudinal axis of the test specimen is parallel to the final direction of rolling.

11.3 Location:

11.3.1 *Plates*—Test specimens shall be taken from a corner of the plate.

11.3.2 *W and HP Shapes with Flanges 6 in. [150 mm] or Wider*—Test specimens shall be selected from a point in the flange $\frac{2}{3}$ of the way from the flange centerline to the flange toe.

11.3.3 *Shapes Other Than Those in 11.3.2*—Test specimens shall be selected from the webs of beams, channels, and zees; from the stems of rolled tees; and from the legs of angles and bulb angles, except where full-section test specimens for angles are used and the elongation acceptance criteria are increased accordingly. (See 11.6.2.)

11.3.4 Bars:

11.3.4.1 Test specimens for bars to be used for pins and rollers shall be taken so that the axis is: midway between the center and the surface for pins and rollers less than 3 in. [75

mm] in diameter; 1 in. [25 mm] from the surface for pins and rollers 3 in. [75 mm] and over in diameter; or as specified in Annex A1 of Test Methods and Definitions A370 if the applicable foregoing requirement is not practicable.

11.3.4.2 Test specimens for bars other than those to be used for pins and rollers shall be taken as specified in Annex A1 of Test Methods and Definitions A370.

11.4 Test Frequency:

11.4.1 *Structural Products Produced from an As-Rolled Structural Product*—The minimum number of pieces or plates-as-rolled to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.1.1 As given in Table B, or

11.4.1.2 One taken from the minimum thickness in the heat and one taken from the maximum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.4.2 *Structural Products Produced from Coil and Furnished without Heat Treatment or with Stress Relieving Only:*

11.4.2.1 Except as allowed by 11.4.4, the minimum number of coils to be tested for each heat and strength gradation, where applicable, shall be as given in Table C, except that it shall be permissible for any individual coil to represent multiple strength gradations.

11.4.2.2 Except as required by 11.4.2.3, two tension test specimens shall be taken from each coil tested, with the first being taken immediately prior to the first structural product to be qualified, and the second being taken from the approximate center lap.

11.4.2.3 If, during decoiling, the amount of material decoiled is less than that required to reach the approximate center lap, the second test for the qualification of the decoiled portion of such a coil shall be taken from a location adjacent to the end of the innermost portion decoiled. For qualification of successive portions from such a coil, an additional test shall be taken adjacent to the innermost portion decoiled, until a test is obtained from the approximate center lap.

11.4.3 *Structural Products Produced from Coil and Furnished Heat Treated by other than Stress Relieving*—The minimum number of pieces to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.3.1 As given in Table B, or

11.4.3.2 One taken from the minimum thickness in the heat and one taken from the maximum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.4.4 *Structural Products Produced from Coil and Qualified Using Test Specimens Heat Treated by Other than Stress Relieving*—The minimum number of pieces to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

TABLE B Minimum Number of Tension Tests Required

Thickness ^A Range Rolled for the Heat	Thickness ^A Difference Between Pieces or Plates-as-rolled in the Thickness ^A Range	Minimum Number of Tension Tests Required
Under 3/8 in. [10 mm]	1/16 in. [2 mm] or less	Two ^B tests per heat, taken from different pieces or plates-as-rolled having any thickness ^A in the thickness ^A range
	More than 1/16 in. [2 mm]	Two ^B tests per heat, one taken from the minimum thickness ^A in the thickness ^A range and one taken from the maximum thickness ^A in the thickness ^A range
3/8 to 2 in. [10 to 50 mm], incl	Less than 3/8 in. [10 mm]	Two ^B tests per heat, taken from different pieces or plates-as-rolled having any thickness ^A in the thickness ^A range
	3/8 in. [10 mm] or more	Two ^B tests per heat, one taken from the minimum thickness ^A in the thickness ^A range and one taken from the maximum thickness ^A in the thickness ^A range
Over 2 in. [50 mm]	Less than 1 in. [25 mm]	Two ^B tests per heat, taken from different pieces or plates-as-rolled having any thickness ^A in the thickness ^A range
	1 in. [25 mm] or more	Two ^B tests per heat, one taken from the minimum thickness ^A in the thickness ^A range and one taken from the maximum thickness ^A in the thickness ^A range

^A Thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the specific structural product rolled.

^B One test, if only one piece or plate-as-rolled is to be qualified.

TABLE C Minimum Number of Coils Required to be Tension Tested

NOTE 1—See 11.4.2.2 and 11.4.2.3 for the number of tests to be taken per coil.

Thickness ^A Difference Between Coils in the Heat	Minimum Number of Coils Required to be Tension Tested
Less than 1/16 in. [2 mm]	Two ^B coils per heat, at any thickness ^A in the heat
1/16 in. [2 mm] or more	Two ^B coils per heat, one at the minimum thickness ^A in the heat and one at the maximum thickness ^A in the heat

^A Thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the specific structural product rolled.

^B One coil, if the product of only one coil is to be qualified.

11.4.4.1 As given in Table B, or

11.4.4.2 One taken from the minimum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.5 Preparation:

11.5.1 Plates:

11.5.1.1 Tension test specimens for plates 3/4 in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements shown in Fig. 3 of Test Methods and Definitions A370 for either the 1 1/2-in. [40-mm] wide test specimen or the 1/2-in. [12.5-mm] wide test specimen.

11.5.1.2 For plates up to 4 in. [100 mm] inclusive, in thickness, the use of 1 1/2-in. [40-mm] wide test specimens, full thickness of the plate and conforming to the requirements shown in Fig. 3 of Test Methods and Definitions A370, shall be subject to the limitation that adequate testing machine capacity is available.

11.5.1.3 For plates over 3/4 in. [20 mm] in thickness, except as permitted in 11.5.1.2, tension test specimens shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A370 for the 0.500-in. [12.5-mm] diameter test specimen. The axis of such test specimens shall be located midway between the center of thickness and the top or bottom surface of the plate.

11.5.2 Shapes:

11.5.2.1 Except where angles are tested in full section, tension test specimens for shapes 3/4 in. [20 mm] and under in thickness shall be the full thickness of the shape. Such test specimen shall conform to the requirements shown in Fig. 3 of

Test Methods and Definitions A370 for either the 1 1/2-in. [40-mm] wide test specimen or the 1/2-in. [12.5-mm] wide test specimen.

11.5.2.2 For shapes up to 5 in. [125 mm] inclusive, in thickness, the use of 1 1/2-in. [40-mm] wide test specimens, full thickness of the shape and conforming to the requirements shown in Fig. 3 of Test Methods and Definitions A370, shall be subject to the limitation that adequate testing machine capacity is available.

11.5.2.3 For shapes over 3/4 in. [20 mm] in thickness, except as permitted in 11.5.2.2, tension test specimens shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A370 for the 0.500-in. [12.5-mm] diameter test specimens. The axis of such test specimens shall be located midway between the center of thickness and the top or bottom surface of the shape.

11.5.3 Bars:

11.5.3.1 Except as otherwise provided below, test specimens for bars shall be in accordance with Annex A1 of Test Methods and Definitions A370.

11.5.3.2 Except as provided in 11.5.3.5, test specimens for bars 3/4 in. [20 mm] and under in thickness shall conform to the requirements shown in Fig. 3 of Test Methods and Definitions A370 for either the 1 1/2-in. [40-mm] wide test specimen or the 1/2-in. [12.5-mm] wide specimen.

11.5.3.3 Except as provided in 11.5.3.4 and 11.5.3.5, test specimens for bars over 3/4 in. [20 mm] in thickness or diameter shall conform either to the requirements for the 1 1/2-in. [40-mm] or 1/2-in. [12.5-mm] wide test specimen shown in Fig. 3 of Test Methods and Definitions A370, or to the requirements for the 0.500-in. [12.5-mm] diameter test specimen shown in Fig. 4 of Test Methods and Definitions A370.

11.5.3.4 For bars other than those to be used for pins and rollers, the manufacturer or processor shall have the option of using test specimens that are machined to a thickness or diameter of at least $\frac{3}{4}$ in. [20 mm] for a length of at least 9 in. [230 mm].

11.5.3.5 Test specimens for bars to be used for pins and rollers shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A370 for the 0.500-in. [12.5-mm] diameter test specimen.

11.6 Elongation Requirement Adjustments:

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin material, adjustments in elongation requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions from the base elongation requirements shall apply:

Nominal Thickness Range, in. [mm]	Elongation Deduction, %
0.299–0.311 [7.60–7.89]	0.5
0.286–0.298 [7.30–7.59]	1.0
0.273–0.285 [7.00–7.29]	1.5
0.259–0.272 [6.60–6.99]	2.0
0.246–0.258 [6.20–6.59]	2.5
0.233–0.245 [5.90–6.19]	3.0
0.219–0.232 [5.50–5.89]	3.5
0.206–0.218 [5.20–5.49]	4.0
0.193–0.205 [4.90–5.19]	4.5
0.180–0.192 [4.60–4.89]	5.0
0.166–0.179 [4.20–4.59]	5.5 ^A
0.153–0.165 [3.90–4.19]	6.0 ^A
0.140–0.152 [3.60–3.89]	6.5 ^A
0.127–0.139 [3.20–3.59]	7.0 ^A
< 0.127 [3.20]	7.5 ^A

^A Elongation deductions for thicknesses less than 0.180 in. [4.60 mm] apply to plates and structural shapes only.

11.6.2 Due to the specimen geometry effect encountered when using full-section test specimens for angles, the elongation requirements for structural-size angles shall be increased by six percentage points when full-section test specimens are used.

11.6.3 Due to the inherently lower elongation that is obtainable in thicker structural products, adjustments in elongation requirements shall be provided. For structural products over 3.5 in. [90 mm] in thickness, a deduction of 0.5 percentage point from the specified percentage of elongation in 2 in. [50 mm] shall be made for each 0.5-in. [12.5-mm] increment of thickness over 3.5 in. [90 mm], up to a maximum deduction of 3.0 percentage points. Accordingly, the following deductions from the base elongation requirements shall apply:

Nominal Thickness Range, in. [mm]	Elongation Deduction, %
3.500–3.999 [90.00–102.49]	0.5
4.000–4.499 [102.50–114.99]	1.0
4.500–4.999 [115.00–127.49]	1.5
5.000–5.499 [127.50–139.99]	2.0
5.500–5.999 [140.00–152.49]	2.5
6.000 and thicker [152.50 and thicker]	3.0

11.6.4 The tensile property requirements tables in many of the product specifications covered by this general requirements specification specify elongation requirements in both 8-in. [200-mm] and 2-in. [50-mm] gage lengths. Unless otherwise

provided in the applicable product specification, both requirements are not required to be applied simultaneously and the elongation need only be determined in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

11.7 Yield Strength Application:

11.7.1 When test specimens do not exhibit a well-defined disproportionate yield point, yield strength shall be determined and substituted for yield point.

11.7.2 The manufacturer or processor shall have the option of substituting yield strength for yield point if the test specimen exhibits a well-defined disproportionate yield point.

11.7.3 Yield strength shall be determined either by the 0.2 % offset method or by the 0.5 % extension-under-load method.

11.8 *Product Tension Tests*—This specification does not provide requirements for product tension testing subsequent to shipment (see 15.1). Therefore, the requirements of 11.1 – 11.7 inclusive and Section 13 apply only for tests conducted at the place of manufacture prior to shipment.

NOTE 6—Compliance to this specification and the applicable product specification by a manufacturer or processor does not preclude the possibility that product tension test results might vary outside specified ranges. The tensile properties will vary within the same heat or piece, be it as-rolled, control-rolled, or heat-treated. Tension testing according to the requirements of this specification does not provide assurance that all products of a heat will be identical in tensile properties with the products tested. If the purchaser wishes to have more confidence than that provided by this specification testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

11.8.1 Appendix X2 provides additional information on the variability of tensile properties in plates and structural shapes

12. Permitted Variations in Dimensions and Weight [Mass]

12.1 One cubic foot of rolled steel is assumed to weigh 490 lb. One cubic metre of rolled steel is assumed to have a mass of 7850 kg.

12.2 *Plates*—The permitted variations for dimensions and weight [mass] shall not exceed the applicable limits in Tables 1 to 15 [Annex A1, Tables A1.1 to A1.15] inclusive.

12.3 Shapes:

12.3.1 Annex A2 lists the designations and dimensions, in both inch-pound and SI units, of shapes that are most commonly available. Radii of fillets and toes of shape profiles vary with individual manufacturers and therefore are not specified.

12.3.2 The permitted variations in dimensions shall not exceed the applicable limits in Tables 16 to 25 [Annex A1, Tables A1.16 to A1.25] inclusive. Permitted variations for special shapes not listed in such tables shall be as agreed upon between the manufacturer and the purchaser.

NOTE 7—Permitted variations are given in Tables 16 to 25 [Annex A1, Tables A1.16 to A1.25] inclusive for some shapes that are not listed in Annex A2 (that is, bulb angles, tees, zeos). Addition of such sections to Annex A2 will be considered by Subcommittee A01.02 when and if a need for such listing is shown.

12.3.3 *Shapes Having One Dimension of the Cross Section 3 in. [75 mm] or Greater (Structural-Size Shapes)*—The cross-sectional area or weight [mass] of each shape shall not vary more than 2.5 % from the theoretical or specified amounts except for shapes with a nominal weight of less than 100 lb/ft, in which the variation shall range from –2.5 % to +3.0 % from the theoretical cross-sectional area or the specified nominal weight [mass].

12.4 *Sheet Piling*—The weight [mass] of each steel sheet pile shall not vary more than 2.5 % from the theoretical or specified weight [mass]. The length of each steel sheet pile shall be not less than the specified length, and not more than 5 in. [125 mm] over the specified length.

12.5 *Hot-Rolled Bars*—The permitted variations in dimensions shall not exceed the applicable limits in Tables 26 to 31 [Annex A1, Tables A1.26 to A1.31] inclusive.

12.6 *Conversion of Permitted Variations from Fractions of an Inch to Decimals*—Permitted variations in dimensions for products covered by this specification are generally given as fractions of an inch and these remain the official permitted variations, where so stated. If the material is to be measured by equipment reporting dimensions as decimals, conversion of permitted variations from fractions of an inch to decimals shall be made to three decimal places; using the rounding method prescribed in Practice E29.

13. Retests

13.1 If any test specimen shows defective machining or develops flaws, the manufacturer or processor shall have the option of discarding it and substituting another test specimen.

13.2 If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of the gage length of a 2-in. [50-mm] specimen or is outside the middle half of the gage length of an 8-in. [200-mm] specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

13.3 Except as provided in 13.3.1, if the results from an original tension specimen fails to meet the specified requirements, but are within 2 ksi [14 MPa] of the required tensile strength, within 1 ksi [7 MPa] of the required yield strength or yield point, or within 2 percentage points of the required elongation, a retest shall be permitted to replace the failing test. A retest shall be performed for the failing original test, with the specimen being randomly selected from the heat. If the results of the retest meet the specified requirements, the heat or lot shall be approved.

13.3.1 For structural products that are tested as given in Table C, both tests from each coil tested to qualify a heat are required to meet all mechanical property requirements. Should either test fail to do so, then that coil shall not be used to qualify the heat; however, the portion of that individual coil that is bracketed by acceptable tests (see 11.4.2.3) is considered to be qualified.

13.4 Quenched and tempered steel plates shall be subject to any additional retest requirements contained in the applicable product specification.

13.5 When the full-section option of 11.3.3 is used and the elongation falls below the specified requirement, the manufacturer or processor shall have the option of making another test using a test specimen permitted in 11.5.2.

14. Test Reports

14.1 Test reports for each heat supplied are required and they shall report the following:

14.1.1 The applicable product specification designation, including year-date and whichever of grade, class, and type are specified in the purchase order, to which the structural product is furnished.

14.1.2 The heat number, heat analysis (see 7.1), and nominal sizes.

NOTE 8—If the amount of copper, chromium, nickel, molybdenum, or silicon is less than 0.02 %, the heat analysis for that element may be reported as <0.02 %. If the amount of columbium (niobium) or vanadium is less than 0.008 %, the heat analysis for that element may be reported as <0.008 %.

14.1.3 For structural products that are tested as given in Table B, two tension test results appropriate to qualify the shipment (see 11.4), except that only one tension test result need be reported if the shipment consists of a single piece or plate-as-rolled.

14.1.3.1 In reporting elongation values, both the percentage increase and the original gage length shall be stated.

14.1.3.2 Yield to tensile ratio when such a requirement is contained in the product specification.

14.1.4 For structural products that are required to be heat treated, either by the applicable product specification or by the purchase order, all heat treatments, including temperature ranges and times at temperature, unless the purchaser and the supplier have agreed to the supply of a heat treatment procedure in place of the actual temperatures and times.

14.1.4.1 Subcritical heat treatment to soften thermally cut edges need not be reported, except for structural products having a specified minimum tensile strength of 95 ksi [655 MPa] or higher, unless such subcritical heating is accomplished at temperatures at least 75°F [40°C] lower than the minimum tempering temperature.

14.1.5 The results of any required austenitic grain size tests (see 8.2 or 8.3, whichever is applicable).

14.1.6 The results of any other test required by the applicable product specification, the applicable supplementary requirements, and the purchase order.

14.2 The thickness of the structural product tested is not necessarily the same as an individual ordered thickness, given that it is the heat that is tested, rather than each ordered item. Tests from specified thicknesses in accordance with 11.4 and encompassing the thicknesses in a shipment shall be sufficient for qualifying the structural product in the shipment. Such test thicknesses are not required to be within previously tested and shipped thicknesses from the same heat.

14.3 For structural products produced from coil that are supplied in the as-rolled condition or have been heat treated by stress relieving only, the test report shall state “Produced from

Coil.” Both test results shall be reported for each qualifying coil, and the location within the coil for each test shall be stated.

14.4 For structural products produced from coil, both the manufacturer and the processor shall be identified on the test report.

14.5 When full-section test specimens have been used for the qualification of angles, that information shall be stated on the test report.

14.6 A signature is not required on the test report; however, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

14.7 For structural products finished by other than the original manufacturer, the supplier of the structural product shall also provide the purchaser with a copy of the original manufacturer’s test report.

14.8 A test report, certificate of inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier’s facility. The content of the EDI transmitted document shall meet the requirements of the applicable product specification and shall conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission shall be responsible for the content of the report.

NOTE 9—The industry definition as invoked here is: EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

15. Inspection and Testing

15.1 The inspector representing the purchaser shall have free entry, at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer’s works that concern the manufacture of the structural product ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the structural product is being furnished in accordance with this general requirements specification, the applicable product specification, and the purchase order. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere with the operation of the manufacturer’s works.

15.2 Where structural products are produced from coil, 15.1 shall apply to the processor instead of the manufacturer, and the place of process shall apply instead of the place of manufacture. Where structural products are produced from coil and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer’s works that concern the manufacture of the structural product ordered.

16. Retreatment

16.1 If any heat-treated structural product fails to meet the mechanical property requirements of the applicable product specification, the manufacturer or the processor shall have the option of heat treating the structural product again. All mechanical property tests shall be repeated and the structural product shall be reexamined for surface defects when it is resubmitted for inspection.

17. Rejection

17.1 Any rejection based upon product analysis made in accordance with the applicable product specification shall be reported to the supplier and samples that represent the rejected structural product shall be preserved for two weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier shall have the option of making claim for a rehearing within that time.

17.2 The purchaser shall have the option of rejecting structural product that exhibits injurious defects subsequent to its acceptance at the manufacturer’s or processor’s works, and so notifying the manufacturer or processor.

18. Identification of Structural Products

18.1 Required Plate Markings:

18.1.1 Except as allowed by 18.1.4.2 and 18.6, plates shall be legibly marked with the following: applicable ASTM designation (see 1.1) (year-date not required); “G” or “MT” if applicable (see 18.1.2); applicable grade; heat number; size and thickness; and name, brand, or trademark of the manufacturer (for plates produced from an as-rolled structural product) or the processor (for plates produced from coil).

18.1.2 Plates that are required to be heat treated, but have not been so heat treated, shall be marked, by the manufacturer or processor, with the letter “G” (denoting green) following the required ASTM designation mark, except that “G” marking is not necessary if such plates are for shipment, for the purpose of obtaining the required heat treatment, to an organization under the manufacturer’s control. Such plates shall have been qualified for shipment on the basis of test specimens that have been so heat treated. Plates that are required to be heat treated, and have been so heat treated, shall be marked, by the party that performed the heat treatment, with the letter “MT” (denoting material treated) following the required ASTM designation mark.

18.1.3 Except as allowed by 18.1.4.2 and 18.6, the required markings for plates shall be by steel die stamping, paint marking, or by means of permanently affixed, colorfast, weather-resistant labels or tags. It shall be the responsibility of the supplier that all required markings be intact and fully legible upon receipt by the purchaser.

18.1.4 Location of Markings:

18.1.4.1 The required markings for plates shall be in at least one place on each finished plate.

18.1.4.2 For secured lifts of all sizes of plates $\frac{3}{8}$ in. [10 mm] (or $\frac{5}{16}$ in. [8 mm] for material specified for bridge construction end use) or under in thickness, and for secured lifts of all thicknesses of plates 36 in. [900 mm] or under in width, the manufacturer or processor shall have the option of placing such

markings on only the top piece of each lift, or of showing such markings on a substantial tag attached to each lift, unless otherwise specified.

18.2 Shapes:

18.2.1 Except as allowed by 18.2.2 and 18.6, shapes shall be marked with the heat number, size of section, length, and mill identification marks on each piece. Shapes with the greatest cross-sectional dimension greater than 6 in. [150 mm] shall have the manufacturer's name, brand, or trademark shown in raised letters at intervals along the length. In addition, shapes shall be identified with the ASTM designation (year-date not required) and grade, either by marking each piece individually, by permanently affixing a colorfast, weather-resistant label or tag, or, if bundled, by attaching a substantial tag to the bundle.

18.2.2 Bundling for shipment of small shapes with the greatest cross-sectional dimension not greater than 6 in. [150 mm] is permissible. Each lift or bundle shall be marked or substantially tagged showing the identification information listed in 18.2.1.

18.2.3 It shall be permissible for the manufacturer to make a full size bundle at the end of a heat by adding product from a consecutively rolled heat of the same nominal chemical composition. The manufacturer shall identify a bundle consisting of product from two heats with the number of the first heat rolled or identify both heats. The manufacturer shall maintain records of the heats contained in each bundle.

18.3 *Steel Sheet Piling*—Steel sheet piling shall be marked with the heat number, size of section, length, and mill identification marks on each piece, either by marking, or by permanently affixing colorfast, weather-resistant label or tag. The manufacturer's name, brand, or trademark shall be shown in raised letters at intervals along the length.

18.4 *Bars*—Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer, purchaser's name and order number, the ASTM designation number (year-date not required), grade number where appropriate, size and length, weight [mass] of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer's option and shall be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars. Bars are not required to be die-stamped.

18.4.1 It shall be permissible for the manufacturer to make a full size bundle at the end of a heat by adding product from a consecutively rolled heat of the same nominal chemical composition. The manufacturer shall identify a bundle consisting of product from two heats with the number of the first heat rolled or identify both heats. The manufacturer shall maintain records of the heats contained in each bundle.

18.5 *Bar Coding*—In addition to the requirements of 18.1 – 18.4 inclusive, the manufacturer or processor shall have the option of using bar coding as a supplementary identification method.

NOTE 10—Bar coding should be consistent with AIAG Standards.

18.6 Subdivided Material:

18.6.1 Except as allowed by 18.6.2, pieces separated from a master structural product by an organization other than the original manufacturer shall be identified with the ASTM designation (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization subdividing the structural product. The identification methods shall be in accordance with the requirements of 18.1 – 18.4 inclusive, except that the raised letters method for shapes and steel sheet piling is not required. If the original manufacturer's identification remains intact, the structural product need not be additionally identified by the organization supplying the structural product.

18.6.2 It shall be permissible for pieces from the same heat of structural product to be bundled or placed in secured lifts, with the identification specified in 18.6.1 placed on the top piece of each lift or shown on a substantial tag attached to each bundle or lift.

19. Packaging, Marking, and Loading for Shipment

19.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A700.

19.2 When Level A is specified, and when specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

19.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and with Fed. Std. No. 123 for civil agencies.

20. Keywords

20.1 bars; general requirements; plates; rolled; shapes; sheet piling; structural steel

TABLE 1 Permitted Variations in Thickness for Rectangular, Carbon, High-Strength, Low-Alloy, and Alloy-Steel Plates, 15 in. and Under in Thickness When Ordered to Thickness

NOTE 1—Tables 1-31 inclusive contain permitted variations in dimensions and weight stated in inch-pound units.

NOTE 2—Permitted variation under specified thickness, 0.01 in. When so specified, these permitted variations may be taken all over, in which case the sum of these permitted variations applies.

NOTE 3—Thickness to be measured at 3/8 to 3/4 in. from the longitudinal edge.

NOTE 4—For thicknesses measured at any location other than that specified in Note 4, the permitted variations over specified thickness shall be 1 3/4 times the amounts in this table, rounded to the nearest 0.01 in.

NOTE 5—Where “...” appears in this table, there is no requirement.

Specified Thickness, in.	Permitted Variations Over Specified Thickness for Widths Given in Inches, in.											
	48 and under	Over 48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 132, excl	132 to 144, excl	144 to 168, excl	168 to 182, excl	182 and over
To 1/4, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	...	...	...
1/4 to 5/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	...	...	...
5/16 to 3/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	...	...
3/8 to 7/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
7/16 to 1/2, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
1/2 to 5/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	...
5/8 to 3/4, excl	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.07
3/4 to 1, excl	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09
1 to 2, excl	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.10	0.11	0.13	0.16
2 to 3, excl	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.15	...
3 to 4, excl	0.11	0.11	0.11	0.11	0.11	0.13	0.14	0.14	0.14	0.15	0.17	...
4 to 6, excl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.20	...
6 to 10, excl	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.27	0.28	...
10 to 12, excl	0.29	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	...
12 to 15, incl	0.29	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	...

TABLE 2 Permitted Variations in Weight for Rectangular Sheared Plates and Universal Mill Plates 613.0 lb/ft² and Under When Ordered to Weight

NOTE 1—Permitted variations in overweight for lots of circular and sketch plates shall be 1 1/4 times the amounts in this table.

NOTE 2—Permitted variations in overweight for single plates shall be 1 1/3 times the amounts in this table.

NOTE 3—Permitted variations in overweight for single circular and sketch plates shall be 1 2/3 times the amounts in this table.

NOTE 4—The adopted standard density of rolled steel is 490 lb/ft³.

NOTE 5—Where “...” appears in this table, there is no requirement.

Specified Weights, lb/ft ²	Permitted Variations in Average Weight of Lots ^A for Widths Given in Inches, Expressed in Percentage of the Specified Weights per Square Foot																					
	48 and under		Over 48 to 60, excl		60 to 72, excl		72 to 84, excl		84 to 96, excl		96 to 108, excl		108 to 120, excl		120 to 132, excl		132 to 144, excl		144 to 168, excl		168 and over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 10, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	11.0	3.0	13.0	3.0	...	...	...	...
10 to 12.5, excl	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.5	3.0	7.0	3.0	8.0	3.0	9.0	3.0	12.0	3.0	...	...
12.5 to 15.0, excl	4.0	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11.0	3.0	...	...
15 to 17.5, excl	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0	10.0	3.0
17.5 to 20, excl	3.5	2.5	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0	9.0	3.0
20 to 25, excl	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0	8.0	3.0
25 to 30, excl	3.0	2.5	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0	7.0	3.0
30 to 40, excl	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0	6.5	3.0
40 to 81.7, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	4.0	3.0	5.5	3.0	6.0	3.0
81.7 to 122.6, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0
122.6 to 163.4, excl	2.5	1.5	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0	3.5	2.0
163.4 to 245.1, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0	3.5	1.0
245.1 to 409.0, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
409.0 to 490.1, excl	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0
490.1 to 613.0, excl	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0

^A The term “lot” means all the plates of each tabular width and weight group represented in each shipment.

TABLE 3 Permitted Variations in Width and Length for Sheared Plates 1½ in. and Under in Thickness; Length Only of Universal Mill Plates 2½ in. and Under in Thickness

Specified Dimensions, in.		Permitted Variations Over Specified Width and Length ^A for Thicknesses Given in Inches or Equivalent Weights Given in Pounds per Square Foot, in.							
Length	Width	To ⅜, excl		⅜ to ½, excl		½ to 1, excl		1 to 2, incl ^B	
		To 15.3, excl		15.3 to 25.5, excl		25.5 to 40.8, excl		40.8 to 81.7, incl	
		Width	Length	Width	Length	Width	Length	Width	Length
To 120, excl	To 60, excl	⅜	½	⅞	⅝	½	¾	⅝	1
	60 to 84, excl	⅞	⅝	½	⅞	⅝	⅞	¾	1
	84 to 108, excl	½	¾	⅝	⅞	¾	1	1	1½
	108 and over	⅝	⅞	¾	1	⅞	1½	1½	1¼
120 to 240, excl	To 60, excl	⅜	¾	½	⅞	⅝	1	¾	1½
	60 to 84, excl	½	¾	⅝	⅞	¾	1	⅞	1¼
	84 to 108, excl	⅞	⅞	⅞	1½	1½	1½	1	1½
	108 and over	⅝	1	¾	1½	⅞	1¼	1½	1½
240 to 360, excl	To 60, excl	⅜	1	½	1½	⅝	1¼	¾	1½
	60 to 84, excl	½	1	⅝	1½	¾	1¼	⅞	1½
	84 to 108, excl	⅞	1	⅞	1½	⅞	1½	1	1½
	108 and over	1½	1½	⅞	1¼	1	1½	1¼	1¾
360 to 480, excl	To 60, excl	⅞	1½	½	1¼	⅝	1½	¾	1½
	60 to 84, excl	½	1¼	⅝	1½	¾	1½	⅞	1½
	84 to 108, excl	⅞	1¼	¾	1½	⅞	1½	1	1½
	108 and over	¾	1½	⅞	1½	1	1½	1¼	1½
480 to 600, excl	To 60, excl	⅞	1¼	½	1½	⅝	1½	¾	1½
	60 to 84, excl	½	1½	⅝	1½	¾	1½	⅞	1½
	84 to 108, excl	⅝	1½	¾	1½	⅞	1½	1	1½
	108 and over	¾	1½	⅞	1½	1	1½	1¼	1½
600 to 720, excl	To 60, excl	½	1¾	⅝	1½	¾	1½	⅞	2¼
	60 to 84, excl	⅝	1¾	¾	1½	⅞	1½	1	2¼
	84 to 108, excl	⅝	1¾	¾	1½	⅞	1½	1½	2¼
	108 and over	⅞	1¾	1	2	1½	2¼	1¼	2½
720 and over	To 60, excl	⅞	2	¾	2½	⅞	2¼	1	2¾
	60 to 84, excl	¾	2	⅞	2½	1	2¼	1½	2¾
	84 to 108, excl	¾	2	⅞	2½	1	2¼	1¼	2¾
	108 and over	1	2	1½	2½	1¼	2½	1½	3

^A Permitted variation under specified width and length, ¼ in. By agreement, these permitted variations may be taken all over, in which case the sum of the permitted variations applies.

^B Permitted variations in length apply also to Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2½ in., incl, except for alloy steel up to 2 in. thick.

TABLE 4 Permitted Variations in Width for Mill Edge Carbon and High-Strength, Low-Alloy Plates Produced on Strip Mills (Applies to Plates Produced from Coil and to Plates Produced from an As-Rolled Structural Product)

Specified Width, in.	Permitted Variation Over Specified Width, in. ^A
To 14, excl	⅞
14 to 17, excl	½
17 to 19, excl	⅞
19 to 21, excl	⅝
21 to 24, excl	1½
24 to 26, excl	1¾
26 to 28, excl	1¾
28 to 35, excl	1½
35 to 50, excl	1¼
50 to 60, excl	1½
60 to 65, excl	1½
65 to 70, excl	1¾
70 to 80, excl	1½
80 and over	2

^A No permitted variation under specified width.

TABLE 5 Permitted Variations in Rolled Width for Universal Mill Plates 15 in. and Under in Thickness

Specified Width, in.	Permitted Variations Over Specified Width ^A for Thicknesses Given in Inches or Equivalent Weights Given in Pounds per Square Foot, in.					
	To ⅜, excl	⅜ to ½, excl	½ to 1, excl	1 to 2, incl	Over 2 to 10, incl	Over 10 to 15, incl
	To 15.3, excl	15.3 to 25.5, excl	25.5 to 40.8, excl	40.8 to 81.7, incl	81.7 to 409.0, incl	409.0 to 613.0, incl
Over 8 to 20, excl	⅞	⅞	¾	¼	¾	½
20 to 36, excl	¾	¼	⅝	¾	⅞	⅞
36 and over	⅞	¾	⅞	½	⅞	⅝

^A Permitted variation under specified width, ⅞ in.

TABLE 6 Permitted Variations in Diameter for Sheared Circular Plates 1 in. and Under in Thickness

Specified Diameter, in.	Permitted Variations Over Specified Diameter for Thicknesses Given in Inches, in. ^A		
	To 3/8, excl	3/8 to 5/8, excl	5/8 to 1, incl
To 32, excl	1/4	3/8	1/2
32 to 84, excl	5/16	7/16	9/16
84 to 108, excl	3/8	1/2	5/8
108 to 130, excl	7/16	9/16	11/16
130 and over	1/2	5/8	3/4

^A No permitted variation under specified diameter.

TABLE 7 Permitted Variations in Diameter for Gas-Cut Circular Plates (Not Applicable to Alloy Steel)

Specified Diameter, in.	Permitted Variation Over Specified Diameter for Thicknesses Given in Inches, in. ^A					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	3/8	3/8	1/2	1/2	5/8	3/4
32 to 84, excl	3/8	1/2	1/2	5/8	3/4	7/8
84 to 108, excl	1/2	9/16	5/8	3/4	7/8	1
108 to 130, excl	1/2	9/16	11/16	7/8	1	11/8
130 and over	5/8	3/4	7/8	1	11/8	1 1/4

^A No permitted variation under specified diameter.

TABLE 8 Permitted Variations in Width and Length for Rectangular Plates When Gas Cuttings is Specified or Required (Applies to Alloy Steel Specifications Only)

NOTE 1—These permitted variations shall be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Permitted Variation Over Specified Width and Length, in.
To 2, excl	3/4
2 to 4, excl	1
4 to 6, excl	1 1/8
6 to 8, excl	1 5/16
8 to 15, incl	1 1/2

TABLE 9 Permitted Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Not Applicable to Alloy Steel)

NOTE 1—These permitted variations may be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Permitted Variation Over Specified Width and Length, in.
To 2, excl	1/2
2 to 4, excl	5/8
4 to 6, excl	3/4
6 to 8, excl	7/8
8 to 15, incl	1

TABLE 10 Permitted Variations in Diameter for Gas-Cut Circular Plates (Applies to Alloy Steel Specifications Only)

Specified Diameter, in.	Permitted Variations Over Specified Diameter for Specified Thicknesses Given in Inches, in. ^A					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	1/2	1/2	3/4	3/4	1	1
32 to 84, excl	1/2	5/8	7/8	1	1 1/8	1 1/4
84 to 108, excl	5/8	3/4	1	1 1/8	1 1/4	1 3/8
108 to 130, incl	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2

^A No permitted variation under specified diameter.

TABLE 11 Permitted Camber^A for Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared, Special-Cut, or Gas-Cut Rectangular Plates

Specified Thickness, in.	Specified Weight, lb/ft ²	Specified Width, in.	Permitted Camber, in.
To 2, incl	to 81.7, incl	all	1/8 × (no. of feet of length/5)
Over 2 to 15, incl	81.7 to 613.0, incl	to 30, incl	3/16 × (no. of feet of length/5)
Over 2 to 15, incl	81.7 to 613.0, incl	over 30	1/4 × (no. of feet of length/5)

^A Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE 12 Permitted Camber^A for Sheared Plates and Gas-Cut Rectangular Plates, All Thicknesses (Applies to Carbon Steel Only)

Permitted camber, in. = 1/8 × (number of feet of length/5)

^A Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE 13 Permitted Variations From a Flat Surface for Standard Flatness Carbon Steel Plates

NOTE 1—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed ¼ in. When the longer dimension is from 36 to 72 in., incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than ¼ in.

NOTE 2—These permitted variations apply to plates that have a specified minimum tensile strength of not more than 60 ksi or comparable chemical composition or hardness. The limits in this table are increased 50 % for plates that have a higher specified minimum tensile strength or comparable chemical composition or hardness.

NOTE 3—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 4—Where “...” appears in this table, there is no requirement.

NOTE 5—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Specified Weight, lb/ft ²	Permitted Variations from a Flat Surface for Specified Widths Given in Inches, in. ^{A,B}										
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To ¼, excl	To 10.2, excl	9/16	¾	15/16	1¼	1¾	1½	1¾	1¾	1¾	...	...
¼ to ⅜, excl	10.2 to 15.3, excl	½	5/8	¾	15/16	1½	1¾	1¾	1½	1½	...	...
⅜ to ½, excl	15.3 to 20.4, excl	½	9/16	5/8	5/8	¾	7/8	1	1½	1¼	17/8	2½
½ to ¾, excl	20.4 to 30.6, excl	7/16	½	9/16	5/8	5/8	¾	1	1	1½	1½	2
¾ to 1, excl	30.6 to 40.8, excl	7/16	½	9/16	5/8	5/8	¾	¾	7/8	1	1¾	1¾
1 to 2, excl	40.8 to 81.7, excl	¾	½	½	9/16	9/16	5/8	5/8	11/16	9/8	1½	1½
2 to 4, excl	81.7 to 163.4, excl	5/16	¾	7/16	½	½	½	½	9/16	5/8	7/8	1½
4 to 6, excl	163.4 to 245.1, excl	¾	7/16	½	½	9/16	9/16	5/8	¾	7/8	7/8	1
6 to 8, excl	245.1 to 326.8, excl	7/16	½	½	5/8	11/16	¾	7/8	7/8	1	1	1
8 to 10, excl	326.8 to 409.0, excl	½	½	5/8	11/16	¾	13/16	7/8	15/16	1	1	1
10 to 12, excl	409.0 to 490.1, excl	½	5/8	¾	13/16	7/8	15/16	1	1	1	1	1
12 to 15, excl	490.1 to 613.0, incl	5/8	¾	13/16	7/8	15/16	1	1	1	1	1	...

^A Permitted Variation from a Flat Surface for Length—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width for plates up to 12 ft in length, or in any 12 ft for longer plates.

^B Permitted Variation from a Flat Surface for Width—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

TABLE 14 Permitted Variations From a Flat Surface for Standard Flatness High-Strength Low-Alloy Steel and Alloy Steel Plates, Hot Rolled or Thermally Treated

NOTE 1—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed ⅜ in. When the longer dimension is from 36 to 72 in. incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width.

NOTE 2—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 3—Where “...” appears in this table, there is no requirement.

NOTE 4—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Specified Weight, lb/ft ²	Permitted Variations from a Flat Surface for Specified Widths, in. ^{A,B}										
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To ¼, excl	To 10.2, excl	13/16	1½	1¾	17/8	2	2¼	2¾	2¾	2¾	...	...
¼ to ⅜, excl	10.2 to 15.3, excl	¾	15/16	1½	1¾	1¾	17/8	2	2¼	2¾	...	...
⅜ to ½, excl	15.3 to 20.4, excl	¾	7/8	15/16	15/16	1½	15/16	1½	15/8	17/8	2¾	3½
½ to ¾, excl	20.4 to 30.6, excl	5/8	¾	13/16	7/8	1	1½	1¼	1¾	1¾	2¼	3
¾ to 1, excl	30.6 to 40.8, excl	5/8	¾	7/8	7/8	15/16	1	1½	15/16	1½	2	2½
1 to 2, excl	40.8 to 81.7, excl	9/16	5/8	¾	13/16	7/8	15/16	1	1	1	15/8	2¼
2 to 4, excl	81.7 to 163.4, excl	½	9/16	11/16	¾	¾	¾	¾	7/8	1	1¼	1½
4 to 6, excl	163.4 to 245.1, excl	9/16	11/16	¾	¾	7/8	7/8	15/16	1½	1¼	1¼	1½
6 to 8, excl	245.1 to 326.8, excl	5/8	¾	¾	15/16	1	1½	1¼	15/16	1½	1½	1½
8 to 10, excl	326.8 to 409.0, excl	¾	13/16	15/16	1	1½	1¼	15/16	1¾	1½	1½	1½
10 to 12, excl	409.0 to 490.1, excl	¾	15/16	1½	1¼	15/16	1¾	1½	1½	1½	1½	1½
12 to 15, incl	490.1 to 613.0, incl	7/8	1	13/16	15/16	1¾	1½	1½	1½	1½	1½	1½

^A Permitted Variation from a Flat Surface for Length—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft for longer plates.

^B Permitted Variation from a Flat Surface for Width—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

TABLE 15 Permitted Variations in Waviness for Standard Flatness Plates

NOTE 1—Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the plate at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 12 ft of length. The permitted variation in waviness is a function of the permitted variation from a flat surface as obtained from Table 13 or Table 14, whichever is applicable.

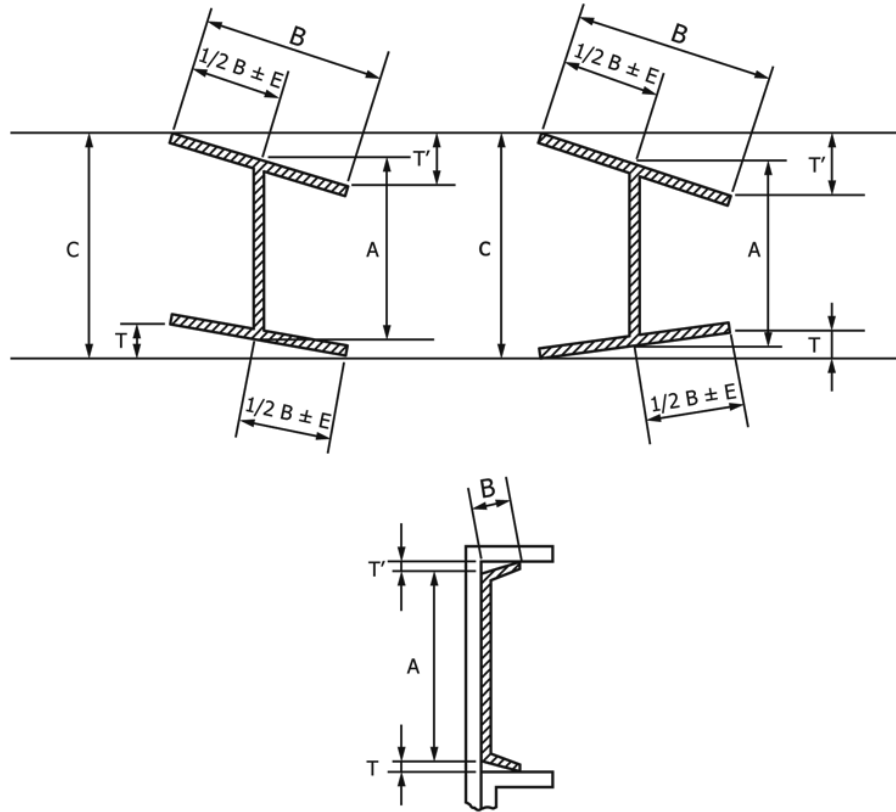
NOTE 2—Plates must be in a horizontal position on a flat surface when waviness is measured.

Permitted Variation from a Flat Surface (from Table 13 or Table 14), in.	Permitted Variation in Waviness, in., When Number of Waves in 12 ft is						
	1	2	3	4	5	6	7
5/16	5/16	1/4	3/16	1/8	1/8	1/16	1/16
3/8	3/8	5/16	3/16	3/16	1/8	1/16	1/16
7/16	7/16	5/16	1/4	3/16	1/8	1/8	1/16
1/2	1/2	3/8	5/16	3/16	3/16	1/8	1/16
9/16	9/16	7/16	5/16	1/4	3/16	1/8	1/8
5/8	5/8	1/2	3/8	1/4	3/16	1/8	1/8
11/16	11/16	1/2	3/8	5/16	3/16	3/16	1/8
3/4	3/4	9/16	7/16	5/16	1/4	3/16	1/8
13/16	13/16	5/8	7/16	5/16	1/4	3/16	1/8
7/8	7/8	11/16	1/2	3/8	1/4	3/16	1/8
15/16	15/16	11/16	1/2	3/8	5/16	1/4	3/16
1	1	3/4	9/16	7/16	5/16	1/4	3/16
1 1/8	1 1/8	7/8	5/8	1/2	3/8	1/4	3/16
1 1/4	1 1/4	15/16	11/16	1/2	3/8	5/16	1/4
1 3/8	1 3/8	1 1/16	3/4	9/16	7/16	5/16	1/4
1 1/2	1 1/2	1 1/8	7/8	5/8	1/2	3/8	1/4
1 5/8	1 5/8	1 1/4	15/16	11/16	1/2	3/8	5/16
1 3/4	1 3/4	1 5/16	1	3/4	9/16	7/16	5/16
1 7/8	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16	5/16
2	2	1 1/2	1 1/8	7/8	5/8	1/2	3/8
2 1/8	2 1/8	1 5/8	1 3/16	7/8	11/16	1/2	3/8
2 1/4	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16	3/8
2 3/8	2 3/8	1 13/16	1 5/16	1	3/4	9/16	7/16
2 1/2	2 1/2	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16
2 5/8	2 5/8	2	1 1/2	1 1/8	13/16	5/8	7/16
2 3/4	2 3/4	2 1/16	1 9/16	1 1/8	7/8	5/8	1/2
2 7/8	2 7/8	2 3/16	1 5/8	1 3/16	15/16	11/16	1/2
3	3	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16
3 1/8	3 1/8	2 3/8	1 3/4	1 5/16	1	3/4	9/16

TABLE 16 Permitted Variations in Cross Section for W, HP, S, M, C, and MC Shapes

NOTE 1—*A* is measured at center line of web for S, M, and W and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 3 in. *B* is measured parallel to flange. *C* is measured parallel to web.

NOTE 2—Where “...” appears in this table, there is no requirement.



Permitted Variations in Sectional Dimensions Given, in.										
Shape	Section Nominal Sizes, in.	A, Depth		B, Flange Width		<i>T</i> + <i>T'</i> ^A Flanges Out-of- Square ^B	<i>E</i> , Web off Cen- ter ^C	<i>C</i> , Maximum Depth at any Cross Section over Theo- retical Depth, in.	Permitted Variations Over or Under Theoreti- cal Web Thickness for Thicknesses Given in Inches, in.	
		Over Theo- retical	Under Theo- retical	Over Theo- retical	Under Theo- retical				³ / ₁₆ and under	Over ³ / ₁₆
W and HP	Up to 12, incl	¹ / ₈	¹ / ₈	¹ / ₄	³ / ₁₆	¹ / ₄	³ / ₁₆	¹ / ₄	...	...
	Over 12	¹ / ₈	¹ / ₈	¹ / ₄	³ / ₁₆	⁵ / ₁₆	³ / ₁₆	¹ / ₄	...	...
S and M	3 to 7, incl	³ / ₃₂	¹ / ₁₆	¹ / ₈	¹ / ₈	¹ / ₃₂	³ / ₁₆	...	...	...
	Over 7 to 14, incl	¹ / ₈	³ / ₃₂	³ / ₃₂	³ / ₃₂	¹ / ₃₂	³ / ₁₆	...	...	...
C and MC	Over 14 to 24, incl	³ / ₁₆	¹ / ₈	³ / ₁₆	³ / ₁₆	¹ / ₃₂	³ / ₁₆	...	...	...
	1½ and under	¹ / ₃₂	¹ / ₃₂	¹ / ₃₂	¹ / ₃₂	¹ / ₃₂	...	...	0.010	0.015
	Over 1½ to 3, excl	¹ / ₁₆	¹ / ₁₆	¹ / ₁₆	¹ / ₁₆	¹ / ₃₂	...	...	0.015	0.020
	3 to 7, incl	³ / ₃₂	¹ / ₁₆	¹ / ₈	¹ / ₈	¹ / ₃₂	...	...	...	...
	Over 7 to 14, incl	¹ / ₈	³ / ₃₂	¹ / ₈	³ / ₃₂	¹ / ₃₂	...	...	...	...
	Over 14	³ / ₁₆	¹ / ₈	¹ / ₈	³ / ₁₆	¹ / ₃₂	...	...	...	...

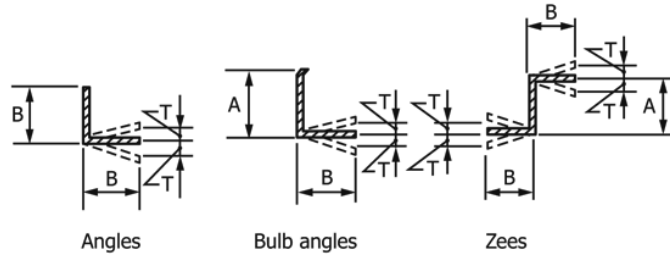
^A *T* + *T'* applies when flanges of channels are toed in or out. For channels ⁵/₈ in. and under in depth, the permitted out-of-square is ³/₆₄ in./in. of depth.

^B Permitted variation is per inch of flange width for S, M, C, and MC shapes.

^C Permitted variation of ³/₁₆ in. max for sections over 426 lb/ft.

TABLE 17 Permitted Variations in Cross Section for Angles (L Shapes), Bulb Angles, and Zees

NOTE 1—Where “...” appears in this table, there is no requirement.



		Permitted Variations in Sectional Dimensions Given, in.					Permitted Variations Over or Under Theoretical Thickness for Thicknesses Given in Inches, in.		
Section	Nominal Size, in.	A, Depth		B, Flange Width or Length of Leg		T, Out-of-Square per Inch of B, in.	$\frac{3}{16}$ and under	Over $\frac{3}{16}$ to $\frac{3}{8}$, incl	Over $\frac{3}{8}$
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				
Angles ^A (L Shapes)	1 and under	...	...	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{3}{128}$ ^B	0.008	0.010	...
	Over 1 to 2, incl	...	...	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{3}{128}$ ^B	0.010	0.010	0.012
	Over 2 to 2½, incl	...	...	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{128}$ ^B	0.012	0.015	0.015
	Over 2½ to 4, incl	...	...	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128}$ ^B	...	...	...
	Over 4 to 6, incl	...	...	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128}$ ^B	...	...	...
	Over 6 to 8, incl	...	...	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{128}$ ^B	...	...	...
	Over 8 to 10, incl	...	...	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{128}$ ^B	...	...	...
Bulb angles	Over 10	...	...	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{128}$ ^B	...	...	...
	(Depth) 3 to 4, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128}$ ^B	...	...	...
	Over 4 to 6, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128}$ ^B	...	...	...
Zees	Over 6	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{128}$ ^B	...	...	...
	3 to 4, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{32}$	...	...	...
	Over 4 to 6, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128}$ ^B	...	...	...

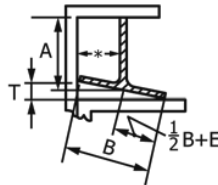
^A For unequal leg angles, longer leg determines classification.

^B $\frac{3}{128}$ in./in. = $1\frac{1}{2}^\circ$.

TABLE 18 Permitted Variations in Sectional Dimensions for Rolled Tees

NOTE 1—*Back of square and center line of stem are to be parallel when measuring “out-of-square.”

NOTE 2—Where “...” appears in this table, there is no requirement.



Permitted Variations in Sectional Dimensions Given, in.											
Tees											
Nominal Size, ^A	A, Depth ^B		B, Width ^B		T, Out-of-Square per Inch of B	E, Web-off-Center	Stem Out-of-Square ^C	Thickness of Flange		Thickness of Stem	
	Over	Under	Over	Under				Over	Under	Over	Under
1¼ and under	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{3}{64}$	...	...	$\frac{1}{32}$	0.010	0.010	0.005	0.020
Over 1¼ to 2, incl	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	...	...	$\frac{1}{16}$	0.012	0.012	0.010	0.020
Over 2 to 3, excl	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	...	...	$\frac{3}{32}$	0.015	0.015	0.015	0.020
3 to 5, incl	$\frac{3}{32}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{32}$	$\frac{3}{32}$	...	...	...	...	...
Over 5 to 7, incl	$\frac{3}{32}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{32}$	$\frac{1}{8}$	...	...	...	...	...

^A The longer member of an unequal tee determines the size for permitted variations.

^B Measurements for both depth and width are overall.

^C Stem-out-of-square is the permitted variation from its true position of the center line of stem, measured at the point.

TABLE 19 Permitted Variations in Length for S, M, C, MC, L, T, Z, and Bulb Angle Shapes

NOTE 1—Where “...” appears in this table, there is no requirement.

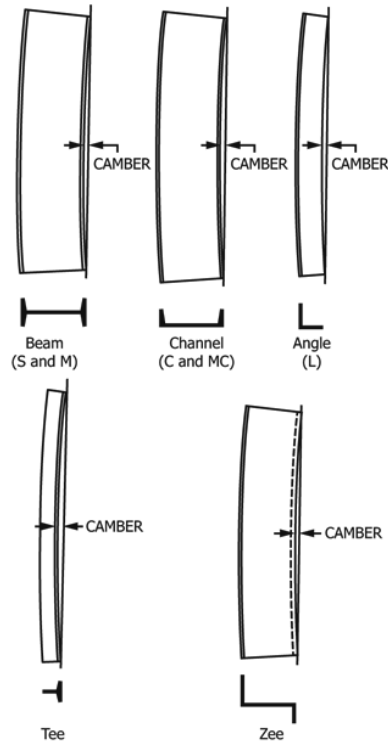
Nominal Size, ^A in.	Permitted Variations from Specified Length for Lengths Given in Feet, in.													
	5 to 10, excl		10 to 20,excl		20 to 30, incl		Over 30 to 40, incl		Over 40 to 50, incl		Over 50 to 65, incl		Over 65 ft	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 3	$\frac{5}{8}$	0	1	0	1½	0	2	0	2½	0	2½	0	...	...
3 and over	1	0	1½	0	1¾	0	2¼	0	2¾	0	2¾	0	...	...

^A Greatest cross-sectional dimension.**TABLE 20 Permitted Variations in End Out-Of-Square for S, M, C, MC, L, T, Z, Bulb Angle, and Flat Bar Shapes**

Shapes	Permitted Variation
S, M, C, and MC	$\frac{1}{64}$ in. per inch of depth
L ^A	$\frac{3}{128}$ in. per inch of leg length or $1\frac{1}{2}^\circ$
Bulb angles	$\frac{3}{128}$ in. per inch of depth or $1\frac{1}{2}^\circ$
Rolled Tees ^A	$\frac{1}{64}$ in. per inch of flange or stem
Zees	$\frac{3}{128}$ in. per inch of sum of both flange lengths
Flat Bars ^B	$\frac{1}{16}$ in. per inch of width but not less than $\frac{5}{16}$ in.

^A Permitted variations in end out-of-square are determined on the longer members of the shape.^B For flat bars, permitted variations in end out-of-square are determined on the width of the bar.

TABLE 21 Permitted Variations in Straightness for S, M, C, MC, L, T, Z, and Bulb Angle Shapes



Positions for Measuring Camber of Shapes

Variable	Nominal Size, ^A in.	Permitted Variation, in.
Camber	Under 3 3 and over	$\frac{1}{4}$ in. in any 5 ft, or $\frac{1}{4} \times$ (number of feet of total length/5) $\frac{1}{8} \times$ (number of feet of total length/5)
Sweep	All	Due to the extreme variations in flexibility of these shapes, permitted variations for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved.

^A Greatest cross-sectional dimension.

TABLE 22 Permitted Variations in Length for W and HP Shapes

Permitted Variations from Specified Length for Lengths Given in Feet, in. ^{A, B}	
Over	Under
4	0

^A For HP and W shapes specified in the order for use as bearing piles, the permitted variations in length are plus 5 in. and minus 0 in. These permitted variations in length also apply to sheet piles.

^B The permitted variations in end out-of-square for W and HP shapes shall be $\frac{1}{64}$ in. per inch of depth, or per inch of flange width if the flange width is larger than the depth.

TABLE 23 Permitted Variations in Length and End Out-of-Square, Milled Shapes

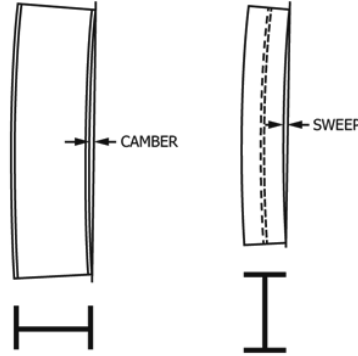
Nominal Depth, in.	Length, ft ^B	Permitted Variations in Length and End Out-of-Square, in. ^A					
		Milled Both Ends ^C			Milled One-End ^C		
		Length		End Out-of-Square	Length		End Out-of-Square (for Milled End)
		Over	Under		Over	Under	
6 to 36	6 to 70	1/32	1/32	1/32	1/4	1/4	1/32

^A Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.

^B The permitted variations in length and end out-of-square are additive.

^C End out-of-square is measured by (a) squaring from the center line of the web and (b) squaring from the center line of the flange. The measured variation from true squareness in either plane shall not exceed the total tabular amount.

TABLE 24 Permitted Variations in Straightness for W and HP Shapes



Positions for Measuring Camber and Sweep of W and HP Shapes

	Permitted Variation in Straightness, in.
Camber and sweep	$\frac{1}{8} \times (\text{number of feet of total length}/10)^A$
When certain sections ^B with a flange width approximately equal to depth are specified in the order for use as columns:	
Lengths of 45 ft and under	$\frac{1}{8} \times (\text{number of feet of total length}/10)$ but not over $\frac{3}{8}$
Lengths over 45 ft	$\frac{3}{8} + [\frac{1}{8} \times ((\text{number of feet of total length} - 45)/10)]$

^A Sections with a flange width less than 6 in., permitted variation for sweep, in. = $\frac{1}{8} \times (\text{number of feet of total length}/5)$.

^B Applies only to:

- 8-in. deep sections 31 lb/ft and heavier,
- 10-in. deep sections 49 lb/ft and heavier,
- 12-in. deep sections 65 lb/ft and heavier,
- 14-in. deep sections 90 lb/ft and heavier,
- 16-in. deep sections 88 lb/ft and heavier, and
- 18-in. deep sections 135 lb/ft and heavier.

For other sections specified in the order for use as columns, the permitted variation is subject to negotiation with the manufacturer.

TABLE 25 Permitted Variations in Dimensions for Split Tees and Split Angles (L Shapes)^A

Specified Depth, in.	Permitted Variation Over or Under Specified Depth, ^B in.
To 6, excl (beams and channels)	1/8
6 to 16, excl (beams and channels)	3/16
16 to 20, excl (beams and channels)	1/4
20 to 24, excl (beams)	5/16
24 and over (beams)	3/8

^A The permitted variations in length for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

^B The above permitted variations in depth of tees or angles include the permitted variations in depth for the beams or channels before splitting. Permitted variations in dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, apply, except:
straightness = $\frac{1}{8}$ in. \times (length in feet/5)

TABLE 26 Permitted Variations in Sectional Dimensions for Square-Edge and Round-Edge Flat Bars

NOTE 1—Where “...” appears in this table, there is no requirement.

Specified Widths, in.	Permitted Variations Over or Under Specified Thickness, for Thicknesses Given in Inches, in.							Permitted Variations From Specified Width, in.	
	0.203 to 0.230, excl	0.230 to ¼, excl	¼ to ½, incl	Over ½ to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl	Over 3	Over	Under
To 1, incl	0.007	0.007	0.008	0.010	...	...	...	1/64	1/64
Over 1 to 2, incl	0.007	0.007	0.012	0.015	1/32	...	...	1/32	1/32
Over 2 to 4, incl	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl	0.009	0.009	0.015	0.020	1/32	3/64	3/64	3/32	1/16
Over 6 to 8, incl	^A	0.015	0.016	0.025	1/32	3/64	1/16	1/8 ^B	3/32 ^B

^A Flats over 6 to 8 in., incl, in width are not available as hot-rolled carbon steel bars in thickness under 0.230 in.^B For flats over 6 to 8 in., in width, and to 3 in. incl in thickness.**TABLE 27 Permitted Variations in Sectional Dimensions for Round and Square Bars and Round-Cornered Squares**

Specified Size, in.	Permitted Variations from Specified Size, in.		Permitted Out-of-Round or Out-of-Square, in. ^A
	Over	Under	
To 5/16	0.005	0.005	0.008
Over 5/16 to 7/16, incl	0.006	0.006	0.009
Over 7/16 to 9/16, incl	0.007	0.007	0.010
Over 9/16 to 7/8, incl	0.008	0.008	0.012
Over 7/8 to 1, incl	0.009	0.009	0.013
Over 1 to 1 1/8, incl	0.010	0.010	0.015
Over 1 1/8 to 1 1/4, incl	0.011	0.011	0.016
Over 1 1/4 to 1 3/8, incl	0.012	0.012	0.018
Over 1 3/8 to 1 1/2, incl	0.014	0.014	0.021
Over 1 1/2 to 2, incl	1/64	1/64	0.023
Over 2 to 2 1/2, incl	1/32	0	0.023
Over 2 1/2 to 3 1/2, incl	3/64	0	0.035
Over 3 1/2 to 4 1/2, incl	1/16	0	0.046
Over 4 1/2 to 5 1/2, incl	5/64	0	0.058
Over 5 1/2 to 6 1/2, incl	1/8	0	0.070
Over 6 1/2 to 8 1/4, incl	5/32	0	0.085
Over 8 1/4 to 9 1/2, incl	3/16	0	0.100
Over 9 1/2 to 10, incl	1/4	0	0.120

^A Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.**TABLE 28 Permitted Variations in Sectional Dimensions for Hexagons**

Specified Sizes Between Opposite Sides, in.	Permitted Variations from Specified Size, in.		Permitted Out-of-Hexagon Section, Three Measurements, in. ^A
	Over	Under	
1/2 and under	0.007	0.007	0.011
Over 1/2 to 1, incl	0.010	0.010	0.015
Over 1 to 1 1/2, incl	0.021	0.013	0.025
Over 1 1/2 to 2, incl	1/32	1/64	1/32
Over 2 to 2 1/2, incl	3/64	1/64	3/64
Over 2 1/2 to 3 1/2, incl	1/16	1/64	1/16

^A Out-of-hexagon section is the greatest difference in distance between any two opposite faces measured at the same transverse cross section.

TABLE 29 Permitted Variations in Straightness for Bars

Permitted Variations in Straightness, in. ^A
¼ in any 5 ft and ¼ × (number of feet of total length/5)

^A Permitted variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.

TABLE 30 Permitted Variations in Length for Hot-Cut Steel Bars^A

NOTE 1—Where “...” appears in this table, there is no requirement.

Specified Sizes of Rounds, Squares, and Hexagons, in.	Specified Sizes of Flats, in.		Permitted Variations Over Specified Length Given in Feet, in. (No Variation Under)				
	Thickness	Width	5 to 10, excl	10 to 20, excl	20 to 30, excl	30 to 40, excl	40 to 60, incl
To 1, incl	To 1, incl	To 3, incl	½	¾	1¼	1¾	2¼
Over 1 to 2, incl	Over 1	To 3, incl	⅝	1	1½	2	2½
Over 1 to 2, incl	To 1, incl	Over 3 to 6, incl	⅝	1	1½	2	2½
Over 2 to 5, incl	Over 1	Over 3 to 6, incl	1	1½	1¾	2¼	2¾
Over 5 to 10, incl	...	...	2	2½	2¾	3	3¼
	0.230 to 1, incl	Over 6 to 8, incl	¾	1¼	1¾	3½	4
	Over 1 to 3, incl	Over 6 to 8, incl	1¼	1¾	2	3½	4
	Hot Sawing						
2 to 5, incl ^B	1 and over	3 and over	^B	1½	1¾	2¼	2¾
Over 5 to 10, incl	...	...	^B	2½	2¾	3	3¼

^A For flats over 6 to 8 in., incl, in width and over 3 in. in thickness, consult the manufacturer for permitted variations in length.

^B Smaller sizes and shorter lengths are not commonly hot sawed.

TABLE 31 Permitted Variations in Length for Bars Recut Both Ends After Straightening^{A,B}

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in.	Permitted Variations from Specified Lengths Given in Feet, in.			
	To 12, incl		Over 12	
	Over	Under	Over	Under
To 3, incl	⅜	⅛	¼	⅛
Over 3 to 6, incl	¼	⅛	⅜	⅛
Over 6 to 8, incl	⅜	⅛	½	⅛
Rounds over 8 to 10, incl	½	⅛	⅝	⅛

^A For flats over 6 to 8 in., incl, in width, and over 3 in. in thickness, consult the manufacturer or processor for permitted variations in length.

^B Permitted variations are sometimes required all over or all under the specified length, in which case the sum of the two permitted variations applies.

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. Those that are considered suitable for use with each material specification are listed in the specification. Other tests may be performed by agreement between the supplier and the purchaser. These additional requirements shall apply only when specified in the order, in which event the specified tests shall be made by the manufacturer or processor before shipment of the material.

S1. Vacuum Treatment

S1.1 The steel shall be made by a process that includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

S2. Product Analysis

S2.1 Product analyses shall be made for those elements specified or restricted by the applicable product specification for the applicable grade, class, and type. Specimens for analysis shall be taken adjacent to or from the tension test

specimen, or from a sample taken from the same relative location as that from which the tension test specimen was taken.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 Prior to testing, the test specimens representing the structural product for acceptance purposes for mechanical properties shall be thermally treated to simulate a post-weld heat treatment below the critical temperature (A_{c3}), using the heat treatment parameters (such as temperature range, time,

and cooling rates) specified in the order. The test results for such heat-treated test specimens shall meet the applicable product specification requirements.

S4. Additional Tension Test

S4.1 *Plate*—One tension test shall be made from each unit plate rolled from a slab or directly from an ingot, except that for quenched and tempered plates, a test shall be taken from each unit plate heat treated. The results obtained shall be reported on the mill test reports when such tests are required by the order.

S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with Specification A673/A673M.

S5.2 The frequency of testing, the test temperature to be used, and the absorbed energy requirements shall be as specified on the order.

S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and Over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with Test Method E208. The specimens shall represent the material in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of pieces to be tested and whether a maximum nil-ductility transition (NDT) temperature is mandatory or if the test results are for information only.

S8. Ultrasonic Examination

S8.1 The material shall be ultrasonically examined in accordance with the requirements specified on the order.

S15. Reduction of Area Measurement

S15.1 The reduction of area, as determined on the 0.500-in. [12.5-mm] diameter round tension test specimen in accordance with Test Methods and Definitions A370, shall not be less than 40 %.

S18. Maximum Tensile Strength

S18.1 Steel having a specified minimum tensile strength of less than 70 ksi [485 MPa] shall not exceed the minimum specified tensile strength by more than 30 ksi [205 MPa].

S18.2 Steel having a minimum specified tensile strength of 70 ksi [485 MPa] or higher shall not exceed the minimum specified tensile strength by more than 25 ksi [170 MPa].

S23. Copper-Bearing Steel (for improved atmospheric corrosion resistance)

S23.1 The copper content shall be a minimum of 0.20 % on heat analysis, 0.18 on product analysis.

S26. Subdivided Material—Marking of Individual Pieces

S26.1 Subdivided pieces shall be individually identified by marking, stenciling, or die stamping the applicable product specification designation (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization that subdivided the structural product. As an alternative, individual subdivided pieces shall be identified by a code traceable to the original required identification, provided that the trademark, name, or brand of the organization that subdivided the structural product is also placed on the structural product and the original required identification, cross referenced on the code, is furnished with the structural product.

S27. Restrictive Plate Flatness

S27.1 As-rolled or normalized carbon steel plates ordered to restrictive flatness shall conform to the permitted variations from a flat surface given in Table S27.1 or Table S27.2, whichever is applicable.

S27.2 As-rolled or normalized high-strength low-alloy steel plates ordered to restrictive flatness shall conform to the permitted variations from a flat surface given in Table S27.3 or Table S27.4, whichever is applicable.

TABLE S27.1 Permitted Variations From a Flat Surface for As-Rolled or Normalized Carbon Steel Plates Ordered to Half-Standard Flatness

NOTE 1—*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed $\frac{1}{4}$ in. in each direction. When the longer dimension is from 36 to 72 in., incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than $\frac{1}{4}$ in.

NOTE 4—The permitted variations given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permitted variations are $1\frac{1}{2}$ times the amounts in this table.

NOTE 5—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 6—Permitted variations in waviness do not apply.

NOTE 7—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Specified Weights, lb/ft ²	Permitted Variations From a Flat Surface for Specified Widths Given in Inches, in.					
		48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, incl
To $\frac{1}{4}$, excl	To 10.2, excl	$\frac{15}{32}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$
$\frac{1}{4}$ to $\frac{3}{8}$, excl	10.2 to 15.3, excl	$\frac{3}{8}$	$\frac{15}{32}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
$\frac{3}{8}$ to $\frac{1}{2}$, excl	15.3 to 20.4, excl	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl	20.4 to 30.6, excl	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
$\frac{3}{4}$ to 1, excl	30.6 to 40.8, excl	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
1 to 2, incl	40.8 to 51.7, incl	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$

TABLE S27.2 Permitted Variations From a Flat Surface for As-Rolled or Normalized Carbon Steel Plates Ordered to Half-Standard Flatness

NOTE 1—*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, incl., the permitted flatness variation should not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4—The permitted variations given in this table apply to plates that have a minimum specified tensile strength not over 415 MPa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permitted variations are $1\frac{1}{2}$ times the amounts in this table.

NOTE 5—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 6—Permitted variations in waviness do not apply.

NOTE 7—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Specified Weights, kg/m ²	Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm					
		1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, incl
To 6, excl	To 47.1 excl	12	16	17	19	20	22
6 to 10, excl	47.1 to 78.5, excl	9	12	14	16	17	19
10 to 12, excl	78.5 to 94.2, excl	8	8	9	11	12	14
12 to 20, excl	94.2 to 157.0, excl	7	8	8	9	12	12
20 to 25, excl	157.0 to 196.2, excl	7	8	8	8	9	11
25 to 50, incl	196.2 to 392.5, incl	6	7	7	8	8	8

TABLE S27.3 Permitted Variations From a Flat Surface for As-Rolled or Normalized High-Strength Low-Alloy Steel Plates Ordered to Half-Standard Flatness

NOTE 1—*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed $\frac{3}{8}$ in. in each direction. When the larger dimension is from 36 to 72 in., incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than $\frac{3}{8}$ in.

NOTE 4—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of those plates.

NOTE 5—Permitted variations in waviness do not apply.

NOTE 6—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Specified Weights, lb/ft ²	Permitted Variations From a Flat Surface for Specified Widths Given in Inches, in.					
		48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, incl
To $\frac{1}{4}$, excl	To 10.2 excl	$\frac{1}{16}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{5}{16}$
$\frac{1}{4}$ to $\frac{3}{8}$, excl	10.2 to 15.3, excl	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$1\frac{1}{4}$	1	$1\frac{1}{8}$
$\frac{3}{8}$ to $\frac{1}{2}$, excl	15.3 to 20.4, excl	$\frac{15}{32}$	$\frac{15}{32}$	$\frac{9}{16}$	$2\frac{1}{32}$	$\frac{3}{4}$	$1\frac{9}{16}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl	20.4 to 30.6, excl	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$1\frac{1}{16}$
$\frac{3}{4}$ to 1, excl	30.6 to 40.8, excl	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{15}{32}$	$\frac{1}{2}$	$\frac{9}{16}$	$2\frac{1}{32}$
1 to 2, incl	40.8 to 51.7, incl	$\frac{3}{8}$	$\frac{13}{32}$	$\frac{7}{16}$	$1\frac{5}{32}$	$\frac{1}{2}$	$\frac{1}{2}$

TABLE S27.4 Permitted Variations From a Flat Surface for As-Rolled or Normalized High-Strength Low-Alloy Steel Plates Ordered to Half-Standard Flatness

NOTE 1—*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 10 mm in each direction. When the larger dimension is from 900 to 1800 mm, incl., the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width but in no case less than 10 mm.

NOTE 4—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 5—Permitted variations in waviness do not apply.

NOTE 6—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Specified Weights, kg/m ²	Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm					
		1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, incl
To 6, excl	To 47.1 excl	17	24	25	28	30	33
6 to 10, excl	47.1 to 78.5, excl	14	17	22	24	25	28
10 to 12, excl	78.5 to 94.2, excl	12	12	14	16	19	20
12 to 20, excl	94.2 to 157.0, excl	11	11	12	14	16	17
20 to 25, excl	157.0 to 196.2, excl	11	11	12	12	14	16
25 to 50, incl	196.2 to 392.5, incl	9	10	11	12	12	12

S28. Fine Grain Practice

S28.1 The steel shall be made to fine grain practice.

S29. Fine Austenitic Grain Size

S29.1 The requirements for fine austenitic grain size (see 8.1 and 8.3) shall be met.

S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location

S30.1 For shapes with a flange thickness equal to or greater than $1\frac{1}{2}$ in. [38.1 mm] that are specified in the purchase order to be tested in accordance with this supplementary

requirement, Charpy V-notch impact tests shall be conducted in accordance with Specification A673/A673M, using specimens taken from the alternate core location. Unless otherwise specified in the purchase order, the minimum average absorbed energy for each test shall be 20 ft-lbf [27 J] and the test temperature shall be 70°F [21°C].

S30.2 The frequency of testing shall be Frequency (H), except that, for rolled shapes produced from ingots, the frequency shall be Frequency (P) and the specimens shall be

taken from a location representing the top of an ingot or part of an ingot used to produce the product represented by such specimens.

S31. Maximum Carbon Equivalent for Weldability

S31.1 Plates and shapes shall be supplied with a specific maximum carbon equivalent value as specified by the purchaser. This value shall be based upon heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S31.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S31.3 For additional information on the weldability of steel, see Appendix X3.

S32. Single Heat Bundles

S32.1 Bundles containing shapes or bars shall be from a single heat of steel.

ANNEXES

(Mandatory Information)

A1. PERMITTED VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Tables A1.1-A1.31 inclusive contain permitted variations in dimensions and mass stated in SI Units.

TABLE A1.1 Permitted Variations in Thickness for Rectangular Carbon, High-Strength Low Alloy, and Alloy Steel Plates, 300 mm and Under in Thickness When Ordered to Thickness

NOTE 1—Permitted variation under specified thickness, 0.3 mm. When so specified, these permitted variations may be taken all over, in which case the sum of these permitted variations applies.

NOTE 2—Thickness to be measured at 10 to 20 mm from the longitudinal edge.

NOTE 3—For specified thicknesses not listed in this table, the permitted variations in thickness shall be as given for the next higher value of specified thickness that is listed in this table.

NOTE 4—For thickness measured at any location other than that specified in Note 2, the permitted variations over specified thickness shall be 1³/₄ times the amounts in this table, rounded to the nearest 0.1 mm.

NOTE 5—Where “...” appears in this table, there is no requirement.

Specified Thickness, mm	Permitted Variations Over Specified Thickness for Widths Given in Millimetres, mm										
	1200 and Under	Over 1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3300, excl	3300 to 3600, excl	3600 to 4200, excl	4200 and Over
5.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
5.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
6.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.1	...	...
7.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	...
8.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	...
9.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	...
10.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
11.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
12.0	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.3	1.5	1.8
14.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
16.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
18.0	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.4	1.6	2.0
20.0	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.2	1.4	1.6	2.0
22.0	0.8	0.9	0.9	0.9	1.0	1.1	1.3	1.3	1.5	1.8	2.0
25.0	0.9	0.9	1.0	1.0	1.0	1.2	1.3	1.5	1.5	1.8	2.2
28.0	1.0	1.0	1.1	1.1	1.1	1.3	1.4	1.8	1.8	2.0	2.2
30.0	1.1	1.1	1.2	1.2	1.2	1.4	1.5	1.8	1.8	2.1	2.4
32.0	1.2	1.2	1.3	1.3	1.3	1.5	1.6	2.0	2.0	2.3	2.6
35.0	1.3	1.3	1.4	1.4	1.4	1.6	1.7	2.3	2.3	2.5	2.8
38.0	1.4	1.4	1.5	1.5	1.5	1.7	1.8	2.3	2.3	2.7	3.0
40.0	1.5	1.5	1.6	1.6	1.6	1.8	2.0	2.5	2.5	2.8	3.3
45.0	1.6	1.6	1.7	1.8	1.8	2.0	2.3	2.8	2.8	3.0	3.5
50.0	1.8	1.8	1.8	2.0	2.0	2.3	2.5	3.0	3.0	3.3	3.8
55.0	2.0	2.0	2.0	2.2	2.2	2.5	2.8	3.3	3.3	3.5	3.8
60.0	2.3	2.3	2.3	2.4	2.4	2.8	3.0	3.4	3.4	3.8	4.0
70.0	2.5	2.5	2.5	2.6	2.6	3.0	3.3	3.5	3.6	4.0	4.0
80.0	2.8	2.8	2.8	2.8	2.8	3.3	3.5	3.5	3.6	4.0	4.0
90.0	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.6	4.0	4.4
100.0	3.3	3.3	3.3	3.3	3.5	3.8	3.8	3.8	3.8	4.4	4.4
110.0	3.5	3.5	3.5	3.5	3.5	3.8	3.8	3.8	3.8	4.4	4.4
120.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.8	4.8
130.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.2	5.2
140.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	5.6	5.6
150.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.6	5.6
160.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	5.6	5.6
180.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	6.3	6.3
200.0	5.8	5.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0	7.0
250.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8.8
300.0	7.5	7.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0

TABLE A1.2 Permitted Variations in Mass for Rectangular Sheared Plates and Universal Mill Plates 2983 kg/m² and Under When Ordered to Mass

NOTE 1—Permitted variations in excess mass for lots of circular and sketch plates shall be 1¼ times the amounts in this table.

NOTE 2—Permitted variations in excess mass for single plates shall be 1⅓ times the amounts in this table.

NOTE 3—Permitted variations in excess mass for single circular and sketch plates shall be 1½ times the amounts in this table.

NOTE 4—The adopted standard density for rolled steel is 7850 kg/m³.

NOTE 5—Where “...” appears in this table, there is no requirement.

Specified Mass, kg/m ²	Permitted Variations in Average Mass of Lots ^A for Widths Given in Millimetres, Expressed in Percentage of the Specified Masses per Square Metre																					
	1200 and Under		Over 1200 to 1500, excl		1500 to 1800, excl		1800 to 2100, excl		2100 to 2400, excl		2400 to 2700, excl		2700 to 3000, excl		3000 to 3300, excl		3300 to 3600, excl		3600 to 4200, excl		4200 and Over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 51.02, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	...	...	...	...	...	...	...	...
51.02 to 62.80, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	6.5	3.0	7.0	3.0	8.0	3.0	9.0	3.0	...	...	...	...
62.80 to 74.58, excl	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11	3.0	...	...
74.58 to 86.35, excl	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0	10	3.0
86.35 to 102.0, excl	3.5	2.5	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0	9.0	3.0
102.0 to 125.6, excl	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0	8.0	3.0
125.6 to 149.2, excl	3.0	2.5	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0	7.0	3.0
149.2 to 196.2, excl	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0	6.5	3.0
196.2 to 392.5, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	4.0	3.0	5.5	3.0	6.0	3.0
392.5 to 588.8, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0
588.8 to 785.0, excl	2.5	1.5	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0	3.5	2.0
785.0 to 1178, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0	3.5	1.0
1178 to 1962, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
1962 to 2355, excl	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0
2355 to 2983, incl	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0

^A The term “lot” means all the plates of each tabular width and mass group represented in each shipment.

TABLE A1.3 Permitted Variations in Width and Length for Sheared Plates 40 mm and Under in Thickness; Length Only of Universal Mill Plates 65 mm and Under in Thickness

Specified Dimensions, mm		Permitted Variations Over Specified Width and Length ^A for Thicknesses Given in Millimetres and Equivalent Masses Given in Kilograms per Square Metre, mm							
Length	Width	To 10.5, excl		10.5 to 16, excl		16 to 25, excl		25 to 50, incl ^B	
		To 78.50, excl		78.50 to 125.6, excl		125.6 to 196.2, excl		196.2 to 392.5, excl	
		Width	Length	Width	Length	Width	Length	Width	Length
To 3000, excl	To 1500, excl	10	13	11	16	13	19	16	25
	1500 to 2100, excl	11	16	13	18	16	22	19	25
	2100 to 2700, excl	13	19	16	22	19	25	25	29
	2700 and over	16	22	19	25	22	29	29	32
3000 to 6000, excl	To 1500, excl	10	19	13	22	16	25	19	29
	1500 to 2100, excl	13	19	16	22	19	25	22	32
	2100 to 2700, excl	14	22	18	24	21	29	25	35
	2700 and over	16	25	19	29	22	32	29	35
6000 to 9000, excl	To 1500, excl	10	25	13	29	16	32	19	38
	1500 to 2100, excl	13	25	16	29	19	32	22	38
	2100 to 2700, excl	14	25	18	32	22	35	25	38
	2700 and over	18	29	22	32	25	35	32	44
9000 to 12 000, excl	To 1500, excl	11	29	13	32	16	35	19	41
	1500 to 2100, excl	13	32	16	35	19	38	22	41
	2100 to 2700, excl	14	32	19	35	22	38	25	48
	2700 and over	19	35	22	38	25	41	32	48
12 000 to 15 000, excl	To 1500, excl	11	32	13	38	16	41	19	48
	1500 to 2100, excl	13	35	16	38	19	41	22	48
	2100 to 2700, excl	16	35	19	38	22	41	25	48
	2700 and over	19	38	22	41	25	44	32	48
15 000 to 18 000, excl	To 1500, excl	13	44	16	48	19	48	22	57
	1500 to 2100, excl	16	44	19	48	22	48	25	57
	2100 to 2700, excl	16	44	19	48	22	48	29	57
	2700 and over	22	44	25	51	29	57	32	64
18 000 and over	To 1500, excl	14	51	19	54	22	57	25	70
	1500 to 2100, excl	19	51	22	54	25	57	29	70
	2100 to 2700, excl	19	51	22	54	25	57	32	70
	2700 and over	25	51	29	60	32	64	35	76

^A Permitted variations under specified width and length, 6 mm. By agreement, these permitted variations may be taken all over, in which case the sum of the permitted variations applies.

^B Permitted variations in length apply also to Universal Mill plates up to 300 mm in width for thicknesses over 50 to 65 mm, incl, except for alloy steel up to 50 mm thick.

TABLE A1.4 Permitted Variations in Width for Mill Edge Carbon and High Strength Low-Alloy Plates Produced on Strip Mills (Applies to Plates Produced from Coil and to Plates Produced from an As-Rolled Structural Product)

Specified Width, mm	Permitted Variation Over Specified Width, mm ^A
To 360, excl	11
360 to 430, excl	13
430 to 480, excl	14
480 to 530, excl	16
530 to 610, excl	17
610 to 660, excl	21
660 to 710, excl	24
710 to 890, excl	29
890 to 1270, excl	32
1270 to 1520, excl	38
1520 to 1650, excl	41
1650 to 1780, excl	44
1780 to 2030, excl	47
2030 and over	51

^A No permitted variation under specified width.

TABLE A1.5 Permitted Variations in Rolled Width for Universal Mill Plates 380 mm and Under in Thickness

Specified Width, mm	Permitted Variations Over Specified Width ^A for Thickness Given in Millimetres or Equivalent Masses Given in Kilograms per Square Metre, mm					
	To 10, excl	10 to 16, excl	16 to 25, incl	25 to 50, incl	Over 50 to 250, incl	Over 250 to 400, incl
	To 78.50, excl	78.50 to 125.6, excl	125.6 to 196.2, excl	196.2 to 392.5, incl	Over 392.5 to 1962, incl	Over 1962 to 3140, incl
Over 200 to 500, excl	3	3	5	6	10	13
500 to 900, excl	5	6	8	10	11	14
900 and over	8	10	11	13	14	16

^A Permitted variation under specified width, 3 mm.

TABLE A1.6 Permitted Variations in Diameter for Sheared Circular Plates 25 mm and Under in Thickness

Specified Diameters, mm	Permitted Variations Over Specified Diameter for Thicknesses Given in Millimetres, mm ^A		
	To 10, excl	10 to 16, excl	16 to 25, incl
To 800, excl	6	10	13
800 to 2100, excl	8	11	14
2100 to 2700, excl	10	13	16
2700 to 3300, excl	11	14	17
3300 and over	13	16	19

^A No permitted variation under specified diameter.

TABLE A1.7 Permitted Variations in Diameter for Gas-Cut Circular Plates (Not Applicable to Alloy Steel)

Specified Diameters, mm	Permitted Variation Over Specified Diameter for Thicknesses Given, mm ^A					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	10	10	13	13	16	19
800 to 2100, excl	10	13	13	16	19	22
2100 to 2700, excl	13	14	16	19	22	25
2700 to 3300, excl	13	14	17	22	25	29
3300 and over	16	19	22	25	29	32

^A No permitted variations under specified diameter.

TABLE A1.8 Permitted Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Applies to Alloy Steel Specifications Only)

NOTE 1—Plates with universal rolled edges will be gas cut to length only.

NOTE 2—These permitted variations shall be taken all under or divided over and under, if so specified.

Specified Thickness, mm	Permitted Variation Over Specified Width and Length, mm
To 50, excl	19
50 to 100, excl	25
100 to 150, excl	29
150 to 200, excl	33
200 to 400, excl	38

TABLE A1.9 Permitted Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Not Applicable to Alloy Steel)

NOTE 1—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, mm	Permitted Variation Over Specified Width and Length, mm ^A
To 50, excl	13
50 to 100, excl	16
100 to 150, excl	19
150 to 200, excl	22
200 to 400, incl	25

^A These permitted variations shall be taken all under or divided over and under, if so specified.

TABLE A1.10 Permitted Variations in Diameter for Gas-Cut Circular Plates (Applies to Alloy Steel Specifications Only)

Specified Diameter, mm	Permitted Variations Over Specified Diameter for Specified Thicknesses Given in Millimetres, mm ^A					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	13	13	19	19	25	25
800 to 2100, excl	13	16	22	25	29	32
2100 to 2700, excl	16	19	25	29	32	35
2700 to 3300, incl	22	25	29	32	35	38

^A No permitted variations under specified diameter.

TABLE A1.11 Permitted Camber^A for Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared or Gas-Cut Rectangular Plates

Specified Width, mm	Permitted Camber, mm
To 750, incl	Length in millimetres/300
Over 750 to 1500	Length in millimetres/250

^A Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A1.12 Permitted Camber^A for Sheared Plates and Gas-Cut Rectangular Plates, All Thicknesses (Applies to Carbon Steel Only)

Permitted camber, mm = length in millimetres/500
--

^A Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A1.13 Permitted Variations From a Flat Surface for Standard Flatness Carbon Steel Plates

NOTE 1—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 6 mm. When the longer dimension is from 900 to 1800 mm, incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 2—These permitted variations apply to plates that have a specified minimum tensile strength of not more than 415 MPa or comparable chemical composition or hardness. The limits in this table are increased 50 % for plates that have a higher specified minimum tensile strength or comparable chemical composition or hardness.

NOTE 3—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 4—Where “...” appears in this table, there is no requirement.

NOTE 5—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Specified Mass, kg/m ²	Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm ^{A,B}										
		To 900, excl	900 to 1200, excl	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3600, excl	3600 to 4200, excl	4200 and over
To 6, excl	To 47.1, excl	14	19	24	32	35	38	41	44	48	...	...
6 to 10, excl	47.1 to 78.5, excl	13	16	19	24	29	32	35	38	41	...	...
10 to 12, excl	78.5 to 94.2, excl	13	14	16	16	19	22	25	29	32	48	54
12 to 20, excl	94.2 to 157.0, excl	11	13	14	16	16	19	25	25	29	38	51
20 to 25, excl	157.0 to 196.2, excl	11	13	14	16	16	16	19	22	25	35	44
25 to 50, excl	196.2 to 392.5, excl	10	13	13	14	14	16	16	16	18	29	38
50 to 100, excl	392.5 to 785.0, excl	8	10	11	13	13	13	13	14	16	22	29
100 to 150, excl	785.0 to 1178, excl	10	11	13	13	14	14	16	19	22	22	25
150 to 200, excl	1178 to 1570, excl	11	13	13	16	18	19	22	22	25	25	25
200 to 250, excl	1570 to 1962, excl	13	13	16	18	19	21	22	24	25	25	25
250 to 300, excl	1962 to 2355, excl	13	16	19	21	22	24	25	25	25	25	25
300 to 400, incl	2355 to 3140, incl	16	19	21	22	24	25	25	25	25	25	...

^A Permitted Variation From a Flat Surface Along the Length—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width for plates up to 4000 mm in length, or in any 4000 mm for longer plates.

^B Permitted Variation From a Flat Surface Across the Width—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

TABLE A1.14 Permitted Variations From a Flat Surface for Standard Flatness High-Strength Low-Alloy Steel and Alloy Steel Plates, Hot Rolled or Thermally Treated

NOTE 1—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 10 mm. When the longer dimension is from 900 to 1800 mm, incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width.

NOTE 2—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 3—Where “...” appears in this table, there is no requirement.

NOTE 4—Plates must be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Specified Mass, kg/m ²	Permitted Variations from a Flat Surface for Specified Widths Given in Millimetres, mm ^{A,B}										
		To 900, excl	900 to 1200, excl	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3600, excl	3600 to 4200, excl	4200 and over
To 6, excl	To 47.1, excl	21	29	35	48	51	57	60	67	70	...	...
6 to 10, excl	47.1 to 78.5, excl	19	24	29	35	44	48	51	57	60	...	...
10 to 12, excl	78.5 to 94.2, excl	19	22	24	24	29	33	38	41	48	70	79
12 to 20, excl	94.2 to 157.0, excl	16	19	22	22	25	29	32	35	41	57	76
20 to 25, excl	157.0 to 196.2, excl	16	19	22	22	24	25	29	33	38	51	67
25 to 50, excl	196.2 to 392.5, excl	14	16	19	21	22	24	25	25	25	41	57
50 to 100, excl	392.5 to 785.0, excl	13	14	18	19	19	19	19	22	25	32	41
100 to 150, excl	785.0 to 1178, excl	14	18	19	19	22	22	24	29	32	32	38
150 to 200, excl	1178 to 1570, excl	16	19	19	24	25	29	32	33	38	38	38
200 to 250, excl	1570 to 1962, excl	19	21	24	25	29	32	33	35	38	38	38
250 to 300, excl	1962 to 2355, excl	19	24	29	32	33	35	38	38	38	38	38
300 to 400, incl	2355 to 3140, incl	22	25	30	33	35	38	38	38	38	38	38

^A Permitted Variation From a Flat Surface Along the Length—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm for longer plates.

^B Permitted Variation From a Flat Surface Across the Width—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

TABLE A1.15 Permitted Variations in Waviness for Standard Flatness Plates

NOTE 1—Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the plate at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 4000 mm of length. The permitted variation in waviness is a function of the permitted variation from a flat surface as obtained from Table A1.13 or Table A1.14, whichever is applicable.

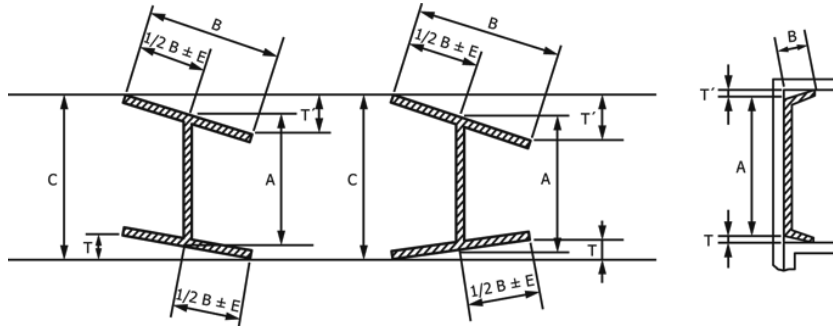
NOTE 2—Plates must be in a horizontal position on a flat surface when waviness is measured.

Permitted Variation from a Flat Surface (from Table A1.13 or Table A1.14), mm	Permitted Variations in Waviness, mm, When Number of Waves in 4000 mm is						
	1	2	3	4	5	6	7
8	8	6	5	3	3	2	2
10	10	8	5	5	3	2	2
11	11	8	6	5	3	3	2
13	13	10	8	5	5	3	2
14	14	11	8	6	5	3	2
16	16	13	10	6	5	3	2
17	17	13	10	8	5	5	2
19	19	14	11	8	6	5	2
21	21	16	11	8	6	5	2
22	22	17	13	10	6	5	2
24	24	17	13	10	8	6	5
25	25	19	14	11	8	6	5
29	29	22	16	13	10	6	5
32	32	24	17	13	10	8	6
35	35	27	19	14	11	8	6
38	38	29	22	16	13	10	6
41	41	32	24	17	13	10	8
44	44	33	25	19	14	11	8
48	48	37	27	21	14	11	8
51	51	38	29	22	16	13	10
54	54	41	30	22	17	13	10
57	57	43	32	24	17	14	10
60	60	46	33	25	19	14	11
64	64	48	37	27	21	14	11
67	67	51	38	29	21	16	11
70	70	52	40	29	22	16	13
73	73	56	41	30	24	17	13
76	76	57	43	32	24	17	14
79	79	60	44	33	25	19	14

TABLE A1.16 Permitted Variations in Cross Section for W, HP, S, M, C, and MC Shapes

NOTE 1—A is measured at center lines of web for S, M, W, and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 75 mm. B is measured parallel to flange. C is measured parallel to web.

NOTE 2—Where “...” appears in this table, there is no requirement.



Permitted Variations in Sectional Dimensions Given, mm											
Shape	Section Nominal Size, mm	A, Depth		B, Flange Width		$T + T'$ ^A Flanges Out-of-Square ^B	E, Web off Center ^C	C, Maximum Depth at any Cross Section over Theoretical Depth	Permitted Variations Over or Under Theoretical Web Thickness for Thicknesses Given in Millimetres, mm		
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				5 and Under	Over 5	
W and HP	up to 310, incl over 310	4	3	6	5	6	5	6	...	...
		4	3	6	5	8	5	6	...	...
S and M	75 to 180, incl	2	2	3	3	0.03	5	...	...	...
	over 180 to 360, incl	3	2	4	4	0.03	5	...	...	...
	over 360 to 610, incl	5	3	5	5	0.03	5	...	...	...
C and MC	40 and under	1	1	1	1	0.03	...	...	0.2	0.4
	over 40 to 75, excl	2	2	2	2	0.03	...	...	0.4	0.5
	75 to 180, incl	3	2	3	3	0.03	...	...	...	...
	over 180 to 360, incl	3	3	3	4	0.03	...	...	...	...
	over 360	5	4	3	5	0.03	...	...	...	...

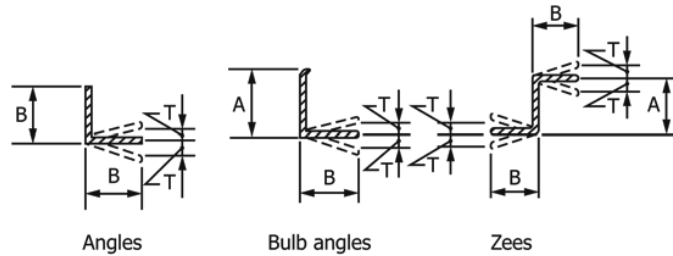
^A $T + T'$ applies when flanges of channels are toed in or out. For channels 16 mm and under in depth, the permitted out-of-square is 0.05 mm/mm of depth. The permitted variation shall be rounded to the nearest millimetre after calculation.

^B Permitted variation is per millimetre of flange width for S, M, C, and MC shapes.

^C Permitted variation of 8 mm max for sections over 634 kg/m.

TABLE A1.17 Permitted Variations in Cross Section for Angles (L Shapes), Bulb Angles, and Zees

NOTE 1—Where “...” appears in this table, there is no requirement.



		Permitted Variations in Sectional Dimensions Given, mm					Permitted Variations Over or Under Theoretical Thickness for Thicknesses Given in Millimetres, mm		
Section	Nominal Size, mm	A, Depth		B, Flange Width, or Length of Leg		T, Out-of-Square per Millimetre of B	5 and Under	Over 5 to 10	Over 10
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				
Angles ^A (L shapes)	25 and under	...	...	1	1	0.026 ^B	0.2	0.2	...
	Over 25 to 51, incl	...	...	1	1	0.026 ^B	0.2	0.2	0.3
	Over 51 to 64, incl	...	...	2	2	0.026 ^B	0.3	0.4	0.4
	Over 64 to 102, incl	...	...	3	2	0.026 ^B	...	...	...
	Over 102 to 152, incl	...	...	3	3	0.026 ^B	...	...	...
	Over 152 to 203, incl	...	...	5	3	0.026 ^B	...	...	...
	Over 203 to 254, incl	...	...	6	6	0.026 ^B	...	...	...
Over 254	...	...	6	10	0.026 ^B	...	...	...
Bulb angles	(depth) 76 to 102, incl	3	2	4	2	0.026 ^B	...	...	...
	Over 102 to 155, incl	3	2	4	3	0.026 ^B	...	...	...
	Over 152	3	2	5	3	0.026 ^B	...	...	...
Zees	76 to 102, incl	3	2	4	2	0.026 ^B	...	...	...
	Over 102 to 152, incl	3	2	4	3	0.026 ^B	...	...	...

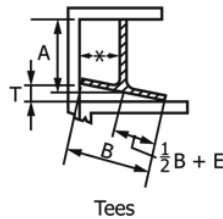
^A For unequal leg angles, longer leg determines classification.

^B 0.026 mm/mm = 1½°. The permitted variation shall be rounded to the nearest millimetre after calculation.

TABLE A1.18 Permitted Variations in Sectional Dimensions for Rolled Tees

NOTE 1—*Back of square and center line of stem are to be parallel when measuring “out-of-square.”

NOTE 2—Where “...” appears in this table, there is no requirement.



		Permitted Variations in Sectional Dimensions Given, mm									
Nominal Size ^A	A, Depth ^B		B, Width ^B		T, Out-of-Square per Millimetre of B	E, Web Off-Center, max	Stem Out-of-Square ^C	Thickness of Flange		Thickness of Stem	
	Over	Under	Over	Under				Over	Under	Over	Under
30 and under	1	1	1	1	...	...	1	0.2	0.2	0.1	0.5
Over 30 to 50, incl	2	2	2	2	...	...	2	0.3	0.3	0.2	0.5
Over 50 to 75, excl	2	2	2	2	...	...	2	0.4	0.4	0.4	0.5
Over 75 to 125, incl	2	2	3	3	0.03	2	...	...	...	...	...
Over 125 to 180, incl	2	2	3	3	0.03	3	...	...	...	...	...

^A The longer member of an unequal tee determines the size for permitted variations.

^B Measurements for both depth and width are overall.

^C Stem out-of-square is the permitted variation from its true position of the center line of stem, measured at the point.

TABLE A1.19 Permitted Variations in Length for S, M, C, MC, L, T, Z, and Bulb Angle Shapes

NOTE 1—Where “...” appears in this table, there is no requirement.

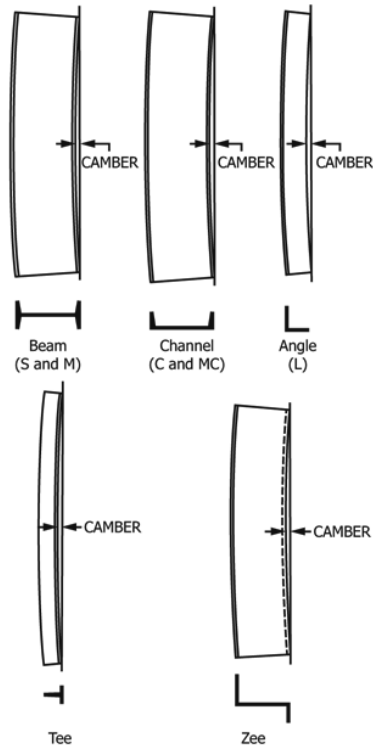
Nominal Size, ^A mm	Permitted Variations From Specified Length for Lengths Given in Metres, mm													
	1.5 to 3, excl		3 to 6, excl		6 to 9, incl		Over 9 to 12, incl		Over 12 to 15, incl		Over 15 to 20, incl		Over 20 m	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 75	16	0	25	0	38	0	51	0	64	0	64	0	...	...
75 and over	25	0	38	0	45	0	57	0	70	0	70	0	...	...

^A Greatest cross-sectional dimension.**TABLE A1.20 Permitted Variations in End Out-of-Square for S, M, C, MC, L, T, Z, Bulb Angle, and Flat Bar Shapes**

Shapes	Permitted Variation
S, M, C, and MC	0.017 mm per millimetre of depth
L ^A	0.026 mm per millimetre of leg length or 1½ °
Bulb angles	0.026 mm per millimetre of depth or 1½ °
Rolled tees ^A	0.017 mm per millimetre of flange or stem
Zees	0.026 mm per millimetre of sum of both flange lengths
Flat Bars ^B	0.017 mm per millimetre of width but not less than 2 mm

^A Permitted variations in ends out-of-square are determined on the longer members of the shape.^B For flat bars, permitted variations in end out-of-square are determined on the width of the bar.

TABLE A1.21 Permitted Variations in Straightness for S, M, C, MC, L, T, Z, and Bulb Angle Shapes



Positions for Measuring Camber of Shapes

Variable	Nominal Size, ^A mm	Permitted Variation, mm
Camber	Under 75	4 × number of metres of total length
	75 and over	2 × number of metres of total length
Sweep	All	Due to the extreme variations in flexibility of these shapes, permitted variations for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved.

^A Greatest cross-sectional dimension.

TABLE A1.22 Permitted Variations in Length for W and HP Shapes

Permitted Variations from Specified Length for Lengths Given in Metres, mm ^{A, B}	
Over	Under
100	0

^A For HP and W shapes specified in the order for use as bearing piles, the permitted variations in length are plus 125 and minus 0 mm. These permitted variations in length also apply to sheet piles.

^B The permitted variations in end out-of-square for W and HP shapes shall be 0.016 mm per millimetre of depth, or per millimetre of flange width if the flange width is larger than the depth. The permitted variations shall be rounded to the nearest millimetre after calculation.

TABLE A1.23 Permitted Variations for Length and End Out-of-Square, Milled Shapes

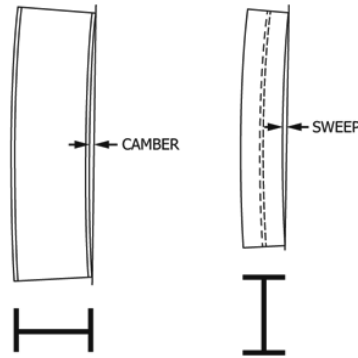
Permitted Variations in Length and End Out-of-Square, mm ^A							
Nominal Depth, mm	Length, ^C m	Milled Both Ends ^B			Milled One End ^B		
		Length		End Out-of-Square	Length		End Out-of-Square-(for Milled End)
		Over	Under		Over	Under	
150 to 920	2 to 21	1	1	1	6	6	1

^A The permitted variations in length and end out-of-square are additive.

^B End out-of-square is measured by (a) squaring from the center line of the web and (b) squaring from the center line of the flange. The measured variation from true squareness in either plane shall not exceed the total tabular amount.

^C Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.

TABLE A1.24 Permitted Variations in Straightness for W and HP Shapes



Positions for Measuring Camber and Sweep of W and HP Shapes

	Permitted Variation in Straightness, mm
Camber and sweep	$1 \times \text{number of metres of total length}^A$
When certain sections ^B with a flange width approximately equal to depth are specified in the order for use as columns:	
Lengths of 14 m and under	$1 \times \text{number of metres of total length, but not over 10}$
Lengths over 14 m	$10 + [1 \times (\text{number of metres of total length} - 14 \text{ m})]$

^A Sections with a flange width less than 150 mm, permitted variation for sweep, mm = $2 \times \text{number of metres of total length}$.

^B Applies only to:

- 200-mm deep sections—46.1 kg/m and heavier,
- 250-mm deep sections—73 kg/m and heavier,
- 310-mm deep sections—97 kg/m and heavier,
- 360-mm deep sections—116 kg/m and heavier,
- 410-mm deep sections—131 kg/m and heavier, and
- 460-mm deep sections—202 kg/m and heavier.

For other sections specified in the order for use as columns, the permitted variation is subject to negotiation with the manufacturer.

TABLE A1.25 Permitted Variations in Dimensions for Split Tees and Split Angles (L Shapes)^A

Specified Depth, mm	Permitted Variation Over or Under
	Specified Depth, ^B mm
To 150, excl (beams and channels)	3
150 to 410, excl (beams and channels)	5
410 to 510, excl (beams and channels)	6
510 to 610, excl (beams)	8
610 and over (beams)	10

^A The permitted variations in length for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

^B The above permitted variations in depth of tees or angles include the permitted variations in depth for the beams or channels before splitting. Permitted variations in dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, apply, except
straightness = 2 mm × length in metres

TABLE A1.26 Permitted Variations in Sectional Dimensions for Square-Edge and Round-Edge Flat Bars

NOTE 1—Where “...” appears in this table, there is no requirement.

Specified Widths, mm	Permitted Variations Over or Under Specified Thickness, for Thicknesses Given in Millimetres, mm						Permitted Variations from Specified Width, mm	
	Over 5 to 6, incl	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75	Over 75	Over	Under
To 25, incl	0.18	0.20	0.25	...	...	...	0.5	0.5
Over 25 to 50, incl	0.18	0.30	0.40	0.8	...	...	1.0	1.0
Over 50 to 100, incl	0.20	0.40	0.50	0.8	1.2	1.2	1.5	1.0
Over 100 to 150, incl	0.25	0.40	0.50	0.8	1.2	1.2	2.5	1.5
Over 150 to 200, incl	^A	0.40	0.65	0.8	1.2	1.6	3.0	2.5

^A Flats over 150 to 200 mm, incl, in width are not available as hot-rolled bars in thickness 6 mm and under.

TABLE A1.27 Permitted Variations in Sectional Dimensions for Round and Square Bars and Round-Cornered Squares

NOTE 1—Where “...” appears in this table, there is no requirement.

Specified Sizes, mm	Permitted Variation Over or Under Specified Size		Permitted Out-of-Round or Out-of-Square Section ^A	
	mm	%	mm	%
	Up to 7.0, incl	0.13	...	0.20
Over 7.0 to 11.0, incl	0.15	...	0.22	...
Over 11.0 to 15.0, incl	0.18	...	0.27	...
Over 15.0 to 19.0, incl	0.20	...	0.30	...
Over 19.0 to 250, incl	...	1 ^B	...	1½ ^B

^A Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.

^B The permitted variation shall be rounded to the nearest tenth of a millimetre after calculation.

TABLE A1.28 Permitted Variations in Sectional Dimensions for Hexagons

Specified Sizes Between Opposite Sides, mm	Permitted Variations from Specified Size, mm		Out-of-Hexagon Section, mm ^A
	Over	Under	
To 13 incl	0.18	0.18	0.3
Over 13 to 25 incl	0.25	0.25	0.4
Over 25 to 40 incl	0.55	0.35	0.6
Over 40 to 50 incl	0.8	0.40	0.8
Over 50 to 65 incl	1.2	0.40	1.2
Over 65 to 80 incl	1.6	1.6	

^A Out-of-hexagon section is the greatest difference in distance between any two opposite faces, measured at the same transverse cross section.

TABLE A1.29 Permitted Variations in Straightness for Bars

Maximum Permitted Variation in Straightness, mm ^A
6 mm in any 1500 mm and (length in millimetres/250) ^B

^A Permitted variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.
^B Round to the nearest whole millimetre.

TABLE A1.30 Permitted Variations in Length for Hot-Cut Steel Bars^A

NOTE 1—Where “...” appears in this table, there is no requirement.

Specified Sizes of Rounds, Squares, and Hexagons, mm	Specified Sizes of Flats, mm		Permitted Variations Over Specified Lengths Given in Metres, mm (No Variation Under)				
	Thickness	Width	1.5 to 3, excl	3 to 6, excl	6 to 9, excl	9 to 12, excl	12 to 18, incl
To 25, incl	to 25, incl	to 75, incl	15	20	35	45	60
Over 25 to 50, incl	over 25	to 75, incl	15	25	40	50	65
	to 25, incl	over 75 to 150, incl	15	25	40	50	65
Over 50 to 125, incl	over 25	over 75 to 150, incl	25	40	45	60	70
Over 125 to 250, incl	...	...	50	65	70	75	85
	over 6 to 25, incl	over 150 to 200, incl	20	30	45	90	100
	over 25 to 75, incl	over 150 to 200, incl	30	45	50	90	100
Bar size sections	...	...	15	25	40	50	65
Hot Sawing ^B							
50 to 125, incl	25 and over	75 and over	^B	40	45	60	70
Over 125 to 250, incl	...	...	^B	65	70	75	85

^A For flats over 150 to 200 mm, incl, in width and over 75 mm in thickness, consult the manufacturer for permitted variations in length.

^B Smaller sizes and shorter lengths are not commonly hot sawed.

TABLE A1.31 Permitted Variations in Length for Bars Recut Both Ends After Straightening^{A,B}

Sizes of Rounds, Squares, Hexagons, Widths of Flats and Maximum Dimensions of Other Sections, mm	Permitted Variations Over Specified Length Given in Metres, mm (No Variation Under)	
	to 3.7, incl	over 3.7
To 75, incl	6	8
Over 75 to 150, incl	8	11
Over 150 to 200, incl	11	14
Rounds over 200 to 250, incl	14	18

^A For flats over 150 to 200 mm, incl, in width, and over 75 mm in thickness, consult the manufacturer or the processor for permitted variations in length.

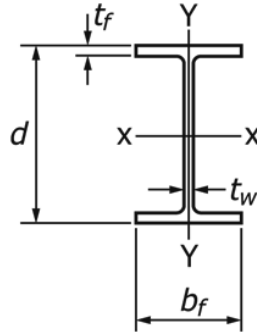
^B Permitted variations are sometimes required all over or all under the specified length, in which case the sum of the two permitted variations applies.

A2. DIMENSIONS OF STANDARD SHAPE PROFILES

A2.1 Listed herein are dimensions and weight [mass] of some standard shape profiles. The values stated in inch-pound units are independent of the values stated in SI units, and the values from the two systems are not to be combined in any

way. Unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

TABLE A2.1 “W” Shapes



Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A _x in. ²	Depth d _x in.	Flange		Web Thickness t _w , in. ⁴	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A _x mm ²	Depth d _x mm	Flange		Web Thick- ness t _w , mm ⁴
			Width b _f in.	Thick- ness t _f in. ⁴					Width b _f mm	Thick- ness, t _f mm ⁴	
W44 × 408	120.5	44.80	16.142	2.165	1.220	W1100 × 607	77 740	1 138	410	55.0	31.0
× 368	108.9	44.41	16.024	1.969	1.102	× 548	70 250	1 128	407	50.0	28.0
× 335	98.7	44.02	15.945	1.770	1.025	× 499	63 500	1 118	405	45.0	26.0
× 290	85.8	43.62	15.825	1.575	0.865	× 433	55 100	1 108	402	40.0	22.0
× 262	77.2	43.31	15.750	1.415	0.785	× 390	49 700	1 100	400	36.0	20.0
× 230	67.9	42.91	15.750	1.220	0.710	× 343	43 600	1 090	400	31.0	18.0
W40 × 655	192.6	43.62	16.870	3.540	1.970	W1000 × 976	124 300	1 108	428	89.9	50.0
× 593	174.4	42.99	16.690	3.230	1.790	× 883	112 500	1 092	424	82.0	45.5
× 503	147.8	42.05	16.415	2.755	1.535	× 748	95 300	1 068	417	70.0	39.0
× 431	126.7	41.26	16.220	2.360	1.340	× 642	81 800	1 048	412	60.0	34.0
× 397	117.0	40.95	16.120	2.200	1.220	× 591	75 300	1 040	409	55.9	31.0
× 372	109.4	40.63	16.065	2.045	1.160	× 554	70 600	1 032	408	52.0	29.5
× 362	107.0	40.55	16.020	2.010	1.120	× 539	68 700	1 030	407	51.1	28.4
× 324	95.3	40.16	15.910	1.810	1.000	× 483	61 500	1 020	404	46.0	25.4
× 297	87.4	39.84	15.825	1.650	0.930	× 443	56 400	1 012	402	41.9	23.6
× 277	81.3	39.69	15.830	1.575	0.830	× 412	52 500	1 008	402	40.0	21.1
× 249	73.3	39.38	15.750	1.420	0.750	× 371	47 300	1 000	400	36.1	19.0
× 215	63.3	38.98	15.750	1.220	0.650	× 321	40 800	990	400	31.0	16.5
× 199	58.4	38.67	15.750	1.065	0.650	× 296	37 700	982	400	27.1	16.5
W40 × 392	115.3	41.57	12.360	2.520	1.415	W1000 × 584	74 400	1 056	314	64.0	36.0
× 331	97.5	40.79	12.165	2.125	1.220	× 494	62 900	1 036	309	54.0	31.0
× 327	95.9	40.79	12.130	2.130	1.180	× 486	61 900	1 036	308	54.1	30.0
× 294	86.2	40.39	12.010	1.930	1.060	× 438	55 600	1 026	305	49.0	26.9
× 278	81.9	40.16	11.970	1.810	1.025	× 415	52 800	1 020	304	46.0	26.0
× 264	77.6	40.00	11.930	1.730	0.960	× 393	50 100	1 016	303	43.9	24.4
× 235	68.9	39.69	11.890	1.575	0.830	× 350	44 600	1 008	302	40.0	21.1
× 211	62.0	39.37	11.810	1.415	0.750	× 314	40 000	1 000	300	35.9	19.1
× 183	53.7	38.98	11.810	1.200	0.650	× 272	34 600	990	300	31.0	16.5
× 167	49.1	38.59	11.810	1.025	0.650	× 249	31 700	980	300	26.0	16.5
× 149	43.8	38.20	11.810	0.830	0.630	× 222	28 200	970	300	21.1	16.0
W36 × 925	271.9	43.05	18.620	4.530	3.020	W920 × 1377	175 400	1 093	473	115.1	76.7
× 853	250.6	43.05	18.150	4.530	2.520	× 1269	161 700	1 093	461	115.1	64.0
× 802	235.9	42.57	17.990	4.290	2.380	× 1194	152 200	1 081	457	109.0	60.5
× 723	212.7	41.79	17.755	3.900	2.165	× 1077	137 200	1 061	451	99.1	55.0
× 652	191.7	41.05	17.575	3.540	1.970	× 970	123 700	1 043	446	89.9	50.0
× 529	155.6	39.79	17.220	2.910	1.610	× 787	100 400	1 011	437	73.9	40.9
× 487	143.2	39.33	17.105	2.680	1.500	× 725	92 400	999	434	68.1	38.1
× 441	129.7	38.85	16.965	2.440	1.360	× 656	83 700	987	431	62.0	34.5

TABLE A2.1 Continued

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A , in. ²	Depth d , in.	Flange		Web Thickness t_w , in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A , mm ²	Depth d , mm	Flange		Web Thick- ness t_w , mm ^A
			Width b_f in.	Thick- ness t_f , in. ^A					Width b_f mm	Thick- ness, t_f , mm ^A	
× 395	116.2	38.37	16.830	2.200	1.220	× 588	75 000	975	427	55.9	31.0
× 361	106.1	37.99	16.730	2.010	1.120	× 537	68 500	965	425	51.1	28.4
× 330	97.0	37.67	16.630	1.850	1.020	× 491	62 600	957	422	47.0	25.9
× 302	88.8	37.33	16.655	1.680	0.945	× 449	57 600	948	423	42.7	24.0
× 282	82.9	37.11	16.595	1.570	0.885	× 420	53 500	943	422	39.9	22.5
× 262	77.0	36.85	16.550	1.440	0.840	× 390	49 700	936	420	36.6	21.3
× 247	72.5	36.67	16.510	1.350	0.800	× 368	46 800	931	419	34.3	20.3
× 231	68.0	36.49	16.470	1.260	0.760	× 344	43 900	927	418	32.0	19.3
W36 × 387	113.6	39.09	12.677	2.559	1.421	W920 × 576	73 320	993	322	65.0	36.1
× 350	102.9	38.62	12.559	2.319	1.299	× 521	66 370	981	319	58.9	33.0
× 318	93.6	38.23	12.441	2.130	1.181	× 474	60 390	971	316	54.1	30.0
× 286	84.0	37.83	12.323	1.929	1.059	× 425	54 200	961	313	49.0	26.9
× 256	75.4	37.43	12.215	1.730	0.960	× 381	48 600	951	310	43.9	24.4
× 232	68.1	37.12	12.120	1.570	0.870	× 345	44 000	943	308	39.9	22.1
× 210	61.8	36.69	12.180	1.360	0.830	× 313	39 900	932	309	34.5	21.1
× 194	57.0	36.49	12.115	1.260	0.765	× 289	36 800	927	308	32.0	19.4
× 182	53.6	36.33	12.075	1.180	0.725	× 271	34 600	923	307	30.0	18.4
× 170	50.0	36.17	12.030	1.100	0.680	× 253	32 300	919	306	27.9	17.3
× 160	47.0	36.01	12.000	1.020	0.650	× 238	30 300	915	305	25.9	16.5
× 150	44.2	35.85	11.975	0.940	0.625	× 223	28 500	911	304	23.9	15.9
× 135	39.7	35.55	11.950	0.790	0.600	× 201	25 600	903	304	20.1	15.2
W33 × 387	114.0	35.95	16.200	2.280	1.260	W840 × 576	73 500	913	411	57.9	32.0
× 354	104.1	35.55	16.100	2.090	1.160	× 527	67 200	903	409	53.1	29.5
× 318	93.5	35.16	15.985	1.890	1.040	× 473	60 300	893	406	48.0	26.4
× 291	85.6	34.84	15.905	1.730	0.960	× 433	55 200	885	404	43.9	24.4
× 263	77.4	34.53	15.805	1.570	0.870	× 392	49 900	877	401	39.9	22.1
× 241	70.9	34.18	15.860	1.400	0.830	× 359	45 700	868	403	35.6	21.1
× 221	65.0	33.93	15.805	1.275	0.775	× 329	41 900	862	401	32.4	19.7
× 201	59.1	33.68	15.745	1.150	0.715	× 299	38 100	855	400	29.2	18.2
W33 × 169	49.5	33.82	11.500	1.220	0.670	W840 × 251	31 900	859	292	31.0	17.0
× 152	44.7	33.49	11.565	1.055	0.635	× 226	28 800	851	294	26.8	16.1
× 141	41.6	33.30	11.535	0.960	0.605	× 210	26 800	846	293	24.4	15.4
× 130	38.3	33.09	11.510	0.855	0.580	× 193	24 700	840	292	21.7	14.7
× 118	34.7	32.86	11.480	0.740	0.550	× 176	22 400	835	292	18.8	14.0
W30 × 391	115.0	33.19	15.590	2.440	1.360	W760 × 582	74 200	843	396	62.0	34.5
× 357	104.8	32.80	15.470	2.240	1.240	× 531	67 600	833	393	56.9	31.5
× 326	95.7	32.40	15.370	2.050	1.140	× 484	61 700	823	390	52.1	29.0
× 292	85.7	32.01	15.255	1.850	1.020	× 434	55 300	813	387	47.0	25.9
× 261	76.7	31.61	15.155	1.650	0.930	× 389	49 500	803	385	41.9	23.6
× 235	69.0	31.30	15.055	1.500	0.830	× 350	44 500	795	382	38.1	21.1
× 211	62.0	30.94	15.105	1.315	0.775	× 314	40 000	786	384	33.4	19.7
× 191	56.1	30.68	15.040	1.185	0.710	× 284	36 200	779	382	30.1	18.0
× 173	50.8	30.44	14.985	1.065	0.655	× 257	32 800	773	381	27.1	16.6
W30 × 148	43.5	30.67	10.480	1.180	0.650	W760 × 220	28 100	779	266	30.0	16.5
× 132	38.9	30.31	10.545	1.000	0.615	× 196	25 100	770	268	25.4	15.6
× 124	36.5	30.17	10.515	0.930	0.585	× 185	23 500	766	267	23.6	14.9
× 116	34.2	30.01	10.495	0.850	0.565	× 173	22 100	762	267	21.6	14.4
× 108	31.7	29.83	10.475	0.760	0.545	× 161	20 500	758	266	19.3	13.8
× 99	29.1	29.65	10.450	0.670	0.520	× 147	18 800	753	265	17.0	13.2
× 90	26.4	29.53	10.400	0.610	0.470	× 134	17 000	750	264	15.5	11.9
W27 × 539	158.4	32.52	15.255	3.540	1.970	W690 × 802	102 200	826	387	89.9	50.0
× 368	108.1	30.39	14.665	2.480	1.380	× 548	69 800	772	372	63.0	35.1
× 336	98.7	30.0	14.550	2.280	1.260	× 500	63 700	762	369	57.9	32.0
× 307	90.2	29.61	14.445	2.090	1.160	× 457	58 200	752	367	53.1	29.5
× 281	82.6	29.29	14.350	1.930	1.060	× 419	53 300	744	364	49.0	26.9
× 258	75.7	28.98	14.270	1.770	0.980	× 384	48 900	736	362	45.0	24.9
× 235	69.1	28.66	14.190	1.610	0.910	× 350	44 600	728	360	40.9	23.1
× 217	63.8	28.43	14.115	1.500	0.830	× 323	41 100	722	359	38.1	21.1
× 194	57.0	28.11	14.035	1.340	0.750	× 289	36 800	714	356	34.0	19.0
× 178	52.3	27.81	14.085	1.190	0.725	× 265	33 700	706	358	30.2	18.4
× 161	47.4	27.59	14.020	1.080	0.660	× 240	30 600	701	356	27.4	16.8
× 146	42.9	27.38	13.965	0.975	0.605	× 217	27 700	695	355	24.8	15.4

TABLE A2.1 Continued

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A_f mm ²	Depth d_f mm	Flange		Web Thick- ness t_w mm ^A
			Width b_f in.	Thick- ness t_f in. ^A					Width b_f mm	Thick- ness, t_f mm ^A	
W27 × 129	37.8	27.63	10.010	1.100	0.610	W690 × 192	24 400	702	254	27.9	15.5
× 114	33.5	27.29	10.070	0.930	0.570	× 170	21 600	693	256	23.6	14.5
× 102	30.0	27.09	10.015	0.830	0.515	× 152	19 400	688	254	21.1	13.1
× 94	27.7	26.92	9.990	0.745	0.490	× 140	17 900	684	254	18.9	12.4
× 84	24.8	26.71	9.960	0.640	0.460	× 125	16 000	678	253	16.3	11.7
W24 × 370	108.0	27.99	13.660	2.720	1.520	W610 × 551	70 200	711	347	69.1	38.6
× 335	98.4	27.52	13.520	2.480	1.380	× 498	63 500	699	343	63.0	35.1
× 306	89.8	27.13	13.405	2.280	1.260	× 455	57 900	689	340	57.9	32.0
× 279	82.0	26.73	13.305	2.090	1.160	× 415	52 900	679	338	53.1	29.5
× 250	73.5	26.34	13.185	1.890	1.040	× 372	47 400	669	335	48.0	26.4
× 229	67.2	26.02	13.110	1.730	0.960	× 341	43 400	661	333	43.9	24.4
× 207	60.7	25.71	13.010	1.570	0.870	× 307	39 100	653	330	39.9	22.1
× 192	56.3	25.47	12.950	1.460	0.810	× 285	36 100	647	329	37.1	20.6
× 176	51.7	25.24	12.890	1.340	0.750	× 262	33 300	641	327	34.0	19.0
× 162	47.7	25.00	12.955	1.220	0.705	× 241	30 800	635	329	31.0	17.9
× 146	43.0	24.74	12.900	1.090	0.650	× 217	27 700	628	328	27.7	16.5
× 131	38.5	24.48	12.855	0.960	0.605	× 195	24 800	622	327	24.4	15.4
× 117	34.4	24.26	12.800	0.850	0.550	× 174	22 200	616	325	21.6	14.0
× 104	30.6	24.06	12.750	0.750	0.500	× 155	19 700	611	324	19.0	12.7
W24 × 103	30.3	24.53	9.000	0.980	0.550	W610 × 153	19 600	623	229	24.9	14.0
× 94	27.7	24.31	9.065	0.875	0.515	× 140	17 900	617	230	22.2	13.1
× 84	24.7	24.10	9.020	0.770	0.470	× 125	15 900	612	229	19.6	11.9
× 76	22.4	23.92	8.990	0.680	0.440	× 113	14 500	608	228	17.3	11.2
× 68	20.1	23.73	8.965	0.585	0.415	× 101	13 000	603	228	14.9	10.5
W24 × 62	18.2	23.74	7.040	0.590	0.430	W610 × 92	11 700	603	179	15.0	10.9
× 55	16.2	23.57	7.005	0.505	0.395	× 82	10 500	599	178	12.8	10.0
W21 × 275	80.9	24.13	12.890	2.190	1.220	W530 × 409	52 200	613	327	55.6	31.0
× 248	72.9	23.74	12.775	1.990	1.100	× 369	47 000	603	324	50.5	27.9
× 223	65.6	23.35	12.675	1.790	1.000	× 332	42 300	593	322	45.5	25.4
× 201	59.2	23.03	12.575	1.630	0.910	× 300	38 200	585	319	41.4	23.1
× 182	53.7	22.72	12.500	1.480	0.830	× 272	34 600	577	317	37.6	21.1
× 166	48.9	22.48	12.420	1.360	0.750	× 248	31 500	571	315	34.5	19.0
× 147	43.2	22.06	12.510	1.150	0.720	× 219	27 900	560	318	29.2	18.3
× 132	38.8	21.83	12.440	1.035	0.650	× 196	25 000	554	316	26.3	16.5
× 122	35.9	21.68	12.390	0.960	0.600	× 182	23 200	551	315	24.4	15.2
× 111	32.7	21.51	12.340	0.875	0.550	× 165	21 100	546	313	22.2	14.0
× 101	29.8	21.36	12.290	0.800	0.500	× 150	19 200	543	312	20.3	12.7
W21 × 93	27.3	21.62	8.420	0.930	0.580	W530 × 138	17 600	549	214	23.6	14.7
× 83	24.3	21.43	8.355	0.835	0.515	× 123	15 700	544	212	21.2	13.1
× 73	21.5	21.24	8.295	0.740	0.455	× 109	13 900	539	211	18.8	11.6
× 68	20.0	21.13	8.270	0.685	0.430	× 101	12 900	537	210	17.4	10.9
× 62	18.3	20.99	8.240	0.615	0.400	× 92	11 800	533	209	15.6	10.2
× 55	16.2	20.80	8.220	0.522	0.375	× 82	10 500	528	209	13.3	9.50
× 48	14.1	20.62	8.140	0.430	0.350	× 72	9 180	524	207	10.9	9.00
W21 × 57	16.7	21.06	6.555	0.650	0.405	W530 × 85	10 800	535	166	16.5	10.3
× 50	14.7	20.83	6.530	0.535	0.380	× 74	9 480	529	166	13.6	9.7
× 44	13.0	20.66	6.500	0.450	0.350	× 66	8 390	525	165	11.4	8.9
W18 × 311	91.5	22.32	12.005	2.740	1.520	W460 × 464	59 100	567	305	69.6	38.6
× 283	83.2	21.85	11.890	2.500	1.400	× 421	53 700	555	302	63.5	35.6
× 258	75.9	21.46	11.770	2.300	1.280	× 384	49 000	545	299	58.4	32.5
× 234	68.8	21.06	11.650	2.110	1.160	× 349	44 400	535	296	53.6	29.5
× 211	62.1	20.67	11.555	1.910	1.060	× 315	40 100	525	293	48.5	26.9
× 192	56.4	20.35	11.455	1.750	0.960	× 286	36 400	517	291	44.4	24.4
× 175	51.3	20.04	11.375	1.590	0.890	× 260	33 100	509	289	40.4	22.6
× 158	46.3	19.72	11.300	1.440	0.810	× 235	29 900	501	287	36.6	20.6
× 143	42.1	19.49	11.220	1.320	0.730	× 213	27 100	495	285	33.5	18.5
× 130	38.2	19.25	11.160	1.200	0.670	× 193	24 700	489	283	30.5	17.0
× 119	35.1	18.97	11.265	1.060	0.655	× 177	22 600	482	286	26.9	16.6
× 106	31.1	18.73	11.200	0.940	0.590	× 158	20 100	476	284	23.9	15.0
× 97	28.5	18.59	11.145	0.870	0.535	× 144	18 400	472	283	22.1	13.6
× 86	25.3	18.39	11.090	0.770	0.480	× 128	16 300	467	282	19.6	12.2
× 76	22.3	18.21	11.035	0.680	0.425	× 113	14 400	463	280	17.3	10.8

TABLE A2.1 Continued

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f , in. ²	Depth d_f , in.	Flange		Web Thickness t_w , in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A_f , mm ²	Depth d_f , mm	Flange		Web Thick- ness t_w , mm ^A
			Width b_f , in.	Thick- ness, t_f , in. ^A					Width b_f , mm	Thick- ness, t_f , mm ^A	
W18 × 71	20.8	18.47	7.635	0.810	0.495	W460 × 106	13 400	469	194	20.6	12.6
× 65	19.1	18.35	7.590	0.750	0.450	× 97	12 300	466	193	19.0	11.4
× 60	17.6	18.24	7.555	0.695	0.415	× 89	11 400	463	192	17.7	10.5
× 55	16.2	18.11	7.530	0.630	0.390	× 82	10 500	460	191	16.0	9.9
× 50	14.7	17.99	7.495	0.570	0.355	× 74	9 480	457	190	14.5	9.0
W18 × 46	13.5	18.06	6.060	0.605	0.360	W460 × 68	8 710	459	154	15.4	9.1
× 40	11.8	17.90	6.015	0.525	0.315	× 60	7 610	455	153	13.3	8.0
× 35	10.3	17.70	6.000	0.425	0.300	× 52	6 650	450	152	10.8	7.6
W16 × 100	29.4	16.97	10.425	0.985	0.585	W410 × 149	19 000	431	265	25.0	14.9
× 89	26.2	16.75	10.365	0.875	0.525	× 132	16 900	425	263	22.2	13.3
× 77	22.6	16.52	10.295	0.760	0.455	× 114	14 600	420	261	19.3	11.6
× 67	19.7	16.33	10.235	0.665	0.395	× 100	12 700	415	260	16.9	10.0
W16 × 57	16.8	16.43	7.120	0.715	0.430	W410 × 85	10 800	417	181	18.2	10.9
× 50	14.7	16.26	7.070	0.630	0.380	× 75	9 480	413	180	16.0	9.7
× 45	13.3	16.13	7.035	0.565	0.345	× 67	8 580	410	179	14.4	8.8
× 40	11.8	16.01	6.995	0.505	0.305	× 60	7 610	407	178	12.8	7.7
× 36	10.6	15.86	6.985	0.430	0.295	× 53	6 840	403	177	10.9	7.5
W16 × 31	9.12	15.88	5.525	0.440	0.275	W410 × 46.1	5 880	403	140	11.2	7.0
× 26	7.68	15.69	5.500	0.345	0.250	× 38.8	4 950	399	140	8.8	6.4
W14 × 873	256.5	23.62	18.755	5.510	3.935	W360 × 1299	165 000	600	476	140.0	100.0
× 808	237.3	22.84	18.560	5.120	3.740	× 1202	153 000	580	471	130.0	95.0
× 730	215.0	22.42	17.890	4.910	3.070	× 1086	139 000	569	454	125.0	78.0
× 665	196.0	21.64	17.650	4.520	2.830	× 990	126 000	550	448	115.0	71.9
× 605	178.0	20.92	17.415	4.160	2.595	× 900	115 000	531	442	106.0	65.9
× 550	162.0	20.24	17.200	3.820	2.380	× 818	105 000	514	437	97.0	60.5
× 500	147.0	19.60	17.010	3.500	2.190	× 744	94 800	498	432	88.9	55.6
× 455	134.0	19.02	16.835	3.210	2.015	× 677	86 500	483	428	81.5	51.2
× 426	125.0	18.67	16.695	3.035	1.875	× 634	80 600	474	424	77.1	47.6
× 398	117.0	18.29	16.590	2.845	1.770	× 592	75 500	465	421	72.3	45.0
× 370	109.0	17.92	16.475	2.660	1.655	× 551	70 300	455	418	67.6	42.0
× 342	101.0	17.54	16.360	2.470	1.540	× 509	65 200	446	416	62.7	39.1
× 311	91.4	17.12	16.230	2.260	1.410	× 463	59 000	435	412	57.4	35.8
× 283	83.3	16.74	16.110	2.070	1.290	× 421	53 700	425	409	52.6	32.8
× 257	75.6	16.38	15.995	1.890	1.175	× 382	48 800	416	406	48.0	29.8
× 233	68.5	16.04	15.890	1.720	1.070	× 347	44 200	407	404	43.7	27.2
× 211	62.0	15.72	15.800	1.560	0.980	× 314	40 000	399	401	39.6	24.9
× 193	56.8	15.48	15.710	1.440	0.890	× 287	36 600	393	399	36.6	22.6
× 176	51.8	15.22	15.650	1.310	0.830	× 262	33 400	387	398	33.3	21.1
× 159	46.7	14.98	15.565	1.190	0.745	× 237	30 100	380	395	30.2	18.9
× 145	42.7	14.78	15.500	1.090	0.680	× 216	27 500	375	394	27.7	17.3
W14 × 132	38.8	14.66	14.725	1.030	0.645	W360 × 196	25 000	372	374	26.2	16.4
× 120	35.3	14.48	14.670	0.940	0.590	× 179	22 800	368	373	23.9	15.0
× 109	32.0	14.32	14.605	0.860	0.525	× 162	20 600	364	371	21.8	13.3
× 99	29.1	14.16	14.565	0.780	0.485	× 147	18 800	360	370	19.8	12.3
× 90	26.5	14.02	14.520	0.710	0.440	× 134	17 100	356	369	18.0	11.2
W14 × 82	24.1	14.31	10.130	0.855	0.510	W360 × 122	15 500	363	257	21.7	13.0
× 74	21.8	14.17	10.070	0.785	0.450	× 110	14 100	360	256	19.9	11.4
× 68	20.0	14.04	10.035	0.720	0.415	× 101	12 900	357	255	18.3	10.5
× 61	17.9	13.89	9.995	0.645	0.375	× 91	11 500	353	254	16.4	9.5
W14 × 53	15.6	13.92	8.060	0.660	0.370	W360 × 79	10 100	354	205	16.8	9.4
× 48	14.1	13.79	8.030	0.595	0.340	× 72	9 100	350	204	15.1	8.6
× 43	12.6	13.66	7.995	0.530	0.305	× 64	8 130	347	203	13.5	7.7
W14 × 38	11.2	14.10	6.770	0.515	0.310	W360 × 58	7 230	358	172	13.1	7.9
× 34	10.0	13.98	6.745	0.455	0.285	× 51	6 450	355	171	11.6	7.2
× 30	8.85	13.84	6.730	0.385	0.270	× 44.6	5 710	352	171	9.8	6.9
W14 × 26	7.69	13.91	5.025	0.420	0.255	W360 × 39.0	4 960	353	128	10.7	6.5
× 22	6.49	13.74	5.000	0.335	0.230	× 32.9	4 190	349	127	8.5	5.8

TABLE A2.1 Continued

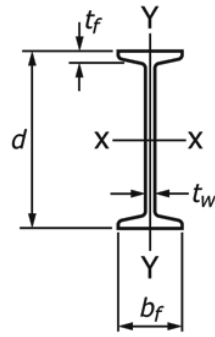
Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A_f mm ²	Depth d_f mm	Flange		Web Thick- ness t_w mm ^A
			Width b_f in.	Thick- ness t_f in. ^A					Width b_f mm	Thick- ness, t_f mm ^A	
W12 x 336	98.8	16.82	13.385	2.955	1.775	W310 x 500	63 700	427	340	75.1	45.1
x 305	89.6	16.32	13.235	2.705	1.625	x 454	57 800	415	336	68.7	41.3
x 279	81.9	15.85	13.140	2.470	1.530	x 415	52 800	403	334	62.7	38.9
x 252	74.1	15.41	13.005	2.250	1.395	x 375	47 800	391	330	57.2	35.4
x 230	67.7	15.05	12.895	2.070	1.285	x 342	43 700	382	328	52.6	32.6
x 210	61.8	14.71	12.790	1.900	1.180	x 313	39 900	374	325	48.3	30.0
x 190	55.8	14.38	12.670	1.735	1.060	x 283	36 000	365	322	44.1	26.9
x 170	50.0	14.03	12.570	1.560	0.960	x 253	32 300	356	319	39.6	24.4
x 152	44.7	13.71	12.480	1.400	0.870	x 226	28 800	348	317	35.6	22.1
x 136	39.9	13.41	12.400	1.250	0.790	x 202	25 700	341	315	31.8	20.1
x 120	35.3	13.12	12.320	1.105	0.710	x 179	22 800	333	313	28.1	18.0
x 106	31.2	12.89	12.220	0.990	0.610	x 158	20 100	327	310	25.1	15.5
x 96	28.2	12.71	12.160	0.900	0.550	x 143	18 200	323	309	22.9	14.0
x 87	25.6	12.53	12.125	0.810	0.515	x 129	16 500	318	308	20.6	13.1
x 79	23.2	12.38	12.080	0.735	0.470	x 117	15 000	314	307	18.7	11.9
x 72	21.1	12.25	12.040	0.670	0.430	x 107	13 600	311	306	17.0	10.9
x 65	19.1	12.12	12.000	0.605	0.390	x 97	12 300	308	305	15.4	9.9
W12 x 58	17.0	12.19	10.010	0.640	0.360	W310 x 86	11 000	310	254	16.3	9.1
x 53	15.6	12.06	9.995	0.575	0.345	x 79	10 100	306	254	14.6	8.8
W12 x 50	14.7	12.19	8.080	0.640	0.370	W310 x 74	9 480	310	205	16.3	9.4
x 45	13.2	12.06	8.045	0.575	0.335	x 67	8 520	306	204	14.6	8.5
x 40	11.8	11.94	8.005	0.515	0.295	x 60	7 610	303	203	13.1	7.5
W12 x 35	10.3	12.50	6.560	0.520	0.300	W310 x 52	6 650	317	167	13.2	7.6
x 30	8.79	12.34	6.520	0.440	0.260	x 44.5	5 670	313	166	11.2	6.6
x 26	7.65	12.22	6.490	0.380	0.230	x 38.7	4 940	310	165	9.7	5.8
W12 x 22	6.48	12.31	4.030	0.425	0.260	W310 x 32.7	4 180	313	102	10.8	6.6
x 19	5.57	12.16	4.005	0.350	0.235	x 28.3	3 590	309	102	8.9	6.0
x 16	4.71	11.99	3.990	0.265	0.220	x 23.8	3 040	305	101	6.7	5.6
x 14	4.16	11.91	3.970	0.225	0.200	x 21.0	2 680	303	101	5.7	5.1
W10 x 112	32.9	11.36	10.415	1.250	0.755	W250 x 167	21 200	289	265	31.8	19.2
x 100	29.4	11.10	10.340	1.120	0.680	x 149	19 000	282	263	28.4	17.3
x 88	25.9	10.84	10.265	0.990	0.605	x 131	16 700	275	261	25.1	15.4
x 77	22.6	10.60	10.190	0.870	0.530	x 115	14 600	269	259	22.1	13.5
x 68	20.0	10.40	10.130	0.770	0.470	x 101	12 900	264	257	19.6	11.9
x 60	17.6	10.22	10.080	0.680	0.420	x 89	11 400	260	256	17.3	10.7
x 54	15.8	10.09	10.030	0.615	0.370	x 80	10 200	256	255	15.6	9.4
x 49	14.4	9.98	10.000	0.560	0.340	x 73	9 290	253	254	14.2	8.6
W10 x 45	13.3	10.10	8.020	0.620	0.350	W250 x 67	8 580	257	204	15.7	8.9
x 39	11.5	9.92	7.985	0.530	0.315	x 58	7 420	252	203	13.5	8.0
x 33	9.71	9.73	7.960	0.435	0.290	x 49.1	6 260	247	202	11.0	7.4
W10 x 30	8.84	10.47	5.810	0.510	0.300	W250 x 44.8	5 700	266	148	13.0	7.6
x 26	7.61	10.33	5.770	0.440	0.260	x 38.5	4 910	262	147	11.2	6.6
x 22	6.49	10.17	5.750	0.360	0.240	x 32.7	4 190	258	146	9.1	6.1
W10 x 19	5.62	10.24	4.020	0.395	0.250	W250 x 28.4	3 630	260	102	10.0	6.4
x 17	4.99	10.11	4.010	0.330	0.240	x 25.3	3 220	257	102	8.4	6.1
x 15	4.41	9.99	4.000	0.270	0.230	x 22.3	2 850	254	102	6.9	5.8
x 12	3.54	9.87	3.960	0.210	0.190	x 17.9	2 280	251	101	5.3	4.8
W8 x 67	19.7	9.00	8.280	0.935	0.570	W200 x 100	12 700	229	210	23.7	14.5
x 58	17.1	8.75	8.220	0.810	0.510	x 86	11 000	222	209	20.6	13.0
x 48	14.1	8.50	8.110	0.685	0.400	x 71	9 100	216	206	17.4	10.2
x 40	11.7	8.25	8.070	0.560	0.360	x 59	7 550	210	205	14.2	9.1
x 35	10.3	8.12	8.020	0.495	0.310	x 52	6 650	206	204	12.6	7.9
x 31	9.13	8.00	7.995	0.435	0.285	x 46.1	5 890	203	203	11.0	7.2
W8 x 28	8.25	8.06	6.535	0.465	0.285	W200 x 41.7	5 320	205	166	11.8	7.2
x 24	7.08	7.93	6.495	0.400	0.245	x 35.9	4 570	201	165	10.2	6.2
W8 x 21	6.16	8.28	5.270	0.400	0.250	W200 x 31.3	3 970	210	134	10.2	6.4
x 18	5.26	8.14	5.250	0.330	0.230	x 26.6	3 390	207	133	8.4	5.8

TABLE A2.1 *Continued*

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A , in. ²	Depth d , in.	Flange		Web Thickness t_w , in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A , mm ²	Depth d , mm	Flange		Web Thick- ness t_w , mm ^A
			Width b_f in.	Thick- ness t_f , in. ^A					Width b_f mm	Thick- ness, t_f , mm ^A	
W8 × 15	4.44	8.11	4.015	0.315	0.245	W200 × 22.5	2 860	206	102	8.0	6.2
× 13	3.84	7.99	4.000	0.255	0.230	× 19.3	2 480	203	102	6.5	5.8
× 10	2.96	7.89	3.940	0.205	0.170	× 15.0	1 910	200	100	5.2	4.3
W6 × 25	7.34	6.38	6.080	0.455	0.320	W150 × 37.1	4 740	162	154	11.6	8.1
× 20	5.87	6.20	6.020	0.365	0.260	× 29.8	3 790	157	153	9.3	6.6
× 15	4.43	5.99	5.990	0.260	0.230	× 22.5	2 860	152	152	6.6	5.8
W6 × 16	4.74	6.28	4.030	0.405	0.260	W150 × 24.0	3 060	160	102	10.3	6.6
× 12	3.55	6.03	4.000	0.280	0.230	× 18.0	2 290	153	102	7.1	5.8
× 9	2.68	5.90	3.940	0.215	0.170	× 13.5	1 730	150	100	5.5	4.3
× 8.5	2.52	5.83	3.940	0.195	0.170	× 13.0	1 630	148	100	4.9	4.3
W5 × 19	5.54	5.15	5.030	0.430	0.270	W130 × 28.1	3 590	131	128	10.9	6.9
× 16	4.68	5.01	5.000	0.360	0.240	× 23.8	3 040	127	127	9.1	6.1
W4 × 13	3.83	4.16	4.060	0.345	0.280	W100 × 19.3	2 470	106	103	8.8	7.1

^A Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

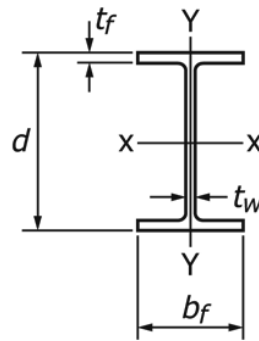
TABLE A2.2 "S" Shapes



Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A, in. ²	Depth d, in.	Flange		Web Thick- ness t _w in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A, mm ²	Depth d, mm	Flange		Web Thick- ness t _w mm ^A
			Width b _f in.	Thick- ness t _f in. ^A					Width b _f mm	Thick- ness, t _f mm ^A	
S 24 × 121 × 106	35.6	24.50	8.050	1.090	0.800	S 610 × 180 × 158	23 000	622	204	27.7	20.3
	31.2	24.50	7.870	1.090	0.620		20 100	622	200	27.7	15.7
S 24 × 100 × 90 × 80	29.3	24.00	7.245	0.870	0.745	S 610 × 149 × 134 × 119	18 900	610	184	22.1	18.9
	26.5	24.00	7.125	0.870	0.625		17 100	610	181	22.1	15.9
	23.5	24.00	7.000	0.870	0.500		15 200	610	178	22.1	12.7
S 20 × 96 × 86	28.2	20.30	7.200	0.920	0.800	S 510 × 143 × 128	18 200	516	183	23.4	20.3
	25.3	20.30	7.060	0.920	0.660		16 300	516	179	23.4	16.8
S 20 × 75 × 66	22.0	20.00	6.385	0.795	0.635	S 510 × 112 × 98	14 200	508	162	20.2	16.1
	19.4	20.00	6.255	0.795	0.505		12 500	508	159	20.2	12.8
S 18 × 70 × 54.7	20.6	18.00	6.251	0.691	0.711	S 460 × 104 × 81.4	13 300	457	159	17.6	18.1
	16.1	18.00	6.001	0.691	0.461		10 400	457	152	17.6	11.7
S 15 × 50 × 42.9	14.7	15.00	5.640	0.622	0.550	S 380 × 74 × 64	9 480	381	143	15.8	14.0
	12.6	15.00	5.501	0.622	0.411		8 130	381	140	15.8	10.4
S 12 × 50 × 40.8	14.7	12.00	5.477	0.659	0.687	S 310 × 74 × 60.7	9 480	305	139	16.7	17.4
	12.0	12.00	5.252	0.659	0.462		7 740	305	133	16.7	11.7
S 12 × 35 × 31.8	10.3	12.00	5.078	0.544	0.428	S 310 × 52 × 47.3	6 650	305	129	13.8	10.9
	9.35	12.00	5.000	0.544	0.350		6 030	305	127	13.8	8.9
S 10 × 35 × 25.4	10.3	10.00	4.944	0.491	0.594	S 250 × 52 × 37.8	6 650	254	126	12.5	15.1
	7.46	10.00	4.661	0.491	0.311		4 810	254	118	12.5	7.9
S 8 × 23 × 18.4	6.77	8.00	4.171	0.425	0.441	S 200 × 34 × 27.4	4 370	203	106	10.8	11.2
	5.41	8.00	4.001	0.425	0.271		3 480	203	102	10.8	6.9
S 6 × 17.25 × 12.5	5.07	6.00	3.565	0.359	0.465	S 150 × 25.7 × 18.6	3 270	152	91	9.1	11.8
	3.67	6.00	3.332	0.359	0.232		2 360	152	85	9.1	5.9
S 5 × 10	2.94	5.00	3.004	0.326	0.214	S 130 × 15	1 880	127	76	8.3	5.4
S 4 × 9.5 × 7.7	2.79	4.00	2.796	0.293	0.326	S 100 × 14.1 × 11.5	1 800	102	71	7.4	8.3
	2.26	4.00	2.663	0.293	0.193		1 450	102	68	7.4	4.9
S 3 × 7.5 × 5.7	2.21	3.00	2.509	0.260	0.349	S 75 × 11.2 × 8.5	1 430	76	64	6.6	8.9
	1.67	3.00	2.330	0.260	0.170		1 080	76	59	6.6	4.3

^A Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

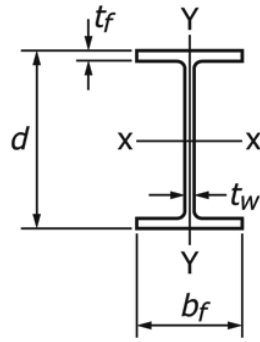
TABLE A2.3 "M" Shapes



Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A , in. ²	Depth d , in.	Flange		Web Thick- ness t_w , in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A , mm ²	Depth d , mm	Flange		Web Thick- ness t_w , mm ^A
			Width b_f , in.	Thick- ness t_f , in. ^A					Width b_f , mm	Thick- ness, t_f , mm ^A	
M 12.5 × 12.4 × 11.6	3.66	12.534	3.750	0.228	0.155	M 318 × 18.5 × 17.3	2 361	318	95	5.8	3.9
	3.43	12.500	3.500	0.211	0.155		2 213	317	89	5.4	3.9
M 12 × 11.8 × 10.8 × 10.0	3.47	12.00	3.065	0.225	0.177	M 310 × 17.6 × 16.1 × 14.9	2 240	305	78	5.7	4.5
	3.18	11.97	3.065	0.210	0.160		2 050	304	78	5.3	4.1
	2.94	11.97	3.250	0.180	0.149		1 900	304	83	4.6	3.8
M 10 × 9.0 × 8.0 × 7.5	2.65	10.00	2.690	0.206	0.157	M 250 × 13.4 × 11.9 × 11.2	1 710	254	68	4.6	3.6
	2.35	9.95	2.690	0.182	0.141		1 520	253	68	5.2	4.0
	2.21	9.99	2.688	0.173	0.130		1 430	253	68	4.4	3.3
M 8 × 6.5 × 6.2	1.92	8.00	2.281	0.189	0.135	M 200 × 9.7 × 9.2	1 240	203	57	4.8	3.4
	1.81	8.00	2.281	0.177	0.129		1 170	203	58	4.5	3.3
M 6 × 4.4 × 3.7	1.29	6.00	1.844	0.171	0.114	M 150 × 6.6 × 5.5	832	152	47	4.3	2.9
	1.09	5.92	2.000	0.129	0.098		703	150	51	3.3	2.5
M 5 × 18.9	5.55	5.00	5.003	0.416	0.316	M 130 × 28.1	3 580	127	127	10.6	8.0
M 4 × 6.0 × 4.08	1.78	3.80	3.80	0.160	0.130	M 100 × 8.9 × 6.1	1 150	97	97	4.1	3.3
	1.20	4.00	2.250	0.170	0.115		775	102	57	4.3	2.9
M 3 × 2.9	0.853	3.00	2.250	0.130	0.090	M 75 × 4.3	550	76	57	3.3	2.3

^A Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

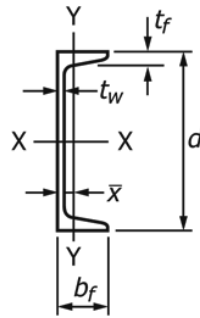
TABLE A2.4 "HP" Shapes



Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A , in. ²	Depth d , in.	Flange		Web Thick- ness t_w , in. ^A	Designation [Nominal Depth in Milli- metres and Mass in Kilo- grams per Metre]	Area A , mm ²	Depth d , mm	Flange		Web Thick- ness t_w , mm ^A
			Width b_f , in.	Thick- ness t_f , in. ^A					Width b_f , mm	Thickness, t_f , mm ^A	
HP18 × 204	60.0	18.25	18.125	1.125	1.125	HP460 × 304	38 700	464	460	28.6	28.6
× 181	53.2	18.00	18.000	1.000	1.000	× 269	34 300	457	457	25.4	25.4
× 157	46.2	17.74	17.870	0.870	0.870	× 234	29 800	451	454	22.1	22.1
× 135	39.8	17.50	17.750	0.750	0.750	× 202	25 700	445	451	19.1	19.1
HP16 × 183	53.8	16.50	16.250	1.125	1.125	HP410 × 272	34 700	419	413	28.6	28.6
× 162	47.7	16.25	16.125	1.000	1.000	× 242	30 800	413	410	25.4	25.4
× 141	41.7	16.00	16.000	0.875	0.875	× 211	26 900	406	406	22.2	22.2
× 121	35.7	15.75	15.875	0.750	0.750	× 181	23 000	400	403	19.1	19.1
× 101	29.8	15.50	15.750	0.625	0.625	× 151	19 200	394	400	15.9	15.9
× 88	25.8	15.33	15.665	0.540	0.540	× 131	16 700	389	398	13.7	13.7
HP14 × 117	34.4	14.21	14.885	0.805	0.805	HP360 × 174	22 200	361	378	20.4	20.4
× 102	30.0	14.01	14.785	0.705	0.705	× 152	19 400	356	376	17.9	17.9
× 89	26.1	13.83	14.695	0.615	0.615	× 132	16 800	351	373	15.6	15.6
× 73	21.4	13.61	14.585	0.505	0.505	× 108	13 800	346	370	12.8	12.8
HP12 × 89	26.2	12.35	12.330	0.720	0.720	HP310 × 132	16 900	314	313	18.3	18.3
× 84	24.6	12.28	12.295	0.685	0.685	× 125	15 900	312	312	17.4	17.4
× 74	21.8	12.13	12.215	0.610	0.605	× 110	14 100	308	310	15.5	15.4
× 63	18.4	11.94	12.125	0.515	0.515	× 93	11 900	303	308	13.1	13.1
× 53	15.5	11.78	12.045	0.435	0.435	× 79	10 000	299	306	11.0	11.0
HP10 × 57	16.8	9.99	10.225	0.565	0.565	HP250 × 85	10 800	254	260	14.4	14.4
× 42	12.4	9.70	10.075	0.420	0.415	× 62	8 000	246	256	10.7	10.5
HP8 × 36	10.6	8.02	8.155	0.445	0.445	HP200 × 53	6 840	204	207	11.3	11.3

^A Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

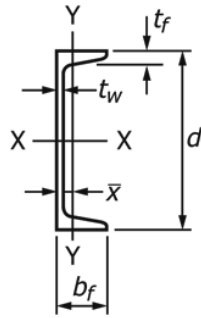
TABLE A2.5 "C" Shapes



Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A, in. ²	Depth d, in.	Flange		Web Thick- ness t _w ^A in. ⁴	Designation [Nominal Depth in Milli- metres in Mass in Kilograms per Metre]	Area A, mm ²	Depth d, mm	Flange		Web Thick- ness t _w ^A mm ⁴
			Width b _f in.	Thick- ness t _f in. ⁴					Width b _f mm	Thick- ness t _f mm ⁴	
C 15 × 50	14.7	15.00	3.716	0.650	0.716	C 380 × 74	9 480	381	94	16.5	18.2
× 40	11.8	15.00	3.520	0.650	0.520	× 60	7 610	381	89	16.5	13.2
× 33.9	9.96	15.00	3.400	0.650	0.400	× 50.4	6 430	381	86	16.5	10.2
C 12 × 30	8.82	12.00	3.170	0.501	0.510	C 310 × 45	5 690	305	80	12.7	13.0
× 25	7.35	12.00	3.047	0.501	0.387	× 37	4 740	305	77	12.7	9.8
× 20.7	6.09	12.00	2.942	0.501	0.282	× 30.8	3 930	305	74	12.7	7.2
C 10 × 30	8.82	10.00	3.033	0.436	0.673	C 250 × 45	5 690	254	76	11.1	17.1
× 25	7.35	10.00	2.886	0.436	0.526	× 37	4 740	254	73	11.1	13.4
× 20	5.88	10.00	2.739	0.436	0.379	× 30	3 790	254	69	11.1	9.6
× 15.3	4.49	10.00	2.600	0.436	0.240	× 22.8	2 900	254	65	11.1	6.1
C 9 × 20	5.88	9.00	2.648	0.413	0.448	C 230 × 30	3 790	229	67	10.5	11.4
× 15	4.41	9.00	2.485	0.413	0.285	× 22	2 850	229	63	10.5	7.2
× 13.4	3.94	9.00	2.433	0.413	0.233	× 19.9	2 540	229	61	10.5	5.9
C 8 × 18.75	5.51	8.00	2.527	0.390	0.487	C 200 × 27.9	3 550	203	64	9.9	12.4
× 13.75	4.04	8.00	2.343	0.390	0.303	× 20.5	2 610	203	59	9.9	7.7
× 11.5	3.38	8.00	2.260	0.390	0.220	× 17.1	2 180	203	57	9.9	5.6
C 7 × 14.75	4.33	7.00	2.299	0.366	0.419	C 180 × 22	2 790	178	58	9.3	10.6
× 12.25	3.60	7.00	2.194	0.366	0.314	× 18.2	2 320	178	55	9.3	8.0
× 9.8	2.87	7.00	2.090	0.366	0.210	× 14.6	1 850	178	53	9.3	5.3
C 6 × 13	3.83	6.00	2.157	0.343	0.437	C 150 × 19.3	2 470	152	54	8.7	11.1
× 10.5	3.09	6.00	2.034	0.343	0.314	× 15.6	1 990	152	51	8.7	8.0
× 8.2	2.40	6.00	1.920	0.343	0.200	× 12.2	1 550	152	48	8.7	5.1
C 5 × 9	2.64	5.00	1.885	0.320	0.325	C 130 × 13	1 700	127	47	8.1	8.3
× 6.7	1.97	5.00	1.750	0.320	0.190	× 10.4	1 270	127	44	8.1	4.8
C 4 × 7.25	2.13	4.00	1.721	0.296	0.321	C 100 × 10.8	1 370	102	43	7.5	8.2
× 6.25	1.84	4.00	1.647	0.296	0.247	× 9.3	1 187	102	42	7.5	6.3
× 5.4	1.59	4.00	1.584	0.296	0.184	× 8	1 030	102	40	7.5	4.7
× 4.5	1.32	4.00	1.520	0.296	0.125	× 6.7	852	102	39	7.5	3.2
C 3 × 6	1.76	3.00	1.596	0.273	0.356	C 75 × 8.9	1 130	76	40	6.9	9.0
× 5	1.47	3.00	1.498	0.273	0.258	× 7.4	948	76	37	6.9	6.6
× 4.1	1.21	3.00	1.410	0.273	0.170	× 6.1	781	76	35	6.9	4.3
× 3.5	1.03	3.00	1.372	0.273	0.132	× 5.2	665	76	35	6.9	3.4

^A Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

TABLE A2.6 "MC" Shapes



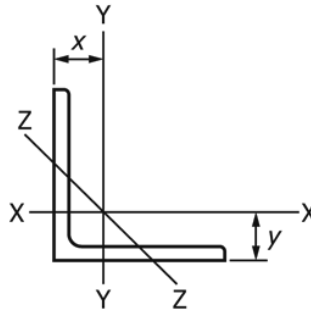
Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area <i>A</i> , in. ²	Depth <i>d</i> , in.	Flange		Web Thick- ness <i>t_w</i> in. ^A	Designation [Nominal Depth in Millimetres and Mass in Kilo- grams per Metre]	Area <i>A</i> , mm ²	Depth <i>d</i> , mm	Flange		Web Thick- ness <i>t_w</i> mm ^A
			Width <i>b_f</i> , in.	Thick- ness <i>t_f</i> in. ^A					Width <i>b_f</i> , mm	Thick- ness <i>t_f</i> mm ^A	
MC 18 × 58	17.1	18.00	4.200	0.625	0.700	MC 460 × 86	11 000	457	107	15.9	17.8
× 51.9	15.3	18.00	4.100	0.625	0.600	× 77.2	9 870	457	104	15.9	15.2
× 45.8	13.5	18.00	4.000	0.625	0.500	× 68.2	8 710	457	102	15.9	12.7
× 42.7	12.6	18.00	3.950	0.625	0.450	× 63.5	8 130	457	100	15.9	11.4
MC 13 × 50	14.7	13.00	4.412	0.610	0.787	MC 330 × 74	9 480	330	112	15.5	20.0
× 40	11.8	13.00	4.185	0.610	0.560	× 60	7 610	330	106	15.5	14.2
× 35	10.3	13.00	4.072	0.610	0.447	× 52	6 640	330	103	15.5	11.4
× 31.8	9.35	13.00	4.000	0.610	0.375	× 47.3	6 030	330	102	15.5	9.5
MC 12 × 50	14.7	12.00	4.135	0.700	0.835	MC 310 × 74	9 480	305	105	17.8	21.2
× 45	13.2	12.00	4.010	0.700	0.710	× 67	8 502	305	102	17.8	18.0
× 40	11.8	12.00	3.890	0.700	0.590	× 60	7 610	305	98	17.8	15.0
× 35	10.3	12.00	3.765	0.700	0.465	× 52	6 620	305	96	17.8	11.8
× 31	9.12	12.00	3.670	0.700	0.370	× 46	5 890	305	93	17.8	9.4
MC 12 × 14.3	4.19	12.00	2.125	0.313	0.250	MC 310 × 21.3	2 700	305	54	8.0	6.4
× 10.6	3.10	12.00	1.500	0.309	0.190	× 15.8	2 000	305	38	7.8	4.8
MC 10 × 41.1	12.1	10.00	4.321	0.575	0.796	MC 250 × 61.2	7 810	254	110	14.6	20.2
× 33.6	9.87	10.00	4.100	0.575	0.575	× 50	6 370	254	104	14.6	14.6
× 28.5	8.37	10.00	3.950	0.575	0.425	× 42.4	5 400	254	100	14.6	10.8
MC 10 × 25	7.35	10.00	3.405	0.575	0.380	MC 250 × 37	4 740	254	86	14.6	9.7
× 22	6.45	10.00	3.315	0.575	0.290	× 33	4 160	254	84	14.6	7.4
MC 10 × 8.4	2.46	10.00	1.500	0.280	0.170	MC 250 × 12.5	1 590	254	38	7.1	4.3
× 6.5	1.91	10.00	1.17	0.202	0.152	× 9.7	1 240	254	28	5.1	3.9
MC 9 × 25.4	7.47	9.00	3.500	0.550	0.450	MC 230 × 37.8	4 820	229	88	14.0	11.4
× 23.9	7.02	9.00	3.450	0.550	0.400	× 35.6	4 530	229	87	14.0	10.2
MC 8 × 22.8	6.70	8.00	3.502	0.525	0.427	MC 200 × 33.9	4 320	203	88	13.3	10.8
× 21.4	6.28	8.00	3.450	0.525	0.375	× 31.8	4 050	203	87	13.3	9.5
MC 8 × 20	5.88	8.00	3.025	0.500	0.400	MC 200 × 29.8	3 790	203	76	12.7	10.2
× 18.7	5.50	8.00	2.978	0.500	0.353	× 27.8	3 550	203	75	12.7	9.0
MC 8 × 8.5	2.50	8.00	1.874	0.311	0.179	MC 200 × 12.6	1 610	203	47	7.9	4.5
MC 7 × 22.7	6.67	7.00	3.603	0.500	0.503	MC 180 × 33.8	4 300	178	91	12.7	12.8
× 19.1	5.61	7.00	3.452	0.500	0.352	× 28.4	3 620	178	87	12.7	8.9
MC 6 × 18	5.29	6.00	3.504	0.475	0.379	MC 150 × 26.8	3 410	152	88	12.1	9.6
× 15.3	4.50	6.00	3.500	0.385	0.340	× 22.8	2 900	152	88	9.8	8.6
MC 6 × 16.3	4.79	6.00	3.000	0.475	0.375	MC 150 × 24.3	3 090	152	76	12.1	9.5
× 15.1	4.44	6.00	2.941	0.475	0.316	× 22.5	2 860	152	74	12.1	8.0
MC 6 × 12	3.53	6.00	2.497	0.375	0.310	MC 150 × 17.9	2 280	152	63	9.5	7.9

TABLE A2.6 *Continued*

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A , in. ²	Depth d , in.	Flange		Web Thick- ness t_w , in. ^A	Designation [Nominal Depth in Millimetres and Mass in Kilo- grams per Metre]	Area A , mm ²	Depth d , mm	Flange		Web Thick- ness t_w , mm ^A
			Width b_f , in.	Thick- ness t_f , in. ^A					Width b_f , mm	Thick- ness t_f , mm ^A	
MC 6 × 7.0 × 6.5	2.07	6.00	1.875	0.291	0.179	MC 150 × 10.4 × 9.7	1 341	152	48	7.4	4.5
	1.93	6.00	1.850	0.291	0.155		1 250	152	47	7.4	3.9
MC 4 × 13.8	4.02	4.00	2.500	0.500	0.500	MC 100 × 20.5	2 594	102	64	13	13
MC 3 × 7.1	2.09	3.00	1.938	0.351	0.312	MC 75 × 10.6	1 348	76	49	8.9	7.9

^A Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

TABLE A2.7 "L" Shapes (Equal Legs)^A



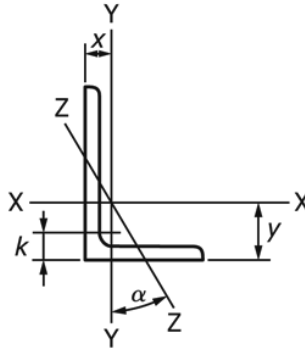
Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L12 × 12 × 1 ³ / ₈	105	30.9	L305 × 305 × 34.9	157	19 900
L12 × 12 × 1 ¹ / ₄	96.4	28.3	L305 × 305 × 31.8	143	18 300
L12 × 12 × 1 ¹ / ₂	87.2	25.6	L305 × 305 × 28.6	130	16 500
L12 × 12 × 1	77.8	22.9	L305 × 305 × 25.4	116	14 700
L10 × 10 × 1 ³ / ₈	87.1	25.6	L254 × 254 × 34.9	130	16 500
L10 × 10 × 1 ¹ / ₄	79.9	23.5	L254 × 254 × 31.8	119	15 100
L10 × 10 × 1 ¹ / ₂	72.3	21.2	L254 × 254 × 28.6	108	13 700
L10 × 10 × 1	64.7	19.0	L254 × 254 × 25.4	96.2	12 300
L10 × 10 × 7 ⁸ / ₁₆	56.9	16.7	L254 × 254 × 22.2	84.6	10 800
L10 × 10 × 3 ⁴ / ₁₆	49.1	14.4	L254 × 254 × 19.1	73.1	9 310
L8 × 8 × 1 ³ / ₈	56.9	16.7	L203 × 203 × 28.6	84.7	10 800
L8 × 8 × 1	51.0	15.0	L203 × 203 × 25.4	75.9	9 680
L8 × 8 × 7 ⁸ / ₁₆	45.0	13.2	L203 × 203 × 22.2	67.0	8 500
L8 × 8 × 3 ⁴ / ₁₆	38.9	11.4	L203 × 203 × 19.0	57.9	7 360
L8 × 8 × 5 ⁸ / ₁₆	32.7	9.61	L203 × 203 × 15.9	48.7	6 200
L8 × 8 × 9 ¹⁶ / ₁₆	29.6	8.68	L203 × 203 × 14.3	44.0	5 600
L8 × 8 × 1 ² / ₂	26.4	7.75	L203 × 203 × 12.7	39.3	5 000
L6 × 6 × 1	37.4	11.0	L152 × 152 × 25.4	55.7	7 100
L6 × 6 × 7 ⁸ / ₁₆	33.1	9.73	L152 × 152 × 22.2	49.3	6 280
L6 × 6 × 3 ⁴ / ₁₆	28.7	8.44	L152 × 152 × 19.0	42.7	5 450
L6 × 6 × 5 ⁸ / ₁₆	24.2	7.11	L152 × 152 × 15.9	36.0	4 590
L6 × 6 × 9 ¹⁶ / ₁₆	21.9	6.43	L152 × 152 × 14.3	32.6	4 150
L6 × 6 × 1 ² / ₂	19.6	5.75	L152 × 152 × 12.7	29.2	3 710
L6 × 6 × 7 ¹⁶ / ₁₆	17.2	5.06	L152 × 152 × 11.1	25.6	3 270
L6 × 6 × 3 ⁸ / ₁₆	14.9	4.36	L152 × 152 × 9.5	22.2	2 810
L6 × 6 × 5 ¹⁶ / ₁₆	12.4	3.65	L152 × 152 × 7.9	18.5	2 360
L5 × 5 × 7 ⁸ / ₁₆	27.2	7.98	L127 × 127 × 22.2	40.5	5 150
L5 × 5 × 3 ⁴ / ₁₆	23.6	6.94	L127 × 127 × 19.0	35.1	4 480
L5 × 5 × 5 ⁸ / ₁₆	20.0	5.86	L127 × 127 × 15.9	29.8	3 780
L5 × 5 × 1 ² / ₂	16.2	4.75	L127 × 127 × 12.7	24.1	3 070
L5 × 5 × 7 ¹⁶ / ₁₆	14.3	4.18	L127 × 127 × 11.1	21.3	2 700
L5 × 5 × 3 ⁸ / ₁₆	12.3	3.61	L127 × 127 × 9.5	18.3	2 330
L5 × 5 × 5 ¹⁶ / ₁₆	10.3	3.03	L127 × 127 × 7.9	15.3	1 960
L4 × 4 × 3 ⁴ / ₁₆	18.5	5.44	L102 × 102 × 19.0	27.5	3 510
L4 × 4 × 5 ⁸ / ₁₆	15.7	4.61	L102 × 102 × 15.9	23.4	2 970
L4 × 4 × 1 ² / ₂	12.8	3.75	L102 × 102 × 12.7	19.0	2 420
L4 × 4 × 7 ¹⁶ / ₁₆	11.3	3.31	L102 × 102 × 11.1	16.8	2 140
L4 × 4 × 3 ⁸ / ₁₆	9.80	2.86	L102 × 102 × 9.5	14.6	1 850
L4 × 4 × 5 ¹⁶ / ₁₆	8.20	2.40	L102 × 102 × 7.9	12.2	1 550
L4 × 4 × 1 ⁴ / ₄	6.60	1.94	L102 × 102 × 6.4	9.8	1 250
L3 ¹ / ₂ × 3 ¹ / ₂ × 1 ² / ₂	11.1	3.25	L89 × 89 × 12.7	16.5	2 100
L3 ¹ / ₂ × 3 ¹ / ₂ × 7 ¹⁶ / ₁₆	9.80	2.87	L89 × 89 × 11.1	14.6	1 850
L3 ¹ / ₂ × 3 ¹ / ₂ × 3 ⁸ / ₁₆	8.50	2.48	L89 × 89 × 9.5	12.6	1 600
L3 ¹ / ₂ × 3 ¹ / ₂ × 5 ¹⁶ / ₁₆	7.20	2.09	L89 × 89 × 7.9	10.7	1 350
L3 ¹ / ₂ × 3 ¹ / ₂ × 1 ⁴ / ₄	5.80	1.69	L89 × 89 × 6.4	8.6	1 090
L3 × 3 × 1 ² / ₂	9.40	2.75	L76 × 76 × 12.7	14.0	1 770
L3 × 3 × 7 ¹⁶ / ₁₆	8.30	2.43	L76 × 76 × 11.1	12.4	1 570
L3 × 3 × 3 ⁸ / ₁₆	7.20	2.11	L76 × 76 × 9.5	10.7	1 360
L3 × 3 × 5 ¹⁶ / ₁₆	6.10	1.78	L76 × 76 × 7.9	9.1	1 150
L3 × 3 × 1 ⁴ / ₄	4.90	1.44	L76 × 76 × 6.4	7.3	929
L3 × 3 × 3 ¹⁶ / ₁₆	3.71	1.09	L76 × 76 × 4.8	5.5	703

TABLE A2.7 *Continued*

Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L2½ × 2½ × ½	7.70	2.25	L64 × 64 × 12.7	11.4	1 450
L2½ × 2½ × ⅜	5.90	1.73	L64 × 64 × 9.5	8.7	1 120
L2½ × 2½ × ⅜ ₁₆	5.00	1.46	L64 × 64 × 7.9	7.4	942
L2½ × 2½ × ¼	4.10	1.19	L64 × 64 × 6.4	6.1	768
L2½ × 2½ × ⅜ ₁₆	3.07	0.90	L64 × 64 × 4.8	4.6	581
L2 × 2 × ⅜	4.70	1.36	L51 × 51 × 9.5	7.0	877
L2 × 2 × ⅜ ₁₆	3.92	1.15	L51 × 51 × 7.9	5.8	742
L2 × 2 × ¼	3.19	0.938	L51 × 51 × 6.4	4.7	605
L2 × 2 × ⅜ ₁₆	2.44	0.715	L51 × 51 × 4.8	3.6	461
L2 × 2 × ⅛	1.65	0.484	L51 × 51 × 3.2	2.4	312
L1¾ × 1¾ × ¼	2.77	0.813	L44 × 44 × 6.4	4.1	525
L1¾ × 1¾ × ⅜ ₁₆	2.12	0.621	L44 × 44 × 4.8	3.1	401
L1¾ × 1¾ × ⅛	1.44	0.422	L44 × 44 × 3.2	2.1	272
L1½ × 1½ × ¼	2.34	0.688	L38 × 38 × 6.4	3.4	444
L1½ × 1½ × ⅜ ₁₆	1.80	0.527	L38 × 38 × 4.8	2.7	340
L1½ × 1½ × ⅜ ₃₂	1.52	0.444	L38 × 38 × 4.0	2.2	286
L1½ × 1½ × ⅛	1.23	0.359	L38 × 38 × 3.2	1.8	232
L1¼ × 1¼ × ¼	1.92	0.563	L32 × 32 × 6.4	2.8	363
L1¼ × 1¼ × ⅜ ₁₆	1.48	0.434	L32 × 32 × 4.8	2.2	280
L1¼ × 1¼ × ⅛	1.01	0.297	L32 × 32 × 3.2	1.5	192
L1 × 1 × ¼	1.49	0.438	L25 × 25 × 6.4	2.2	283
L1 × 1 × ⅜ ₁₆	1.16	0.340	L25 × 25 × 4.8	1.8	219
L1 × 1 × ⅛	0.80	0.234	L25 × 25 × 3.2	1.2	151
L¾ × ¾ × ⅛	0.59	0.172	L19 × 19 × 3.2	0.9	111

⁴ The heel of 12 and 10-in. angles may have a rounded outside corner.

TABLE A2.8 "L" Shapes (Unequal Legs)



Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L8 × 6 × 1	44.2	13.0	L203 × 152 × 25.4	65.5	8 390
L8 × 6 × 7/8	39.1	11.5	L203 × 152 × 22.2	57.9	7 420
L8 × 6 × 3/4	33.8	9.94	L203 × 152 × 19.0	50.1	6 410
L8 × 6 × 5/8	28.5	8.36	L203 × 152 × 15.9	42.2	5 390
L8 × 6 × 9/16	25.7	7.56	L203 × 152 × 14.3	38.1	4 880
L8 × 6 × 1/2	23.0	6.75	L203 × 152 × 12.7	34.1	4 350
L8 × 6 × 7/16	20.2	5.93	L203 × 152 × 11.1	29.9	3 830
L8 × 4 × 1	37.4	11.0	L203 × 102 × 25.4	55.4	7 100
L8 × 4 × 7/8	33.1	9.73	L203 × 102 × 22.2	49.3	6 280
L8 × 4 × 3/4	28.7	8.44	L203 × 102 × 19.0	42.5	5 450
L8 × 4 × 5/8	24.2	7.11	L203 × 102 × 15.9	36.0	4 590
L8 × 4 × 9/16	21.9	6.43	L203 × 102 × 14.3	32.4	4 150
L8 × 4 × 1/2	19.6	5.75	L203 × 102 × 12.7	29.0	3 710
L8 × 4 × 7/16	17.2	5.06	L203 × 102 × 11.1	25.6	3 260
L7 × 4 × 3/4	26.2	7.69	L178 × 102 × 19.0	38.8	4 960
L7 × 4 × 5/8	22.1	6.48	L178 × 102 × 15.9	32.7	4 180
L7 × 4 × 1/2	17.9	5.25	L178 × 102 × 12.7	26.5	3 390
L7 × 4 × 7/16	15.7	4.62	L178 × 102 × 11.1	23.4	2 980
L7 × 4 × 3/8	13.6	3.98	L178 × 102 × 9.5	20.2	2 570
L6 × 4 × 7/8	27.2	7.98	L152 × 102 × 22.2	40.3	5 150
L6 × 4 × 3/4	23.6	6.94	L152 × 102 × 19.0	35.0	4 480
L6 × 4 × 5/8	20.0	5.86	L152 × 102 × 15.9	29.6	3 780
L6 × 4 × 9/16	18.1	5.31	L152 × 102 × 14.3	26.8	3 430
L6 × 4 × 1/2	16.2	4.75	L152 × 102 × 12.7	24.0	3 060
L6 × 4 × 7/16	14.3	4.18	L152 × 102 × 11.1	21.2	2 700
L6 × 4 × 3/8	12.3	3.61	L152 × 102 × 9.5	18.2	2 330
L6 × 4 × 5/16	10.3	3.03	L152 × 102 × 7.9	15.3	1 950
L6 × 3 1/2 × 1/2	15.3	4.50	L152 × 89 × 12.7	22.7	2 900
L6 × 3 1/2 × 3/8	11.7	3.42	L152 × 89 × 9.5	17.3	2 210
L6 × 3 1/2 × 5/16	9.80	2.87	L152 × 89 × 7.9	14.5	1 850
L5 × 3 1/2 × 3/4	19.8	5.81	L127 × 89 × 19.0	29.3	3 750
L5 × 3 1/2 × 5/8	16.8	4.92	L127 × 89 × 15.9	24.9	3 170
L5 × 3 1/2 × 1/2	13.6	4.00	L127 × 89 × 12.7	20.2	2 580
L5 × 3 1/2 × 3/8	10.4	3.05	L127 × 89 × 9.5	15.4	1 970
L5 × 3 1/2 × 5/16	8.70	2.56	L127 × 89 × 7.9	12.9	1 650
L5 × 3 1/2 × 1/4	7.00	2.06	L127 × 89 × 6.4	10.4	1 330
L5 × 3 × 1/2	12.8	3.75	L127 × 76 × 12.7	19.0	2 420
L5 × 3 × 7/16	11.3	3.31	L127 × 76 × 11.1	16.7	2 140
L5 × 3 × 3/8	9.80	2.86	L127 × 76 × 9.5	14.5	1 850
L5 × 3 × 5/16	8.20	2.40	L127 × 76 × 7.9	12.1	1 550
L5 × 3 × 1/4	6.60	1.94	L127 × 76 × 6.4	9.8	1 250
L4 × 3 1/2 × 1/2	11.9	3.50	L102 × 89 × 12.7	17.6	2 260
L4 × 3 1/2 × 3/8	9.10	2.67	L102 × 89 × 9.5	13.5	1 720
L4 × 3 1/2 × 5/16	7.70	2.25	L102 × 89 × 7.9	11.4	1 450
L4 × 3 1/2 × 1/4	6.20	1.81	L102 × 89 × 6.4	9.2	1 170

TABLE A2.8 *Continued*

Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L4 × 3 × 5/8	13.6	3.98	L102 × 76 × 15.9	20.2	2 570
L4 × 3 × 1/2	11.1	3.25	L102 × 76 × 12.7	16.4	2 100
L4 × 3 × 3/8	8.50	2.48	L102 × 76 × 9.5	12.6	1 600
L4 × 3 × 5/16	7.20	2.09	L102 × 76 × 7.9	10.7	1 350
L4 × 3 × 1/4	5.80	1.69	L102 × 76 × 6.4	8.6	1 090
L3 1/2 × 3 × 1/2	10.2	3.00	L89 × 76 × 12.7	15.1	1 940
L3 1/2 × 3 × 7/16	9.10	2.65	L89 × 76 × 11.1	13.5	1 710
L3 1/2 × 3 × 3/8	7.90	2.30	L89 × 76 × 9.5	11.7	1 480
L3 1/2 × 3 × 5/16	6.60	1.93	L89 × 76 × 7.9	9.8	1 250
L3 1/2 × 3 × 1/4	5.40	1.56	L89 × 76 × 6.4	8.0	1 010
L3 1/2 × 2 1/2 × 1/2	9.40	2.75	L89 × 64 × 12.7	13.9	1 770
L3 1/2 × 2 1/2 × 3/8	7.20	2.11	L89 × 64 × 9.5	10.7	1 360
L3 1/2 × 2 1/2 × 5/16	6.10	1.78	L89 × 64 × 7.9	9.0	1 150
L3 1/2 × 2 1/2 × 1/4	4.90	1.44	L89 × 64 × 6.4	7.3	929
L3 × 2 1/2 × 1/2	8.50	2.50	L76 × 64 × 12.7	12.6	1 610
L3 × 2 1/2 × 7/16	7.60	2.21	L76 × 64 × 11.1	11.3	1 430
L3 × 2 1/2 × 3/8	6.60	1.92	L76 × 64 × 9.5	9.8	1 240
L3 × 2 1/2 × 5/16	5.60	1.62	L76 × 64 × 7.9	8.3	1 050
L3 × 2 1/2 × 1/4	4.50	1.31	L76 × 64 × 6.4	6.7	845
L3 × 2 1/2 × 3/16	3.39	0.996	L76 × 64 × 4.8	5.1	643
L3 × 2 × 1/2	7.70	2.25	L76 × 51 × 12.7	11.5	1 450
L3 × 2 × 3/8	5.90	1.73	L76 × 51 × 9.5	8.8	1 120
L3 × 2 × 5/16	5.00	1.46	L76 × 51 × 7.9	7.4	942
L3 × 2 × 1/4	4.10	1.19	L76 × 51 × 6.4	6.1	768
L3 × 2 × 3/16	3.07	0.902	L76 × 51 × 4.8	4.6	582
L2 1/2 × 2 × 3/8	5.30	1.55	L64 × 51 × 9.5	7.9	1 000
L2 1/2 × 2 × 5/16	4.50	1.31	L64 × 51 × 7.9	6.7	845
L2 1/2 × 2 × 1/4	3.62	1.06	L64 × 51 × 6.4	5.4	684
L2 1/2 × 2 × 3/16	2.75	0.809	L64 × 51 × 4.8	4.2	522
L2 1/2 × 1 1/2 × 1/4	3.19	0.938	L64 × 38 × 6.4	4.8	605
L2 1/2 × 1 1/2 × 3/16	2.44	0.715	L64 × 38 × 4.8	3.6	461
L2 × 1 1/2 × 1/4	2.77	0.813	L51 × 38 × 6.4	4.2	525
L2 × 1 1/2 × 3/16	2.12	0.621	L51 × 38 × 4.8	3.1	401
L2 × 1 1/2 × 1/8	1.44	0.422	L51 × 38 × 3.2	2.1	272

APPENDIXES

(Nonmandatory Information)

X1. COIL AS A SOURCE OF STRUCTURAL PRODUCTS

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, such temperatures are higher as the steel thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The differ-

ence in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength with increased percent elongation for the steel with slower cooling rates from the coiling temperature to ambient. Such differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

X2. VARIATION OF TENSILE PROPERTIES IN PLATES AND SHAPES

X2.1 The tension testing requirements of this specification are intended only to characterize the tensile properties of a heat of steel for determination of conformance to the requirements of the applicable product specification. Such testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a heat of steel. It is well known and documented that tensile properties will vary within a heat or individual piece of steel as a function of chemical composition, processing, testing procedure and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results shown on mill test reports. The testing procedures of this specification have been found to provide structural products adequate for normal structural design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was conducted by the American Iron and Steel Institute (AISI). The results of this survey are contained in a *Contributions to the Metallurgy of Steel* entitled “The Variation of Product Analysis and Tensile Properties—Carbon Steel Plates and Wide Flange Shapes” (SU/18, SU/19 and SU/20), published in September 1974. The data are presented in tables of probability that tensile properties at other than the official location may differ from those of the reported test location. Another survey sponsored by the AISI entitled “Statistical Analysis of Structural Plate Mechanical Properties” was published in January

2003. That survey analyzed the results of variability testing on more modern as-rolled steels that were generally of higher minimum yield strength steels and also compared those results statistically to the previous surveys.

X2.3 This specification contains no requirements applicable to product tension tests; conformance to the applicable product specification is determined on the basis of tests performed at the place of manufacture or processing prior to shipment, unless otherwise specified.

X2.4 A task group of ASTM Subcommittee A01.02 has determined, based on review of the earlier AISI data, that the variation in tensile properties of plates and structural shapes can be expressed as a function of specified requirements: one standard deviation equals approximately 4 % of required tensile strength, 8 % of required yield strength, and 3 percentage points of required elongation. The January 2003 survey resulted in similar findings.

X2.5 Acceptance criteria for product testing based upon these values, either below the minimum or above the maximum allowed by the applicable product specification, are generally acceptable to manufacturers. Such tolerances could be considered by users of structural products as a reasonable basis for acceptance of structural products that, due to their inherent variability, deviate from the applicable product specification requirements when subjected to product tension testing.

X3. WELDABILITY OF STEEL

X3.1 *Weldability* is a term that usually refers to the relative ease with which a metal can be welded using conventional practice. Difficulties arise in steel when the cooling rates associated with weld thermal cycles produce microstructures (for example, martensite) that are susceptible to brittle fracture or, more commonly, hydrogen-induced (or cold) cracking. (Solidification or hot cracking is a relatively rare phenomenon that will not be addressed here. See Randall for further information.)

X3.2 The relative sensitivity of steels to forming cold cracking microstructures is called hardenability and can be measured in a number of ways. Perhaps the most popular method of assessing this is by the carbon equivalent (CE) formula, which attempts to equate the relative hardening contributions of a steel’s constituent elements (for example,

manganese, vanadium) to an equivalent amount of carbon, which is the most significant hardening agent. The most popular formula is the International Institute of Welding (IIW) equation presented in S31.2, which has been found suitable for predicting hardenability in a wide range of commonly used carbon-manganese and low alloy steels.

X3.3 It should be noted, however, that for the current generation of low carbon (<0.10 %) low alloy steels that derive strength from a combination of microalloys and thermal processing methods the use of other formulae may more accurately assess hardenability and cold cracking sensitivity.¹³

X3.4 For a vast number of common structural applications it is unnecessary to specify the use of CE limits. However, in

order to obtain a higher level of confidence in avoiding cold cracking, the chemistry controls in S31 are available. A purchaser who specifies the use of S31 should be aware that there are several factors involved in the judicious selection of a maximum CE value, such as the following:

X3.4.1 Actual production joint restraint/base metal thickness(es),

X3.4.2 Filler metal and base metal strength compatibility,

X3.4.3 Deposited weld metal diffusible hydrogen content,

X3.4.4 Preheat and interpass temperatures,

X3.4.5 Filler metal and base metal cleanliness, and

X3.4.6 Heat input.

X3.5 Though it is widely believed that low CE steels are immune to weld cracking problems, failure to consider these factors and others have resulted in weld or base metal HAZ (heat affected zone) cracks in such steels.

X3.6 It is important to note that carbon equivalence is only a qualitative assessment of potential welding problems, and should never be solely relied on to ensure weld integrity. The proper use of welding specifications, coupled with the knowledge of actual construction conditions, must also be used.

X4. RADIUS FOR COLD BENDING

X4.1 Suggested minimum inside bend radii for cold forming are referenced to Group Designations A to F inclusive as defined in Table X4.1. The suggested radii listed in Table X4.2 should be used as minimums in typical shop fabrication. Material that does not form satisfactorily when fabricated in accordance with Table X4.2 may be subject to rejection pending negotiation with the steel supplier. When tighter bends are required, the manufacturer should be consulted.

X4.2 The bend radius and the radius of the male die should be as liberal as the finished part will permit. The width across the shoulders of the female die should be at least eight times the plate thickness. Higher strength steels require larger die openings. The surface of the dies in the area of radius should be smooth.

X4.2.1 Since cracks in cold bending commonly originate from the outside edges, shear burrs and gas cut edges should be removed by grinding. Sharp corners on edges and on punched or gas cut holes should be removed by chamfering or grinding to a radius.

X4.2.2 If possible, parts should be formed such that the bend line is perpendicular to the direction of final rolling. If it is necessary to bend with the bend line parallel to the direction of final rolling, a more generous radius is suggested (1½ times applicable value given in Table X4.2 for bend lines perpendicular to the direction of rolling).

X4.3 References

X4.3.1 Holt, G.E., et al., "Minimum Cold Bend Radii Project—Final Report," Concurrent Technologies Corporation, January 27, 1997.

X4.3.2 Brockenbrough, R.L., "Fabrication Guidelines for Cold Bending," R.L. Brockenbrough & Associates, June 28, 1998.

TABLE X4.1 Group Designations for Cold Bending

Specification	Grade	Group Designation ^A
A36/A36M	^B	B
A131/A131M	A, B, D, CS and E	B
	A, B, D, CS and E (all cold flanging)	B
	AH32, DH32, EH32 and FH32	C
	AH36, DH36, EH36 and FH36	C
	AH40, DH40, EH40 and FH40	C
A242/A242M	^B	C
A283/A283M	A or B	A
	C or D	B
A514/A514M	any	F
A529/A529M	50 [345] or 55 [380]	C
A572/A572M	42 [290]	B
	50 [345]	C
	55 [380]	D
	60 [415] or 65 [450]	E
A573/A573M	58 [400] or 65 [450]	B
	70 [485]	C
A588/A588M	any	C
A633/A633M	any	B
A656/A656M	50 [345]	B
	60 [415]	D
	70 [485]	E
	80 [550] or 100 [690]	F
A678/A678M	A or B	C
	C or D	D
A709/A709M	36 [250]	B
	50 [345], 50W [345W] or HPS 50W [HPS 345W]	C
	HPS 70W [HPS 485W]	D
	HPS 100W [HPS 690W]	F
A710/A710M	A	F
A808/A808M	^B	C
A852/A852M	^B	D
A871/A871M	60 [415] or 65 [450]	E
A945/A945M	50 [345] or 65 [450]	B

^A Steels having a ratio of specified minimum tensile strength to specified minimum yield strength of 1.15 or less are in Group F; other steels are in Groups A to E inclusive, which are grouped on the basis of their having similar specified values for minimum elongation in 2 in. [50 mm].

^B Grade designations are not applicable for this specification.

TABLE X4.2 Suggested Minimum Inside Radii for Cold Bending^A

Group Designation ^B	Thickness (t), in. [mm]			
	Up to ¾ in. [20 mm]	Over ¾ in. [20 mm] To 1 [25 mm, incl]	Over 1 in. [25 mm] To 2 in. [50 mm], incl	Over 2 in. [50 mm]
A	1.5t	1.5t	1.5t	1.5t
B	1.5t	1.5t	1.5t	2.0t
C	1.5t	1.5t	2.0t	2.5t
D	1.5t	1.5t	2.5t	3.0t
E	1.5t	1.5t	3.0t	3.5t
F	1.75t	2.25t	4.5t	5.5t

^A Values are for bend lines perpendicular to the direction of final rolling. These radii apply when the precautions listed in X4.2 are followed. If bend lines are parallel to the direction of final rolling, multiply values by 1.5.

^B Steel specifications included in the group designations may not include the entire thickness range shown in this table.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR STEEL PLATES FOR PRESSURE VESSELS



SA-20/SA-20M



(Identical with ASTM Specification A20/A20M-18.)

Standard Specification for General Requirements for Steel Plates for Pressure Vessels

1. Scope

1.1 This general requirements specification covers a group of common requirements that, unless otherwise specified in the applicable product specification, apply to rolled steel plates for pressure vessels covered by each of the following product specifications issued by ASTM:

Title of Specification	ASTM Designation ⁴
Pressure Vessel Plates, Alloy Steel, Nickel	A203/A203M
Pressure Vessel Plates, Alloy Steel, Molybdenum	A204/A204M
Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel	A225/A225M
Stainless Chromium Steel-Clad Plate	A263
Stainless Chromium-Nickel Steel-Clad Plate	A264
Nickel and Nickel-Base Alloy-Clad Steel Plate	A265
Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength	A285/A285M
Pressure Vessel Plates, Carbon Steel, Manganese-Silicon	A299/A299M
Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	A302/A302M
Pressure Vessel Plates, Alloy Steel, Double-Normalized and Tempered 9 % Nickel	A353/A353M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum	A387/A387M
Pressure Vessel Plates, Carbon Steel, High Strength Manganese	A455/A455M
Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service	A515/A515M
Pressure Vessel Plates, Carbon Steel, Moderate- and Lower-Temperature Service	A516/A516M
Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered	A517/A517M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	A533/A533M

Title of Specification	ASTM Designation ⁴
Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel	A537/A537M
Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium	A542/A542M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum	A543/A543M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 7, 8, and 9 % Nickel	A553/A553M
Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings	A562/A562M
Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service	A612/A612M
Pressure Vessel Plates, 5 % and 5½ % Nickel Alloy Steels, Specially Heat Treated	A645/A645M
Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	A662/A662M
Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, Quenched and Tempered, for Welded Pressure Vessels	A724/A724M
Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium (Niobium) Alloy Steel	A736/A736M
Pressure Vessel Plates, High-Strength Low-Alloy Steel	A737/A737M
Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	A738/A738M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium	A832/A832M
Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Control Process (TMCP)	A841/A841M
Steel Plates, 9 % Nickel Alloy, for Pressure Vessels, Produced by the Direct-Quenching Process	A844/A844M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten	A1017/A1017M

⁴ These designations refer to the latest issue of the respective specification which appears in the *Annual Book of ASTM Standards*, Vol 01.04.

1.1.1 This general requirements specification also covers a group of supplementary requirements that are applicable to several of the above product specifications as indicated therein. Such requirements are provided for use if additional testing or additional restrictions are required by the purchaser, and apply only if specified individually in the purchase order.

1.2 Appendix X1 provides information on coil as a source of plates for pressure vessels.

1.3 Appendix X2 provides information on the variability of tensile properties in plates for pressure vessels.

1.4 Appendix X3 provides information on the variability of Charpy-V-Notch impact test properties in plates for pressure vessels.

1.5 Appendix X4 provides information on cold bending of plates, including suggested minimum inside radii for cold bending.

1.6 These materials are intended to be suitable for fusion welding. When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized.

1.7 In case of any conflict in requirements, the requirements of the applicable product specification prevail over those of this general requirements specification.

1.8 Additional requirements that are specified in the purchase order and accepted by the supplier are permitted, provided that such requirements do not negate any of the requirements of this general requirements specification or the applicable product specification.

1.9 For purposes of determining conformance with this general requirements specification and the applicable product specification, values are to be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E29.

1.10 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.11 This general requirements specification and the applicable product specification are expressed in both inch-pound units and SI units; unless the order specifies the applicable “M” specification designation (SI units), the plates are to be furnished to inch-pound units.

1.12 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

- A203/A203M Specification for Pressure Vessel Plates, Alloy Steel, Nickel
- A204/A204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum
- A225/A225M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel
- A263 Specification for Stainless Chromium Steel-Clad Plate
- A264 Specification for Stainless Chromium-Nickel Steel-Clad Plate
- A265 Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate

- A285/A285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
- A299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
- A302/A302M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
- A353/A353M Specification for Pressure Vessel Plates, Alloy Steel, Double-Normalized and Tempered 9 % Nickel
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A387/A387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
- A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- A455/A455M Specification for Pressure Vessel Plates, Carbon Steel, High-Strength Manganese
- A515/A515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
- A516/A516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
- A517/A517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
- A533/A533M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
- A537/A537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
- A542/A542M Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium
- A543/A543M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum
- A553/A553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 7, 8, and 9 % Nickel
- A562/A562M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings
- A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
- A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- A612/A612M Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service
- A645/A645M Specification for Pressure Vessel Plates, 5 % and 5½ % Nickel Alloy Steels, Specially Heat Treated
- A662/A662M Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service
- A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
- A724/A724M Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, Quenched and Tempered, for Welded Pressure Vessels

A736/A736M Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium (Niobium) Alloy Steel

A737/A737M Specification for Pressure Vessel Plates, High-Strength, Low-Alloy Steel

A738/A738M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A770/A770M Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications

A832/A832M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium

A841/A841M Specification for Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Control Process (TMCP)

A844/A844M Specification for Steel Plates, 9 % Nickel Alloy, for Pressure Vessels, Produced by the Direct-Quenching Process

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A1017/A1017M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten

E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E112 Test Methods for Determining Average Grain Size

E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E709 Guide for Magnetic Particle Testing

2.2 *American Society of Mechanical Engineers Code:*
ASME Boiler and Pressure Vessel Code, Section IX

2.3 *U.S. Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.4 *Automotive Industry Action Group Standard:*
B 1 Bar Code Symbology Standard

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *as-rolled*—for plates, the condition of a plate that has been hot-rolled and will not be or has not yet been heat treated.

3.1.1.1 *Discussion*—The term *as-rolled* by itself is not meant to refer to plates that have been hot-rolled using control-rolling (CR), direct quench (DQT), thermo-mechanical control rolling (TMCP), recrystallization control rolling (RCR), or any similar methods that are intended to produce a set of properties that are not normally achievable were they not employed. The term *as-rolled* is to be distinguished from the established term

plate-as-rolled that does not define the actual condition of a plate, but defines the singular product of a slab or ingot that has been hot-rolled

3.1.2 *coil*—hot-rolled steel in coil form for processing into finished plates.

3.1.3 *exclusive*—when used in relation to ranges, as for ranges of thicknesses in the tables of permissible variations in dimensions, the term is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 1800 mm] *exclusive* includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].

3.1.4 *heat treatment terms*—see 3.1.10, and Terminology A941.

3.1.5 *hot forming*—a forming operation producing permanent deformation, performed after the plate has been heated to the temperature required to produce grain refinement.

3.1.6 *hot-rolled (hot rolling)*—for plates, the process described for a plate that has been rolled from a slab or ingot whose starting temperature is suitably above the recrystallization temperature of the metal to be rolled.

3.1.6.1 *Discussion*—Hot-rolled may be used in conjunction with any rolling process to more effectively describe a specific condition, for example; hot-rolled as-rolled; hot-rolled control-rolled, etc.

3.1.7 *manufacturer*—the organization that directly controls the conversion of steel ingots or slabs, by hot rolling, into plate-as-rolled or into coil; and for plates produced from plate-as-rolled, the organization that directly controls, or is responsible for, one or more of the operations involved in finishing the plates. Such finishing operations include leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.7.1 *Discussion*—The finishing operations need not be done by the organization that did the hot rolling of the plate. For plates produced from coil, see also 3.1.2.

3.1.8 *plate identifier*—the alpha, numeric, or alphanumeric designation used to identify the plate.

3.1.9 *plates*—flat hot-rolled steel, ordered to thickness or weight and typically to width and length, commonly available by size as follows:

Width, in. [mm]	Thickness, in. [mm]
Over 8 [200]	over 0.229 [6.0 mm and over]
Over 48 [1200]	over 0.179 [4.6 mm and over]

3.1.9.1 *Discussion*—Steel plates are available in various thickness, width, and length combinations dependent upon equipment and processing capabilities of various manufacturers and processors. Historic limitations of a plate based upon dimensions (thickness, width, and length) do not take into account current production and processing capabilities. To qualify any plate to a particular product specification requires that all appropriate and necessary tests be performed and that the results meet the limits prescribed in that product specification. If the necessary tests required by a product specification can not be conducted, the plate can not be qualified to that specification. This general requirements specification contains

permitted variations for the commonly available sizes. Permitted variations for other sizes are subject to agreement between the purchaser and the manufacturer or processor, whichever is applicable.

3.1.10 *precipitation heat treatment*—a subcritical temperature thermal treatment performed to cause precipitation of submicroscopic constituents, and so forth, to result in enhancement of some desirable property.

3.1.11 *processor*—the organization that directly controls, or is responsible for, operations involved in the processing of coil into finished plates. Such processing operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.11.1 *Discussion*—The processing operations need not be done by the organization that did the hot rolling of the coil. If only one organization is involved in the hot rolling and processing operations, that organization is termed the *manufacturer* for the hot rolling operation and the *processor* for the processing operations. If more than one organization is involved in the hot rolling and processing operations, the organization that did the hot rolling is termed the *manufacturer* and the organization that does one or more processing operations is termed a *processor*.

3.2 Refer to Terminology A941 for additional terms used in this standard.

4. Ordering Information

4.1 Orders should include the following information, as necessary, to adequately describe the desired product.

4.1.1 Quantity (weight [mass] or number of plates),

4.1.2 Dimensions,

4.1.3 Name of product (for example, plates, carbon steel; plates, alloy steel),

4.1.4 Specification designation (including type, class, and grade as applicable) and year-date,

4.1.5 Condition (as-rolled, normalized, quenched and tempered, etc. If heat treatment of plate is to be performed by the fabricator, this is to be stated. Also, if purchaser specifies a heat-treatment cycle, this is to be stated),

4.1.6 Impact test requirements, if any (see Section 12). (For Charpy V-notch test, include test specimen orientation, testing temperature, and acceptance criteria. For drop-weight test, give testing temperature),

4.1.7 Exclusion of either plates produced from coil or plates produced from plate-as-rolled, if applicable. (See 5.4 and Appendix X1.)

4.1.8 Limits for grain refining elements other than aluminum, if applicable (see 8.3.2),

4.1.9 Paint marking (see 13.2.1),

4.1.10 Supplementary requirements, if any (test specimen heat treatment, special impact test requirements, etc.), and

4.1.11 Additional requirements, if any.

5. Materials and Manufacture

5.1 The steel shall be made in an open-hearth, basic-oxygen, or electric-arc furnace, possibly followed by additional refining in a ladle metallurgy furnace (LMF), or by another method; or

secondary melting by vacuum-arc remelting (VAR), electroslag remelting (ESR), or another method.

5.2 The steel may be strand cast or cast in stationary molds.

5.2.1 *Strand Cast Slabs*:

5.2.1.1 If heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product (slab) may remain unchanged until all of the steel in the slab is from the following heat.

5.2.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The ratio of reduction of thickness from a strand-cast slab to plate shall be at least 3.0:1, except that reduction ratios as low as 2.0:1 are permitted if all of the following limitations are met:

5.3.1 The purchaser agrees to the use of such reduction ratios.

5.3.2 The applicable product specification is A299/A299M, A515/A515M, A516/A516M, A537/A537M, A662/A662M, or A737/A737M.

5.3.3 The specified plate thickness is 3.0 in. [75 mm] or more.

5.3.4 One or more of the following low hydrogen practices are used: vacuum degassing during steelmaking; controlled soaking of the slabs or plates; or controlled slow cooling of the slabs or plates.

5.3.5 The sulfur content is 0.004 % or less, based upon heat analysis.

5.3.6 One or more of the following practices are used: electromagnetic stirring during strand casting; soft reduction during strand casting; heavy pass reductions or other special practices during plate rolling; or combined forging and rolling during plate rolling.

5.3.7 The plates are ultrasonically examined in accordance with Specification A578/A578M, Level C based on continuous scanning over 100 % of the plate surface.

5.3.8 The plates are through-thickness tension tested in accordance with Specification A770/A770M.

5.4 Unless otherwise specified in the purchase order, plates shall be produced from plate-as-rolled or from coil.

5.5 Coils are excluded from qualification to the applicable product specification until they are decoiled, leveled, cut to length, and tested by the processor in accordance with the specified requirements (see Sections 9, 10, 11, 12, 13, 14, 15, 16, and 20.)

5.5.1 Plates produced from coil shall not contain splice welds, unless approved by the purchaser.

6. Heat Treatment

6.1 If plates are required to be heat treated, the heat treatment shall be performed by the manufacturer, the processor, or the fabricator, unless otherwise specified in the applicable product specification.

6.2 If the heat treatment required by the applicable product specification is to be performed by the purchaser or the purchaser's agent, and the plates are to be supplied by the

manufacturer or processor in a condition other than that required by the applicable product specification, the order shall so state.

6.2.1 If plates are ordered without the heat treatment required by the applicable product specification, heat treatment of the plates to conform to the requirements of the applicable product specification shall be the responsibility of the purchaser.

6.3 If heat treatment is to be performed, the plates shall be heat treated as specified in the applicable product specification. The purchaser may specify the heat treatment to be used, provided it is not in conflict with the requirements of the applicable product specification.

6.4 If normalizing is to be performed by the fabricator, the plates shall be either normalized or heated uniformly for hot forming, provided that the temperature to which the plates are heated for hot forming does not significantly exceed the normalizing temperature.

6.5 If no heat treatment is required, the manufacturer or processor shall have the option of heat treating the plates by normalizing, stress relieving, or normalizing and then stress relieving to meet the requirements of the applicable product specification.

6.6 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible to achieve specified mechanical properties, provided that the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

7. Chemical Composition

7.1 Heat Analysis:

7.1.1 Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

7.1.2 For each heat, the heat analysis shall include determination of the content of carbon, manganese, phosphorus, sulfur, silicon, nickel, chromium, molybdenum, copper, vanadium, columbium (niobium); any other element that is specified or restricted by the applicable product specification for the applicable grade, class, and type; aluminum, if the aluminum content is to be used in place of austenitic grain size testing of the heat (see 8.3.2.1); and any other austenitic grain refining element for which limits are specified in the purchase order (see 8.3.2).

7.1.3 Heat analyses shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type. In addition, for elements that are listed in Table 1 but are not specified or restricted in the applicable product specification for the applicable grade, class, and type, heat analyses shall conform to the applicable heat analysis limits given in Table 1.

7.2 Product Analysis:

7.2.1 Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

7.2.2 For each plate-as-rolled, the purchaser shall have the option of chemically analyzing a broken tension test specimen

TABLE 1 Limits on Elements (see 7.1.3 and 7.2.4)

Copper, max % ^A	Heat analysis	0.40
	Product analysis	0.43
Nickel, max % ^A	Heat analysis	0.40
	Product analysis	0.43
Chromium, max % ^{A,B}	Heat analysis	0.30
	Product analysis	0.34
Molybdenum, max % ^{A,B}	Heat analysis	0.12
	Product analysis	0.13
Vanadium, max % ^C	Heat analysis	0.03
	Product analysis	0.04
Columbium (Niobium), ^D max % ^E	Heat analysis	0.02
	Product analysis	0.03
Titanium, max % ^F	Heat analysis	0.03
	Product analysis	0.04
Boron, max %	Heat analysis	0.0010
	Product analysis	0.0015

^A In addition for each heat, based upon the heat analysis, the sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00 %, unless one or more of those elements are specified or restricted by the applicable product specification for the applicable grade, class, and type.

^B In addition for each heat, based upon the heat analysis, the sum of chromium and molybdenum shall not exceed 0.32 %, unless one or both of those elements are specified or restricted by the applicable product specification for the applicable grade, class, and type.

^C By agreement between the purchaser and the supplier, the heat analysis limit for vanadium is permitted to be increased to a value not higher than 0.10 %, and the product analysis limit for vanadium is permitted to be increased to a value not higher than 0.11 %.

^D Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

^E By agreement between the purchaser and the supplier, the heat analysis limit for columbium (niobium) is permitted to be increased to a value not higher than 0.05 %, and the product analysis limit for columbium (niobium) is permitted to be increased to a value not higher than 0.06 %.

^F By agreement between the purchaser and the supplier, the heat analysis limit for titanium is permitted to be increased to a value not higher than 0.04 %, and the product analysis limit for titanium is permitted to be increased to a value not higher than 0.05 %.

or a sample taken from the same relative location as that from which the tension test specimen was obtained.

7.2.3 For elements that are specified or restricted by the applicable product specification for the applicable grade, class, and type, product analyses shall conform to the product analysis requirements of the applicable product specification for the applicable grade, class, and type.

7.2.4 For elements that are listed in Table 1 but are not specified or restricted by the applicable product specification for the applicable grade, class, and type, product analyses shall conform to the applicable product analysis limits given in Table 1.

7.3 *Referee Analysis*—For referee purposes, Test Methods, Practices, and Terminology A751 shall be used.

8. Metallurgical Structure

8.1 Where austenitic grain size testing is required, such testing shall be a McQuaid Ehn test in accordance with Test Methods E112 and at least 70 % of the grains in the area examined shall meet the specified grain size requirement.

8.2 *Coarse Austenitic Grain Size*—Where coarse austenitic grain size is specified one austenitic grain size test per heat shall be made and the grain size number so determined shall be in the range of 1 to 5 inclusive.

8.3 *Fine Austenitic Grain Size:*

8.3.1 Except as allowed in 8.3.2, and when fine austenitic grain size is specified, or when the producer elects to determine the grain size, one McQuaid Ehn test per heat shall be made and the austenitic grain size number so determined shall be 5 or higher, and the chemical requirements of 8.3.2 do not apply.

NOTE 1—Such austenitic grain size numbers may be achieved with lower contents of austenitic grain refining elements than 8.3.2 requires for austenitic grain size testing to be waived.

8.3.2 Unless testing for fine austenitic grain size is specified in the purchase order or the producer elects to test for fine austenitic grain size, the austenitic grain size test need not be made for any heat that has, by heat analysis, one or more of the following:

8.3.2.1 A total aluminum content of 0.020 % or more.

8.3.2.2 An acid soluble aluminum content of 0.015 % or more.

8.3.2.3 A content for an austenitic grain refining element that exceeds the minimum value agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived.

8.3.2.4 Contents for the combination of two or more austenitic grain refining elements that exceed the applicable minimum values agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived.

8.3.2.5 The analysis for the elements mentioned in 8.3.2.1, 8.3.2.2, 8.3.2.3, or 8.3.2.4 shall be included in the test report.

9. Quality

9.1 *General*—Plates shall be free of injurious defects and shall have a workmanlike finish.

9.2 *Surface Imperfections:*

9.2.1 For plates produced from plate-as-rolled, all injurious surface imperfections shall be removed by the manufacturer. For plates produced from coil, all injurious surface imperfections shall be removed by the processor.

9.2.1.1 Shallow imperfections shall be ground to sound metal; the ground area shall be well faired and the thickness of the ground plate shall not be reduced below the minimum thickness permitted.

9.2.1.2 All surface imperfections, the removal of which will reduce the plate thickness below the minimum thickness permitted, shall be cause for rejection of the plate, except that, by agreement with the purchaser, the metal so removed may be replaced with weld metal (see 9.4).

9.3 *Edge Imperfections:*

9.3.1 Laminar-type discontinuities 1 in. [25 mm] and less in length visible to the unaided eye on an edge of a plate as prepared for shipment by the manufacturer or processor are acceptable and do not require exploration.

9.3.2 All larger discontinuities shall be explored to determine their depth and extent. Discontinuities shall be considered continuous when located in the same plane within 5 % of the

plate thickness and separated by a distance less than the length of the smaller of two adjacent discontinuities.

9.3.3 Indications visible to the unaided eye on the cut edges of a plate as prepared for shipment by the manufacturer or processor shall not exceed the limits given in Columns 1 and 2 of Table A1.14 [A2.14].

9.3.4 Larger indications shall be removed by the manufacturer or processor by grinding, provided that the resultant cavity does not exceed the limits given in Columns 3 and 4 of Table A1.14 [A2.14].

9.3.5 Indications of greater magnitude shall be cause for rejection of the plate, except that, by agreement with the purchaser, the defects may be removed and replaced with weld metal (see 9.4).

9.3.6 Indications on the edges of a plate cut during the fabrication shall be cause for rejection of the plate at the discretion of the purchaser if the magnitude exceeds the limits given in Columns 5 and 6 of Table A1.14 [A2.14]. The defects may be removed and replaced with weld metal (see 9.4).

9.3.7 Fabricators should be aware that edge cracks may initiate upon bending a sheared or burned edge during the fabrication process. This is not considered to be a fault of the steel, but is rather a function of the induced cold work or heat affected zone.

9.4 *Repair by Welding:*

9.4.1 Repair welding shall be permitted only with the approval of the purchaser.

9.4.2 Preparation for repair welding shall include inspection to confirm complete removal of the defect.

9.4.3 Repairs shall be made utilizing welding procedures qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code and repair welding shall be done by welders or welding operators meeting the qualification requirements of Section IX.

9.4.4 The weld metal shall have the A-number analysis corresponding to the equivalent ASME P-number of the plate, except that A-1 or A-2 analysis weld metal may be employed for P-1 plates. Other weld metals may be employed that are compatible with the plate being repaired, if so approved by the purchaser. Such weld metals shall be qualified in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

9.4.5 If Charpy impact tests of the plate are required, the welding procedure qualification tests shall also include Charpy impact tests of the weld, the heat-affected zone, and the plate, and the test results shall be reported to the purchaser.

9.4.6 If the plate is subjected to normalizing, quenching and tempering, hot forming, or post-weld heat treating, the welding procedure qualification test plates and the weld repaired plate shall be subjected to the thermal heat treatment as specified by the purchaser.

9.4.7 In addition, repair welds shall meet the requirements of the construction code specified by the purchaser.

10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A370.

10.2 Yield strength shall be determined by either the 0.2 % offset method or the 0.5 % extension under load method, unless otherwise stated in the applicable product specification.

10.3 *Rounding Procedures*—For purposes of determining conformance with the applicable product specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] for tensile and yield strengths, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values, in accordance with the rounding method given in Practice E29.

11. Tension Tests

11.1 Number of Test Coupons:

11.1.1 *Plates Produced from As-Rolled Plates*—For other than quenched and tempered plates, one tension test coupon shall be taken from each plate-as-rolled. Two tension test coupons shall be taken from each quenched and tempered plate, as heat treated. If plates are furnished by the manufacturer or processor in accordance with 11.4.2 and qualified by using test specimens taken from heat-treated test coupons (including normalized, normalized and tempered, and quenched and tempered), one tension test coupon shall be taken from each plate-as-rolled (see Terminology A941 for the definition of plate-as-rolled).

11.1.2 *Plates Produced from Coil and Furnished without Heat Treatment or with Stress Relieving Only*—Except as allowed by 11.1.2.1 and 11.1.4, a minimum of three tension coupons shall be taken from each coil as follows:

11.1.2.1 The first test coupon shall be taken immediately prior to the first plate to be qualified to the applicable product specification, the second test coupon shall be taken from the approximate center lap, and the third test coupon shall be taken immediately after the last plate to be qualified to the applicable product specification. If, during decoiling, the amount of material decoiled is less than that required to reach the next standard test location, a test for qualification of that particular portion of the coil shall be made from a test coupon taken from a location adjacent to the innermost portion decoiled.

11.1.2.2 All plates between any two test locations that meet the requirements of the applicable product specification are acceptable.

11.1.2.3 All plates between a test location that fails to meet the requirements of the applicable product specification and an adjacent test location that meets the requirements of the applicable product specification are rejectable, except that the processor has the option to make other tests after cutting back the coil in either direction.

11.1.3 *Plates Produced from Coil and Furnished Heat Treated by Other than Stress Relieving*—For other than quenched and tempered plates, one tension test coupon shall be taken from each coil. Two tension test coupons shall be taken from each quenched and tempered plate, as heat treated.

11.1.4 *Plates Produced from Coil and Qualified Using Test Specimens Taken from Test Coupons Heat Treated by Other than Stress Relieving*—One tension test coupon shall be taken from each coil.

11.2 *Orientation of Test Specimens*—The longitudinal axis of the tension test specimens shall be transverse to the final rolling direction of the plate.

11.3 *Location of Test Coupons*—Tension test coupons shall be taken from a corner of the plate. For quenched and tempered plates, the two tension test coupons shall be taken from opposite ends of the plate.

11.4 Tests from Heat-Treated Plates:

11.4.1 If heat treatment is performed by the manufacturer or processor, the test specimens shall be taken from the plate in the heat-treated condition or from full-thickness coupons simultaneously heat treated with the plate.

11.4.2 If heat treatment is to be performed by the fabricator, the plates shall be accepted on the basis of tests made on test specimens taken from full-thickness coupons heat treated in accordance with the requirements specified in the applicable product specification or the purchase order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the coupons under conditions it considers appropriate. The purchaser shall be informed of the procedure followed in heat treating the specimens.

11.4.3 If approved by the purchaser, the procedures of 11.4.2 may be implemented on plates heat treated by the manufacturer or processor, except that for plates that are quenched and tempered, all testing required the specification or the purchase order must be performed after plate heat treatment, in accordance with 11.1.1 and 11.4.4, and the results reported.

11.4.4 For plates that are heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.4.4.1 The gage length of the tension test specimen shall be taken at least $1T$ from any as-heat treated edge, where T is the thickness of the plate, and shall be at least $\frac{1}{2}$ in. [12.5 mm] from flame-cut or heat-affected-zone surfaces.

11.4.4.2 A steel thermal buffer pad, $1T$ by $1T$ by at least $3T$, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.4.4.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where the test specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.4.4.2.

11.4.4.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than $3T$ by $3T$ by T and each tension test specimen cut from it shall meet the requirements of 11.4.4.1.

11.4.4.5 If cooling rate data for the plate and cooling rate control devices for the test coupons are available, the test coupons may be heat treated separately in the device, provided that this method is approved by the purchaser.

11.5 Test Specimen Preparation:

11.5.1 Tension test specimens for plates $\frac{3}{4}$ in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements for either the

1½-in. [40-mm] wide or the ½-in. [12.5-mm] wide rectangular tension test specimen of Test Methods and Definitions A370. The 1½-in. [40-mm] wide test specimen may have both edges parallel. The ½-in. [12.5-mm] wide specimen may have a maximum nominal thickness of ¾ in. [20 mm].

11.5.2 For plates up to 4 in. [100 mm], inclusive, in thickness, tension test specimens may be the full thickness of the plate and conform to the requirements for the 1½-in. [40-mm] wide rectangular tension test specimen of Test Methods and Definitions A370 if adequate testing machine capacity is available.

11.5.3 For plates over ¾ in. [20 mm] in thickness, except as permitted in 11.5.2, tension test specimens shall conform to the requirements for the 0.500-in. [12.5-mm] diameter test specimen of Test Methods and Definitions A370. The axis of the test specimen shall be located midway between the center of thickness and the top or bottom surface of the plate.

11.6 Elongation Requirement Adjustments:

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin plate, adjustments in elongation requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in the applicable product specification:

Plate Nominal Thickness Range, in. [mm]	Elongation Deduction, %
0.299–0.311 [7.60–7.89]	0.5
0.286–0.298 [7.30–7.59]	1.0
0.273–0.285 [7.00–7.29]	1.5
0.259–0.272 [6.60–6.99]	2.0
0.246–0.258 [6.20–6.59]	2.5
0.233–0.245 [5.90–6.19]	3.0
0.219–0.232 [5.50–5.89]	3.5
0.206–0.218 [5.20–5.49]	4.0
0.193–0.205 [4.90–5.19]	4.5
less than 0.193 [4.90]	5.0

11.6.2 Due to the inherently lower elongation that is obtainable in thicker plate, adjustments in elongation requirements in 2-in. [50-mm] gage length shall be provided for thicknesses over 3.5 in. [90 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in 2 in. [50 mm] prescribed in the applicable product specification:

Plate Nominal Thickness Range, in. [mm]	Elongation Deduction, %
3.501–3.999 [90.00–102.49]	0.5
4.000–4.499 [102.50–114.99]	1.0
4.500–4.999 [115.00–127.49]	1.5
5.000–5.499 [127.50–139.99]	2.0
5.500–5.999 [140.0–152.49]	2.5
6.000 and thicker [152.50 and thicker]	3.0

11.6.3 A characteristic of certain types of alloy steels is a local disproportionate increase in the degree of necking down or contraction of the test specimens during the tension test, resulting in a decrease in the percentage of elongation as the gage length is increased. The effect is not so pronounced in thicker plates. For such material, if so stated in the applicable product specification for plates up to ¾ in. [20 mm], inclusive, in thickness, if the percentage of elongation of an 8-in. [200-mm] gage length test specimen falls not more than 3 percentage points below the amount prescribed, the elongation shall be considered satisfactory if the percentage of elongation in 2 in. [50 mm] across the break is not less than 25 %.

11.6.4 The tensile requirements tables in many of the product specifications covered by this general requirements specification specify elongation requirements in both 8-in. [200-mm] and 2-in. [50-mm] gage lengths. Unless otherwise provided in the applicable product specification, both requirements are not required to be applied simultaneously, and the elongation need only be determined in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

11.7 This specification does not provide requirements for product tension testing subsequent to shipment (see 15.1). Therefore, the requirements of 11.1 through 11.6 and Section 16 apply only for tests conducted at the place of manufacture prior to shipment. Compliance to Specification A20/20M and the applicable product specification does not preclude the possibility that product tension test results may vary outside specified ranges. The tensile properties will vary within the same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that tension testing in accordance with the requirements of Specification A20/A20M does not provide assurance that all products of a plate-as-rolled will be identical in tensile properties with the products tested. If the purchaser wishes to have more confidence than that provided by Specification A20/A20M testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

11.8 Appendix X2 provides additional information on the variability of tensile properties in plates for pressure vessels.

12. Notch-Toughness Tests

12.1 Charpy V-Notch Tests:

12.1.1 *Number of Tests*—Except for quenched and tempered plates, and except as allowed by 12.1.1.1 and 12.1.1.2, one impact test (3 specimens) for each specified orientation (see 12.1.2) shall be made from each plate-as-rolled. For quenched and tempered plates, one impact test shall be made from each plate, as heat treated.

12.1.1.1 *Plates Ordered Without the Heat Treatment Specified by the Applicable Product Specification*—Coupons for Charpy V-notch tests shall be taken in accordance with the same requirements as given for tensile test coupons in 11.4.2 and 11.4.3.

12.1.1.2 *Plates Produced from Coil*—If Charpy V-notch tests are specified, the number of impact tests required shall be the same as the number specified for tension tests in 11.1.2 or 11.1.3, whichever is applicable. The test coupons shall be taken from the material after decoiling and leveling.

12.1.2 *Orientation of Test Specimens*—The long axis of the test specimens shall be oriented either longitudinal (parallel to the final direction of rolling) or transverse (transverse to the final direction of rolling), as specified in the applicable product specification or the purchase order.

12.1.3 *Location of Test Coupons*—The impact test coupons shall be taken adjacent to the tension test coupons. The impact test coupons shall be subject to the same requirements as those specified for tension tests in 11.4, except that the provisions of

11.4.4.1 apply to the area under the notch of the impact test specimen instead of to the gage length of the tension test specimen.

12.1.4 *Test Method*—Impact testing shall be performed in accordance with Test Methods and Definitions A370 using Charpy V-notch (Type A) specimens as shown in Test Methods and Definitions A370. Except as allowed by 12.1.4.1, full-size specimens (0.394 by 0.394 in. [10 by 10 mm]) shall be used if the plate thickness permits, and their central axis shall correspond as near as practical to the $\frac{1}{4}t$ plane in the plate thickness t . If the plate thickness is insufficient to obtain full-size specimens, the largest possible subsize specimens shall be used.

12.1.4.1 For plates that normally have absorbed energy values in excess of 180 ft-lbf [245 J] if tested using full-size specimens at the specified testing temperature, subsize 0.394 by 0.264 in. [10 by 6.7 mm] specimens may be used in lieu of full-size specimens; however, if this option is used, the acceptance value shall be 75 ft-lbf [100 J] minimum for each test specimen and the lateral expansion in mils [micrometres] shall be reported.

12.1.5 *Test Temperature*—The test temperature shall be as specified in the purchase order, except that the manufacturer or processor shall have the option of using a lower test temperature. If a test temperature is not specified in the purchase order, tests shall be conducted at a temperature no higher than is given in Table A1.15 [A2.15] for the applicable product specification, grade, class, and plate thickness. The actual test temperature used shall be reported with the test results.

12.1.6 *Acceptance Criteria*—Unless otherwise agreed upon, the acceptance criteria shall be as given in Table A1.15 [A2.15] for the applicable product specification, grade, class, and plate thickness.

12.1.6.1 If the acceptance criteria is based upon energy absorption of a full-size specimen, the acceptance criteria for the various subsize specimens shall be as given in Table A1.16 [A2.16], except as otherwise provided in 12.1.4.1.

12.1.6.2 If the acceptance criterion is based upon lateral expansion opposite the notch, the acceptance value shall be the same for all sizes of test specimens.

12.1.7 *Marking*—The letters “LTV” shall be stenciled or stamped on each plate following the class number, grade, etc.

12.1.8 *Variability*—The impact properties of steel can vary within the same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that testing of one plate-as-rolled does not provide assurance that all locations within a plate-as-rolled will be identical in toughness with the location tested. Normalizing or quenching and tempering the product will reduce the degree of variation.

12.1.8.1 Appendix X3 provides additional information on the variability of Charpy V-notch test properties in plates for pressure vessels.

12.2 Drop-Weight Tests:

12.2.1 Where specified, one drop-weight test, consisting of a set of two test specimens, shall be made to the same frequency stated in 12.1.1 in accordance with Test Method E208.

12.2.2 The test coupons shall be obtained adjacent to a tension test coupon. For plates produced from coil, the test coupon locations shall be the same as for Charpy V-notch tests. (See 12.1.) The provisions of 12.1.3 shall also apply.

12.2.3 The testing temperature shall be as specified in the applicable product specification or the purchase order.

12.2.4 Acceptance shall be on the basis of *no-break* performance of both test specimens at the specified testing temperature.

12.2.5 The plates shall be marked as required in 12.1.7, except that the letters “LTD” shall be used instead of “LTV.”

13. Identification of Plates

13.1 Required Markings:

13.1.1 Except as allowed by 13.4, plates shall be legibly marked with the following information: applicable ASTM designation (see 1.1) (year of issue not required); “G” or “MT” if applicable (see 13.1.2); applicable grade, type, and class; heat number; plate identifier; and name, brand, or trademark of the manufacturer (for plates produced in discrete cut lengths of flat product) or the processor (for plates produced from coil and for subdivided plates (see 13.4)).

13.1.2 Plates that are required to be heat treated, but have not been so heat treated, shall be marked, by the manufacturer or processor, with the letter “G” (denoting green) following the required ASTM designation mark, except that “G” marking is not necessary if such plates are for shipment, for the purpose of obtaining the required heat treatment, to an organization under the manufacturer’s control. Plates that are required to be heat treated, and have been so heat treated, shall be marked, by the party that performed the heat treatment, with the letters “MT” (denoting material treated) following the required ASTM designation mark.

NOTE 2—Any stress relief of test specimens intended to simulate post-weld heat treatment is not included in the above heat treatment.

13.2 Types of Marking:

13.2.1 Except as allowed by 13.4, the required markings for plates over $\frac{1}{4}$ in. [6 mm] in thickness shall be by steel die stamping, unless paint marking is specified in the purchase order.

13.2.2 Except as allowed by 13.4, the required markings for plates $\frac{1}{4}$ in. [6 mm] and under in thickness shall be by paint marking or by steel die stamping using low-stress (either round-nose or interrupted-dot) impressions.

13.3 Location of Markings:

13.3.1 Except as allowed by 13.4, the required markings for plates with a maximum lengthwise or crosswise dimension more than 72 in. [1800 mm] shall be in at least two places on each finished plate, at least 12 in. [300 mm] from the edges of the plate.

13.3.2 Except as allowed by 13.4, the required markings for plates with a maximum lengthwise and crosswise dimension of 72 in. [1800 mm] or less shall be in at least one place on each finished plate, approximately midway between the center and an edge of the plate.

13.4 Subdivided Plates:

13.4.1 By agreement between the purchaser and the manufacturer or processor, each subdivided plate (a plate separated

from a master plate) shall be legibly marked with the name, brand, or trademark of the organization that subdivided the plate plus a code traceable to the required markings, provided that the information required in 13.1, cross referenced to that code, is furnished with the plates.

13.4.2 By agreement between the purchaser and the manufacturer or processor, subdivided plates that are from the same master plate and placed in secured lifts shall have the information required in 13.1 paint marked on the top piece of each lift or shown on a substantial tag attached to each lift.

13.5 *Bar Coding*—In addition to the requirements of 13.1 to 13.4 inclusive, the manufacturer or processor shall have the option of using bar coding as a supplementary identification method.

NOTE 3—Bar coding should be consistent with AIAG Standard B 1.

14. Permissible Variations in Dimensions or Mass

14.1 One cubic foot of rolled steel shall be assumed to weigh 490 lb, unless otherwise stated in the applicable product specification. One cubic metre of rolled steel is assumed to have a mass of 7850 kg, unless otherwise stated in the applicable product specification.

14.2 For carbon steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex A1, Table A1.1 to Table A1.9, and Table A1.13 [Annex A2, Table A2.1 to Table A2.9, and Table A2.13].

14.3 For alloy steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex 1, Table A1.1 to Table A1.4, Table A1.8, and Table A1.10 to Table A1.13. [Annex 2, Table A2.1 to Table A2.4, Table A2.8 and Table A2.10 to Table A2.13].

14.4 *Conversions of Permitted Variations from Fractions of an Inch to Decimals*—Permitted variations in dimensions for products covered by this specification are generally given as fractions of inch and these remain the official permitted variations, where so stated. If the material is to be measured by equipment reporting dimensions as decimals, conversion of permitted variations from fractions of an inch to decimals shall be made to three decimal places; using the rounding method prescribed in Practice E29.

15. Inspection and Testing

15.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the plate ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the plate is being furnished in accordance with this general requirements specification, the applicable product specification, and the purchase order. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the manufacturer's works.

15.2 If plates are produced from coil, 15.1 shall apply to the "processor" instead of to the "manufacturer" and the "place of

process" shall apply instead of the "place of manufacture." If plates are produced from coil and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the plate ordered.

16. Retests

16.1 *Tension Test*—In addition to the provisions of Test Methods and Definitions A370, the following retest provisions shall apply:

16.1.1 If any test specimen shows defective machining, or develops flaws, it may be discarded and another test specimen substituted.

16.1.2 If the percentage of elongation of any tension test specimen is less than that specified, and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of the gage length of a 2-in. [50-mm] test specimen or is outside the middle half of the gage length of an 8-in. [200-mm] test specimen as indicated by scribe marks on the test specimen before testing, one retest shall be allowed.

16.1.3 If the results from an original tension test specimen fail to meet the specified requirements but are within 2 ksi [10 MPa] of the required tensile strength or within 1 ksi [5 MPa] of the required yield strength or yield point, or within 2 percentage points of the required elongation or reduction of area, one retest shall be permitted to replace the failing test.

16.1.4 The results of the retest shall meet the specified requirements.

16.2 Charpy V-Notch Tests:

16.2.1 The retest provisions of Test Methods and Definitions A370 shall apply, except that the 5 ft-lbf [7 J] absolute minimum for an individual specimen shall not apply if two thirds of the specified minimum average is less than 5 ft-lbf [7 J].

16.2.2 If Charpy V-notch impact test lateral expansion values are specified, if the value of one specimen falls below the specified minimum value and not below $\frac{2}{3}$ of the specified minimum value, and if the average of the three specimens equals or exceeds the specified minimum value, a retest of three additional specimens may be made. Each of the three retest specimens shall equal or exceed the specified minimum value.

16.2.3 If the required values are not obtained on Charpy V-notch retests as specified in 16.2.1 and 16.2.2, or if the values in the initial test are below the values required for retest, no further retests are permitted unless the plate is heat treated or reheat treated. After heat treatment or reheat treatment, a set of three specimens shall be tested and each shall equal or exceed the specified minimum value.

16.2.4 If the option of 12.1.4.1 is used and the test result falls below the 75 ft-lbf [100 J] minimum specified, another test may be made using full-size test specimens.

17. Retreatment

17.1 If any heat-treated plate fails to meet the mechanical requirements of the applicable product specification, the manufacturer or processor shall have the option of heat treating

the plate again. All mechanical-property tests shall be repeated and the plate surface shall be reexamined for surface defects when it is resubmitted for inspection.

18. Rejection

18.1 Any rejection based upon product analysis made in accordance with the applicable product specification shall be reported to the supplier and samples that represent the rejected plate shall be preserved for 2 weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier shall have the option of making claim for a rehearing within that time.

18.2 Plates that show injurious defects subsequent to their acceptance at the manufacturer's or processor's works may be rejected. In such cases, the manufacturer or processor shall be notified.

19. Test Reports

19.1 The manufacturer or processor shall report the results of all tests required by the applicable product specification, the applicable supplementary requirements, and the purchase order. The heat number, the plate identifier of the plate tested, and the nominal plate thickness shall be shown on the test report. The year-date of the specification to which the plates are furnished shall be included in the test report.

19.1.1 In reporting elongation values, both the percentage increase and the original gage length shall be stated.

19.2 For plates rolled from a strand-cast slab with a reduction ratio in the range from 2.0:1 to 3.0:1, exclusive, the specific practices (see 5.3.4 and 5.3.6) that were used by the manufacturer shall be reported, and the test reports shall state that the limitations of 5.3 have been met.

19.3 All heat treatment, exclusive of subcritical heating to soften thermally cut edges, shall be reported, including temperature ranges and times at temperature. This exclusion does not apply to those plates with specified minimum tensile strengths of 95 ksi [655 MPa] or higher, unless such subcritical heating is accomplished at temperatures at least 75°F [40°C] below the minimum tempering temperature. The reports shall state whether the plates only, the test coupons only, or both plates and test coupons were heat treated.

19.4 If Charpy V-notch tests are specified, the test specimen size used shall be reported.

19.5 If so specified in the purchaser order, the manufacturer shall also furnish a certificate of compliance stating that the plates have been manufactured, inspected, and tested in accor-

dance with the requirements of the applicable product specification. For plates produced from coil, the processor shall furnish the required certification.

19.6 For plates produced from coil and furnished without heat treatment or with stress relieving only, the results of all tests required by 11.1.2 shall be reported for each qualifying coil.

19.7 Plates that are required to be heat treated, but have not been so heat treated, shall be certified by the responsible manufacturer on the basis of tests made on heat treated coupons and such tests shall be made and reported. For plates where the heat treatment of the coupons consists of quench and tempering, the manufacturer or processor responsible for the heat treatment of the plate shall repeat any required mechanical tests after plate heat treatment and they shall be the basis for final certification of the plate.

19.8 A signature is not required on the test report; however, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

19.9 Copies of the original manufacturer's test report shall be included with any subsequent test report.

19.10 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

20. Packaging, Marking, and Loading for Shipment

20.1 Packaging, marking, and loading for shipment shall be in accordance with those procedures recommended by Guide A700.

20.2 *For USA Government Procurement*—Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

21. Keywords

21.1 general delivery requirement; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use if desired by the purchaser. Those that are considered suitable for use with a product specification are listed in the product specification. Other tests may be performed by agreement between the manufacturer or processor and the purchaser. These supplementary requirements shall apply only if specified in the purchase order, in which event the specified tests shall be made by the manufacturer or processor before shipment of the plates.

S1. Vacuum Treatment

S1.1 The steel shall be made by a process that includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

S2. Product Analysis

S2.1 A product analysis shall be made of each plate as rolled. The specimens for analysis shall be taken adjacent to or from a broken tension test specimen.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 Prior to testing, the test coupons representing the plate for acceptance purposes for mechanical properties shall be thermally treated to simulate a post-weld heat treatment below the critical temperature (A_{c3}), using the heat treatment parameters (such as temperature range, time, and cooling rates) specified in the purchase order. For tests using specimens taken from such heat treated test coupons, the test results shall meet the requirements of the applicable product specification.

S4. Additional Tension Test

S4.1 *Other Than Quenched-and-Tempered Plates*—In addition to the required single tension test, a second tension test shall be made using a test specimen taken from a test coupon taken from a corner of the plate-as-rolled on the end opposite the single test specimen and in a direction parallel to the single test specimen. The results obtained using this second test specimen shall meet the requirements of the applicable product specification.

S4.2 *Quenched-and-Tempered Plates 2 in. [50 mm] or Greater in Thickness*—In addition to the required tension tests, two additional test coupons shall be taken from the bottom corner of the plate. One shall be taken at the center of the plate thickness and the other immediately beneath the surface. Mandatory conformance of these additional tests with the specified properties shall be a matter of agreement between the manufacturer and the purchaser.

S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with 12.1.

S5.2 The orientation of the test specimens, whether longitudinal or transverse to the direction of rolling, shall be as specified in the purchase order.

S5.3 The test temperature and the required acceptance criteria, if other than those required in 12.1, shall be as specified in the purchase order.

S5.4 The recorded results shall include test specimen orientation, test specimen size, test temperature, absorbed energy values, and, if specified in the purchase order for other than Class VI plates, lateral expansion opposite the notch. The percent shear fracture appearance shall also be recorded if specified in the purchase order.

S6. Drop-Weight Test (for Plates 0.625 in. [16 mm] and Over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with the requirements of Test Method E208. The specimens shall represent the plates in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of plates to be tested and whether a maximum NDT temperature is mandatory or if the test results are for information only.

S7. High-Temperature Tension Tests

S7.1 A short-time elevated temperature tension test shall be made to represent each plate or each heat of steel as indicated by the purchaser. The specimens for testing shall be obtained as required for the room temperature tension tests specified in the body of this general requirements specification. The high-temperature tests shall be made in accordance with the requirements of Test Methods E21. Mandatory conformance of such additional tests with the specified properties shall be a matter for agreement between the manufacturer or processor and the purchaser.

S8. Ultrasonic Examination in Accordance with A435/A435M

S8.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A435/A435M.

S9. Magnetic Particle Examination

S9.1 All plate edges shall be examined by magnetic particles in accordance with the procedures covered in Guide E709. The acceptability of defects revealed by this examination shall be judged in accordance with the requirements for quality in 9.3.

S10. Charpy V-Notch Impact Transition Curve

S10.1 Sufficient impact tests of the same specimen size shall be made from the plate test material to establish a transition curve. The test temperature range shall be wide enough to establish the upper and lower shelf energies, with sufficient testing at intermediate temperatures to permit plotting a reasonable smooth curve. A plot of the data is not required. The

manufacturer shall report the specimen orientation, test temperature, and absorbed energy for each specimen tested. Lateral expansion and percent shear shall also be reported when specified in the purchase order. The number of plates tested and the specimen orientation shall be the same as in 12.1 unless otherwise specified in the purchase order.

S11. Ultrasonic Examination in Accordance with A577/A577M

S11.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A577/A577M.

S12. Ultrasonic Examination in Accordance with A578/A578M

S12.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A578/A578M. The acceptance level shall be as specified in the purchase order.

S13. NDT Temperature Determination

S13.1 The NDT temperature shall be established in accordance with Test Method E208 using coupons from a single plate. The number of plates to be so tested shall be subject to agreement between the purchaser and the manufacturer or processor.

S15. Reduction of Area Measurement

S15.1 A reduction of area measurement shall be taken while making the required tension test. Reduction of area shall be determined only on the 0.500-in. [12.5-mm] round specimen as shown in Fig. 5 of Test Methods and Definitions A370. The minimum acceptance limit shall be 40 %.

S16. Thermal Stress Relief of Mechanical Test Coupons

S16.1 Test coupons representing the plates shall be thermally stress relieved by gradually and uniformly heating them to a temperature between 1100 and 1200°F [595 and 650°C], or a temperature range otherwise agreed upon between the manufacturer or processor and the purchaser, holding at temperature for at least 1 h/in. [2.4 min/mm] of thickness and cooling in still air to a temperature not exceeding 600°F [315°C].

S17. Vacuum Carbon-Deoxidized Steel

S17.1 Material shall be vacuum carbon-deoxidized, in which case the silicon content at the time of vacuum deoxidizing shall be 0.12 % maximum, and the content of deoxidizers such as aluminum, zirconium, and titanium should be kept low enough to allow deoxidation by carbon. The test report shall indicate that the steel was vacuum carbon-deoxidized. The minimum heat analysis and product analysis requirements for silicon do not apply to vacuum carbon-deoxidized steel.

S19. Restricted Chemical Requirements

S19.1 Restricted heat analysis and product analysis limits are applicable, as specified in the purchase order.

S20. Maximum Carbon Equivalent for Weldability

S20.1 Plates shall be supplied with a specific maximum carbon equivalent value. This value shall be based upon the heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S20.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S20.3 The maximum value of the carbon equivalent for carbon steels (including C-Mn, C-Mn-Si, C-Mn-Si-Al steels), are given in Table S20.1.

S21. Restricted Limits on Elements

For each heat, based upon the heat analysis, the content shall not exceed 0.35 % for copper, 0.25 % for nickel, 0.25 % for chromium, 0.08 % for molybdenum, or 0.70 % for the sum of those four elements.

S22. Through-Thickness Tension Tests

S22.1 Through-thickness tension tests shall be made in accordance with the requirements of Specification A770/A770M. (See Ordering Information in Specification A770/A770M for the additional information that may be needed.)

S24. Strain Age Test

S24.1 Test coupons shall be given a strain age treatment designated by the purchaser. Charpy V-notch tests shall be conducted on the strain aged specimens. Heat treatment, strain aging, test temperature, and acceptance criteria shall be as agreed upon between the manufacturer or processor and the purchaser.

S25. Weldability

S25.1 Weldability tests shall be conducted. The type of test and the acceptance criteria shall be as agreed upon between the manufacturer or processor and the purchaser.

S26. Low-Sulfur Steels

S26.1 The steel shall be made to 0.010 % sulfur maximum. Lower sulfur levels and sulfide shape control practices can be specified by agreement between the manufacturer or processor and the purchaser.

TABLE S20.1 Maximum Carbon Equivalent for Weldability

Specified Minimum UTS ksi [MPa]	Maximum Carbon Equivalent Value	
	Thickness up to 2 in. [50 mm] incl	Thickness over 2 in. [50 mm]
60 ≤ UTS < 70 [415 ≤ UTS < 485]	0.45	0.46
70 ≤ UTS < 80 [485 ≤ UTS < 550]	0.47	0.48 ^A
UTS ≥ 80 [UTS ≥ 550]	0.48 ^{A,B}	...

^A If simulated PWHT of the test coupons is specified (S3), the maximum carbon equivalent value may be increased up to 0.50 upon agreement between purchaser and supplier.

^B Applicable to quenched-and-tempered material; for other conditions, maximum carbon equivalent shall be by agreement between purchaser and supplier.

S27. Restrictive Plate Flatness

S27.1 Carbon steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness given in Table S27.1 or Table S27.2.

S27.2 High-strength low-alloy steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness given in Table S27.3 or Table S27.4.

S28. Heat Treatment in the Working Zone of a Surveyed Furnace

S28.1 Plates shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A991/A991M, provided that such working zone was established using a variation of 25°F [15°C] or less from the furnace set point.

S28.2 The test report shall indicate that S28 applies.

TABLE S27.1 Permissible Variations from Flatness for Carbon Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed ¼ in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than ¼ in.

NOTE 4—The variations given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the permissible variations are 1½ times the amounts shown in the table below.

NOTE 5—This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 6—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 7—A “Z” indicates that there is no published restricted value for the size.

NOTE 8—Plates shall be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Permissible Variations from a Flat Surface for Specified Widths, in.					
	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, incl
To ¼, excl	¾	1 ⁵ / ₁₆	Z	Z	Z	Z
¼ to ⅜, excl	9/ ₁₆	¾	7/ ₈	1 ⁵ / ₁₆	1-1/ ₁₆	1-1/ ₈
⅜ to ½, excl	5/ ₁₆	5/ ₁₆	3/ ₈	7/ ₁₆	1/2	9/ ₁₆
½ to ¾, excl	5/ ₁₆	5/ ₁₆	5/ ₁₆	3/ ₈	1/2	1/2
¾ to 1, excl	5/ ₁₆	5/ ₁₆	5/ ₁₆	5/ ₁₆	3/ ₈	7/ ₁₆
1 to 2, incl	1/4	5/ ₁₆	5/ ₁₆	5/ ₁₆	5/ ₁₆	3/ ₈

TABLE S27.2 Permissible Variations from Flatness for Carbon Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4—The variations given in this table apply to plates that have a minimum specified tensile strength not over 415 MPa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the permissible variations are 1½ times the amounts shown in the table below.

NOTE 5—This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 6—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 7—A “Z” indicates that there is no published restricted value for the size.

NOTE 8—Plates shall be in horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Permissible Variations from a Flat Surface for Specified Widths, mm					
	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, incl
To 6, excl	18	24	Z	Z	Z	Z
6 to 10, excl	15	18	22	24	27	29
10 to 12, excl	8	8	10	11	13	15
12 to 20, excl	7	8	8	10	13	13
20 to 25, excl	7	8	8	8	10	11
25 to 50, excl	7	7	7	8	8	8

TABLE S27.3 Permissible Variations from Flatness for High-Strength Low-Alloy Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed ⅜ in. in each direction. When the larger dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width but in no case less than ⅜ in.

NOTE 4—This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 5—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 6—A “Z” indicates that there is no published restricted value for the size.

NOTE 7—Plates shall be in horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Permissible Variations from a Flat Surface for Specified Widths, in.					
	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, incl
To ¼, excl	1/16	1/16	Z	Z	Z	Z
¼ to ⅜, excl	7/16	1/16	15/16	17/16	1½	1 11/16
⅜ to ½, excl	½	½	9/16	11/16	¾	13/16
½ to ¾, excl	7/16	7/16	½	9/16	5/8	11/16
¾ to 1, excl	7/16	7/16	½	½	9/16	11/16
1 to 2, incl	3/8	7/16	7/16	½	½	½

TABLE S27.4 Permissible Variations from Flatness for High-Strength Low-Alloy Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 10 mm in each direction. When the larger dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 10 mm.

NOTE 4—This table and these notes cover the variations for flatness of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 5—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 6—A “Z” indicates that there is no published restricted value for the size.

NOTE 7—Plates shall in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Permissible Variations from a Flat Surface for Specified Widths, mm					
	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, incl
To 6, excl	27	36	Z	Z	Z	Z
6 to 10, excl	22	27	33	36	39	43
10 to 12, excl	12	12	15	17	19	21
12 to 20, excl	11	11	13	15	16	18
20 to 25, excl	11	11	12	13	15	17
25 to 50, excl	10	11	11	12	13	13

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC.—INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions, and notch toughness information, expressed in inch-pound units of measurement.

TABLE A1.1 Permissible Variations in Thickness for Rectangular Plates

NOTE 1—Permissible variation under specified thickness, 0.01 in. When so specified, these permitted variations may be taken all over, in which case the sum of these permitted variations applies.

NOTE 2—Thickness to be measured at 3/8 to 3/4 in. from the longitudinal edge.

NOTE 3—For thickness measured at any location other than that specified in Note 2, the permissible maximum over-tolerance shall be increased by 75 %, rounded to the nearest 0.01 in.

Specified Thickness, in.	Tolerance Over Specified Thickness for Widths Given, in.											
	48 and under	Over 48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 132, excl	132 to 144, excl	144 to 168, excl	168 to 182, excl	182 and over
To 1/4, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	...	...	...
1/4 to 5/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	...	...	...
5/16 to 3/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	...	...
3/8 to 7/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
7/16 to 1/2, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
1/2 to 5/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	...
5/8 to 3/4, excl	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.07
3/4 to 1, excl	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09
1 to 2, excl	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.10	0.11	0.13	0.16
2 to 3, excl	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.15	...
3 to 4, excl	0.11	0.11	0.11	0.11	0.11	0.13	0.14	0.14	0.14	0.15	0.17	...
4 to 6, excl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.20	...
6 to 10, excl	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.27	0.28	...
10 to 12, excl	0.29	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	...
12 to 15, incl	0.29	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	...

TABLE A1.2 Permissible Variations in Width and Length for Sheared Plates 1 1/2 in. and Under in Thickness; Length Only for Universal Mill Plates 2 1/2 in. and Under in Thickness

Specified Dimensions, in.		Permissible Variations over Specified Width and Length ^A for Thicknesses Given in inches, in.							
Length	Width	To 3/8, excl		3/8 to 5/8, excl		5/8 to 1, excl		1 to 2, incl ^B	
		Width	Length	Width	Length	Width	Length	Width	Length
To 120, excl	over 8 to 60, excl	3/8	1/2	7/16	5/8	1/2	3/4	5/8	1
	60 to 84, excl	7/16	5/8	1/2	11/16	5/8	7/8	3/4	1
	84 to 108, excl	1/2	3/4	5/8	7/8	3/4	1	1	1 1/8
120 to 240, excl	108 and over	5/8	3/4	3/4	1	7/8	1 1/8	1 1/8	1 1/4
	over 8 to 60, excl	3/8	3/4	1/2	7/8	5/8	1	3/4	1 1/8
	60 to 84, excl	1/2	3/4	5/8	7/8	3/4	1	7/8	1 1/4
240 to 360, excl	84 to 108, excl	9/16	7/8	11/16	1 1/16	1 3/16	1 1/8	1	1 3/8
	108 and over	5/8	1	3/4	1 1/8	7/8	1 1/4	1 1/8	1 3/8
	over 8 to 60, excl	3/8	1	1/2	1 1/8	5/8	1 1/4	3/4	1 1/2
360 to 480, excl	60 to 84, excl	1/2	1	5/8	1 1/8	3/4	1 1/4	7/8	1 1/2
	84 to 108, excl	9/16	1	11/16	1 1/8	7/8	1 3/8	1	1 1/2
	108 and over	1 1/16	1 1/8	7/8	1 1/4	1	1 3/8	1 1/4	1 3/4
480 to 600, excl	over 8 to 60, excl	7/16	1 1/8	1/2	1 1/4	5/8	1 3/8	3/4	1 5/8
	60 to 84, excl	1/2	1 1/4	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8
	84 to 108, excl	9/16	1 1/4	3/4	1 3/8	7/8	1 1/2	1	1 7/8
600 to 720, excl	108 and over	3/4	1 3/8	7/8	1 1/2	1	1 5/8	1 1/4	1 7/8
	over 8 to 60, excl	7/16	1 1/4	1/2	1 1/2	5/8	1 5/8	3/4	1 7/8
	60 to 84, excl	1/2	1 3/8	5/8	1 1/2	3/4	1 5/8	7/8	1 7/8
720 and over	84 to 108, excl	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8	1	1 7/8
	108 and over	3/4	1 1/2	7/8	1 5/8	1	1 3/4	1 1/4	1 7/8
	over 8 to 60, excl	1/2	1 3/4	5/8	1 7/8	3/4	1 7/8	7/8	2 1/4
60 to 84, excl	60 to 84, excl	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1	2 1/4
	84 to 108, excl	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1 1/8	2 1/4
	108 and over	7/8	1 3/4	1	2	1 1/8	2 1/4	1 1/4	2 1/2
over 8 to 60, excl	over 8 to 60, excl	9/16	2	3/4	2 1/8	7/8	2 1/4	1	2 3/4
	60 to 84, excl	3/4	2	7/8	2 1/8	1	2 1/4	1 1/8	2 3/4
	84 to 108, excl	3/4	2	7/8	2 1/8	1	2 1/4	1 1/4	2 3/4
108 and over	1	2	1 1/8	2 3/8	1 1/4	2 1/2	1 3/8	3	

^A Permissible variation under specified width and length: 1/4 in. By agreement, these permitted variations may be taken all over, in which case the sum of these permitted variations applies.

^B Permissible variations in length apply also to Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2 1/2 in., incl, except for alloy steel up to 2 in. thick.

TABLE A1.3 Permissible Variations in Rolled Width for Universal Mill Carbon Steel, High-Strength Low-Alloy Steel, and Alloy-Steel Plates 15 in. and under in ThicknessNOTE 1—Permissible variation under specified width shall be $\frac{1}{8}$ in.

Specified Width, in.	Variations Over Specified Width for Thicknesses Given, in.					
	To $\frac{3}{8}$, excl	$\frac{3}{8}$ to $\frac{5}{8}$, excl	$\frac{5}{8}$ to 1, excl	1 to 2, incl	Over 2 to 10, incl	Over 10 to 15, incl
Over 8 to 20, excl	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
20 to 36, excl	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{9}{16}$
36 and over	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$

TABLE A1.4 Permissible Variations in Diameter for Sheared Circular Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Plates 1 in. and under in Thickness

NOTE 1—No permissible variations under specified diameter.

Specified Diameter, in.	Permissible Variations Over Specified Diameter for Thicknesses Given, in.		
	To $\frac{3}{8}$, excl	$\frac{3}{8}$ to $\frac{5}{8}$, excl	$\frac{5}{8}$ to 1, incl
To 32, excl	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
32 to 84, excl	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{9}{16}$
84 to 108, excl	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$
108 to 130, incl	$\frac{7}{16}$	$\frac{9}{16}$	$1\frac{1}{16}$

TABLE A1.5 Permissible Variations in Width and Length for Rectangular Carbon Steel and High-Strength Low-Alloy Steel Plates when Gas Cutting is Specified or Required

NOTE 1—These variations may be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Variations Over for All Specified Widths or Lengths, in.
To 2, excl	$\frac{1}{2}$
2 to 4, excl	$\frac{5}{8}$
4 to 6, excl	$\frac{3}{4}$
6 to 8, excl	$\frac{7}{8}$
8 to 15, incl	1

TABLE A1.6 Permissible Variations in Diameter for Gas-Cut Circular Carbon Steel and High-Strength Low-Alloy Steel Plates

NOTE 1—No permissible variations under specified diameter

Specified Diameter, in.	Variations Over Specified Diameter for Thicknesses Given, in.					
	To 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
32 to 84, excl	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
84 to 108, excl	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
108 to 130, excl	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{16}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
130 and over	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$

TABLE A1.7 Permissible Camber for Carbon Steel Sheared or Gas-Cut Rectangular Plates all Thicknesses

NOTE 1—Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

Maximum permissible camber, in. = $\frac{1}{8}$ in. \times (number of feet of length/5)

TABLE A1.8 Permissible Camber for Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared or Gas-Cut Rectangular Plates

Dimension, in.		Camber for Thickness and Widths Given
Thickness	Width	
To 2, incl	all	$\frac{1}{8}$ in. \times (number of feet of length/5)
Over 2 to 15, incl	to 30, incl	$\frac{3}{16}$ in. \times (number of feet of length/5)
Over 2 to 15, incl	over 30	$\frac{1}{4}$ in. \times (number of feet of length/5)

TABLE A1.9 Permissible Variations from Flatness for Carbon Steel Plates

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed $\frac{1}{4}$ in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than $\frac{1}{4}$ in.

NOTE 4—The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the limits given in the table are increased to $1\frac{1}{2}$ times the amounts in the above table.

NOTE 5—This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 6—Plates shall be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Variations from a Flat Surface for Specified Widths, in.										
	Over 8 to 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and over
To $\frac{1}{4}$, excl	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	...	...
$\frac{1}{4}$ to $\frac{3}{8}$, excl	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	...	...
$\frac{3}{8}$ to $\frac{1}{2}$, excl	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{7}{8}$	$2\frac{1}{8}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	1	1	$1\frac{1}{8}$	$1\frac{1}{2}$	2
$\frac{3}{4}$ to 1, excl	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{3}{8}$	$1\frac{3}{4}$
1 to 2, excl	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{1}{2}$
2 to 4, excl	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{1}{8}$
4 to 6, excl	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	1
6 to 8, excl	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	1	1	1
8 to 10, excl	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{3}{4}$	$1\frac{3}{16}$	$\frac{7}{8}$	$1\frac{5}{16}$	1	1	1
10 to 12, excl	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$1\frac{3}{16}$	$\frac{7}{8}$	$1\frac{5}{16}$	1	1	1	1	1
12 to 15, incl	$\frac{5}{8}$	$\frac{3}{4}$	$1\frac{3}{16}$	$\frac{7}{8}$	$1\frac{5}{16}$	1	1	1	1	1	...

TABLE A1.10 Permissible Variations in Width and Length for Rectangular Alloy Steel Plates when Gas Cutting is Specified or Required

NOTE 1—These variations may be taken all under or divided over and under, if so specified.

NOTE 2— Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Variations Over for All Specified Widths and Lengths, in.
To 2, excl	3/4
2 to 4, excl	1
4 to 6, excl	1 1/8
6 to 8, excl	1 5/16
8 to 15, incl	1 1/2

TABLE A1.11 Permissible Variations in Diameter for Gas-Cut Circular Alloy Steel Plates

NOTE 1—No permissible variations under specified diameter.

Specified Diameter, in.	Variations Over Specified Diameter for Thicknesses Given, in.					
	To 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	1/2	3/4	3/4	3/4	1	1
32 to 84, excl	1/2	5/8	7/8	1	1 1/8	1 1/4
84 to 108, excl	5/8	3/4	1	1 1/8	1 1/4	1 3/8
108 to 130, incl	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2

TABLE A1.12 Permissible Variations from Flatness for High-Strength Low-Alloy Steel and Alloy Steel Plates

NOTE 1—*Flatness Tolerances for Length*—The longer dimension specified is considered the length and variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Tolerances for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation shall not exceed 3/8 in. When the larger dimension is from 36 to 72 in., incl, the variation shall not exceed 75 % of the tabular amount for the specified width.

NOTE 4—This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 5—Plates shall be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, in.	Variations from a Flat Surface for Specified Widths, in.										
	Over 8 to 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To 1/4, excl	13/16	1 1/8	1 3/8	1 7/8	2	2 1/4	2 3/8	2 5/8	2 3/4	...	...
1/4 to 3/8, excl	3/4	1 5/16	1 1/8	1 3/8	1 3/4	1 7/8	2	2 1/4	2 3/8	...	...
3/8 to 1/2, excl	3/4	7/8	1 5/16	1 5/16	1 1/8	1 5/16	1 1/2	1 5/8	1 7/8	2 3/4	3 1/8
1/2 to 3/4, excl	5/8	3/4	1 3/16	7/8	1	1 1/8	1 1/4	1 3/8	1 5/8	2 1/4	3
3/4 to 1, excl	5/8	3/4	7/8	7/8	1 5/16	1	1 1/8	1 5/16	1 1/2	2	2 5/8
1 to 2, excl	9/16	5/8	3/4	1 3/16	7/8	1 5/16	1	1	1	1 5/8	2 1/4
2 to 4, excl	1/2	9/16	1 1/16	3/4	3/4	3/4	3/4	7/8	1	1 1/4	1 5/8
4 to 6, excl	9/16	1 1/16	3/4	3/4	7/8	7/8	1 5/16	1 1/8	1 1/4	1 1/4	1 1/2
6 to 8, excl	5/8	3/4	3/4	1 5/16	1	1 1/8	1 1/4	1 5/16	1 1/2	1 1/2	1 1/2
8 to 10, excl	3/4	1 3/16	1 5/16	1	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2
10 to 12, excl	3/4	1 5/16	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
12 to 15, incl	7/8	1	1 3/16	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2

TABLE A1.13 Waviness Tolerances for Rectangular Plates, Universal Mill Plates, Circular Plates, and Sketch Plates

NOTE 1—Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 12 ft of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A1.9 and A1.12.

Flatness Tolerance from Tables A1.9 and A1.12	When Number of Waves in 12 ft is:						
	1	2	3	4	5	6	7
5/16	5/16	1/4	3/16	1/8	1/8	1/16	1/16
3/8	3/8	5/16	3/16	3/16	1/8	1/16	1/16
7/16	7/16	5/16	1/4	3/16	1/8	1/8	1/16
1/2	1/2	3/8	5/16	3/16	3/16	1/8	1/16
9/16	9/16	7/16	5/16	1/4	3/16	1/8	1/8
5/8	5/8	1/2	3/8	1/4	3/16	1/8	1/8
11/16	11/16	1/2	3/8	5/16	3/16	3/16	1/8
3/4	3/4	9/16	7/16	5/16	1/4	3/16	1/8
13/16	13/16	5/8	7/16	5/16	1/4	3/16	1/8
7/8	7/8	11/16	1/2	3/8	1/4	3/16	1/8
15/16	15/16	11/16	1/2	3/8	5/16	1/4	3/16
1	1	3/4	9/16	7/16	5/16	1/4	3/16
1 1/8	1 1/8	7/8	5/8	1/2	3/8	1/4	3/16
1 1/4	1 1/4	15/16	11/16	1/2	3/8	5/16	1/4
1 3/8	1 3/8	1 1/16	3/4	9/16	7/16	5/16	1/4
1 1/2	1 1/2	1 1/8	7/8	5/8	1/2	3/8	1/4
1 5/8	1 5/8	1 1/4	15/16	1 1/16	1/2	3/8	5/16
1 3/4	1 3/4	1 5/16	1	3/4	9/16	7/16	5/16
1 7/8	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16	5/16
2	2	1 1/2	1 1/8	7/8	5/8	1/2	3/8
2 1/8	2 1/8	1 5/8	1 3/16	7/8	1 1/16	1/2	3/8
2 1/4	2 1/4	1 11/16	1 1/4	15/16	1 1/16	9/16	3/8
2 3/8	2 3/8	1 13/16	1 5/16	1	3/4	9/16	7/16
2 1/2	2 1/2	1 7/8	1 7/16	1 1/16	1 3/16	9/16	7/16
2 5/8	2 5/8	2	1 1/2	1 1/8	1 3/16	5/8	7/16
2 3/4	2 3/4	2 1/16	1 9/16	1 1/8	7/8	5/8	1/2
2 7/8	2 7/8	2 3/16	1 5/8	1 3/16	1 5/16	1 1/16	1/2
3	3	2 1/4	1 11/16	1 1/4	1 5/16	1 1/16	9/16
3 1/8	3 1/8	2 3/8	1 3/4	1 5/16	1	3/4	9/16

TABLE A1.14 Visible Edge Indications Extending Approximately Parallel to Rolled Surfaces

Plate Specification and Thickness	Acceptable		Remove by Grinding		Acceptable on Edges Cut in Fabrication	
	Depth	Length ^A	Depth	Length ^A	Depth	Length ^A
	Column	1	2	3	4	5	6
Other than killed, ^B to 2 in., incl	1/8 in. max	any	over 1/8 in. to 1/4 in., incl	over 1 in.	1/4 in. max	any
Killed, ^C to 6 in., incl	1/16 in. max	any	over 1/16 in. to 1/8 in., incl	over 1 in.	1/8 in. max	any
Killed, ^C over 6 in.	1/8 in. max	any	over 1/8 in. to 1/2 in., incl	over 1 in.	1/2 in. max	any

^A Laminar-type discontinuities 1 in. and less in length are acceptable and do not require exploration.

^B Specifications: A285; A433; A442 in thicknesses to 1 in., incl; or A455.

^C The specification in 1.1 of this standard, other than those listed in the above Footnote B.

TABLE A1.15 Generally Available Grade-Thickness-Minimum Test Temperature Combinations Meeting Charpy V-Notch Requirements Indicated (Normalized or Quenched and Tempered Condition)

NOTE 1—The minimum temperatures listed are for longitudinal tests. For transverse tests, the available minimum temperature may be somewhat higher.

Acceptance Criteria Charpy V-Notch			Test Temperature, °F for Plate Thicknesses (Unless Otherwise Agreed Upon)				
Class ^B	Energy Absorption		Specification and Grade ^A	1 in. and Under	Over 1 in. to 2 in., incl.	Over 2 in. to 3 in., incl.	Over 3 in. to 5 in., incl.
	Minimum For 3 Specimens ^C ft-lbf	Average Minimum For 1 Specimen ^C ft-lbf					
I	10	7	A285 Grade A	+40	+60	...	...
			A285 Grade B	+50	+70	...	...
			A285 Grade C	+60	+80	...	...
II	13	10	A455	+25	...	...	...
III	13	10	A203 Grade A	-90	-90	-75	...
			A203 Grade D	-150	-150	-125	...
IV	15	12	A442 Grade 55 (1½ in. max thickness)	...	-20	...	...
			A442 Grade 60 (1½ in. max thickness)	...	-15	...	...
			A516 Grade 55	-60	-60	-50	-50
			A516 Grade 60	-60	-50	-50	-50
			A516 Grade 65	-60	-50	-40	-25
			A537 Class 1 (Over 2½ -4 in.)	...	...	-75	-50
			A662 Grade A	-75	-75	...	...
			A662 Grade B	-60	-60	...	...
			A203 Grade B	-90	-90	-75	...
			A203 Grade E	-150	-150	-125	...
			A203 Grade F (4 in. max)	...	...	-160	-160
			A299	+20	+30	+30	+40
			A516 Grade 70	-50	-40	-30	-20
			A537 Class 1 (2½ in. max)	-80	-75	-75	...
			A537 Class 2 (Over 2½ -4 in.)	...	...	-75	-50
V	20	15	A662 Grade C	-50	-50	...	...
			A203 Grade F	-160	-160	...	...
			A537 Class 2 (2½ in. max)	-90	-90	-90	...
			A612	-50	...	...	...
			A724 Grade A	-50	...	...	...
VI	15	15	A353	-320	-320	...	...
			A553 Type I	-320	-320	...	...
			A553 Type II	-275	-275	...	...
			A645	-275	-275	...	...
			A517 all (2½ in. max thickness)	^A	^A	...	...
			A724 Grade B	-50	...	...	...
			Lateral Expansion Mils. Minimum Each Specimen Transverse Test				

^A Testing temperature as specified in the purchase order, but no higher than 32°F.
^B Class I is *Other Than Killed* with a specified minimum tensile strength of 65 ksi or lower.
 Class II is *Other Than Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.
 Class III is *Killed* with a specified minimum tensile strength of 65 ksi or lower.
 Class IV is *Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.
 Class V is *Killed* with a specified minimum tensile strength of over 75 ksi to but not including 95 ksi.
 Class VI is *Killed* with a specified minimum tensile strength of 95 ksi or over.
^C Full size (10 by 10 mm) specimens.

TABLE A1.16 Charpy V-Notch Test Acceptance Criteria for Various Subsize Specimens^A

Full Size, 10 by 10 mm		¾ Size, 10 by 7.5 mm		½ Size, 10 by 6.7 mm		¼ Size, 10 by 5 mm		⅓ Size, 10 by 3.3 mm		¼ Size, 10 by 2.5 mm	
ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]
40	[54]	30	[41]	27	[37]	20	[27]	13	[18]	10	[14]
35	[48]	26	[35]	23	[31]	18	[24]	12	[16]	9	[12]
30	[41]	22	[30]	20	[27]	15	[20]	10	[14]	8	[11]
25	[34]	19	[26]	17	[23]	12	[16]	8	[11]	6	[8]
20	[27]	15	[20]	13	[18]	10	[14]	7	[10]	5	[7]
16	[22]	12	[16]	11	[15]	8	[11]	5	[7]	4	[5]
15	[20]	11	[15]	10	[14]	8	[11]	5	[7]	4	[5]
13	[18]	10	[14]	9	[12]	6	[8]	4	[5]	3	[4]
12	[16]	9	[12]	8	[11]	6	[8]	4	[5]	3	[4]
10	[14]	8	[11]	7	[10]	5	[7]	3	[4]	2	[3]
7	[10]	5	[7]	5	[7]	4	[5]	2	[3]	2	[3]

^A Interpolation shall be made for specimens with widths intermediate of those listed. Interpolated values shall be rounded to the nearest whole number as prescribed in Practice E29.

TABLE A1.17 Permissible Variations in Width for Mill Edge Carbon Steel and High-Strength Low-Alloy Steel Plates Produced on Strip Mills

NOTE 1—Applies to plates produced from coil and plates produced from plate-as-rolled.

Specified Width, in.	Variations over Specified Width, in ^A
To 14, excl	7/16
14 to 17, excl	1/2
17 to 19, excl	9/16
19 to 21, excl	5/8
21 to 24, excl	11/16
24 to 26, excl	13/16
26 to 28, excl	15/16
28 to 35, excl	1 1/8
35 to 50, excl	1 1/4
50 to 60, excl	1 1/2
60 to 65, excl	1 5/8
65 to 70, excl	1 3/4
70 to 80, excl	1 7/8
80 and over	2

^A No permissible variation under specified width.

A2. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC.—SI UNITS

A2.1 Listed herein are permissible variations in dimensions, and notch toughness information, expressed in SI units.

TABLE A2.1 Permissible Variations in Thickness for Rectangular Plates

NOTE 1—Permissible variation under specified thickness, 0.3 mm. When so specified, these permitted variations may be taken all over, in which case the sum of these permitted variations applies.

NOTE 2—Thickness shall be measured 10 to 20 mm from the longitudinal edge.

NOTE 3—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

NOTE 4—For thickness measured at any location other than that specified in Note 2, the permissible maximum over tolerance shall be increased by 75 %, rounded to the nearest 0.1 mm.

Specified Thickness, mm	Tolerance Over Specified Thickness for Widths Given in Millimetres, mm										
	1200 and Under	Over 1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3300, excl	3300 to 3600, excl	3600 to 4200, excl	4200 and Over
5.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0		
5.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0		
6.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.1		
7.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	
8.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	
9.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	
10.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
11.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
12.0	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.3	1.5	1.8
14.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
16.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
18.0	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.4	1.6	2.0
20.0	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.2	1.4	1.6	2.0
22.0	0.8	0.9	0.9	0.9	1.0	1.1	1.3	1.3	1.5	1.8	2.0
25.0	0.9	0.9	1.0	1.0	1.0	1.2	1.3	1.5	1.5	1.8	2.2
28.0	1.0	1.0	1.1	1.1	1.1	1.3	1.4	1.8	1.8	2.0	2.2
30.0	1.1	1.1	1.2	1.2	1.2	1.4	1.5	1.8	1.8	2.1	2.4
32.0	1.2	1.2	1.3	1.3	1.3	1.5	1.6	2.0	2.0	2.3	2.6
35.0	1.3	1.3	1.4	1.4	1.4	1.6	1.7	2.3	2.3	2.5	2.8
38.0	1.4	1.4	1.5	1.5	1.5	1.7	1.8	2.3	2.3	2.7	3.0
40.0	1.5	1.5	1.6	1.6	1.6	1.8	2.0	2.5	2.5	2.8	3.3
45.0	1.6	1.6	1.7	1.8	1.8	2.0	2.3	2.8	2.8	3.0	3.5
50.0	1.8	1.8	1.8	2.0	2.0	2.3	2.5	3.0	3.0	3.3	3.8
55.0	2.0	2.0	2.0	2.2	2.2	2.5	2.8	3.3	3.3	3.5	3.8
60.0	2.3	2.3	2.3	2.4	2.4	2.8	3.0	3.4	3.4	3.8	4.0
70.0	2.5	2.5	2.5	2.6	2.6	3.0	3.3	3.5	3.6	4.0	4.0
80.0	2.8	2.8	2.8	2.8	2.8	3.3	3.5	3.5	3.6	4.0	4.0
90.0	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.6	4.0	4.4
100.0	3.3	3.3	3.3	3.3	3.5	3.8	3.8	3.8	3.8	4.4	4.4
110.0	3.5	3.5	3.5	3.5	3.5	3.8	3.8	3.8	3.8	4.4	4.4
120.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.8	4.8
130.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.2	5.2
140.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	5.6	5.6
150.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.6	5.6
160.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	5.6	5.6
180.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	6.3	6.3
200.0	5.8	5.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0	7.0
250.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8.8
300.0	7.5	7.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0

TABLE A2.2 Permissible Variations in Width and Length for Sheared Plates 40 mm and Under in Thickness; Length only for Universal Mill Plates 65 mm and Under in Thickness

Specified Dimensions, mm		Permissible Variations over Specified Width and Length ^A for Thicknesses Given in millimetres, mm							
Length	Width	To 10, excl		10 to 16, excl		16 to 25, excl		25 to 50, incl ^B	
		Width	Length	Width	Length	Width	Length	Width	Length
To 3 000 excl	to 1500 excl	10	13	11	16	13	19	16	25
	1500 to 2100 excl	11	16	13	17	16	22	19	25
	2100 to 2700 excl	13	19	16	22	19	25	25	29
	2700 and over	16	22	19	25	22	29	29	32
3 000 to 6 000 excl	to 1500 excl	10	19	13	22	16	25	19	29
	1500 to 2100 excl	13	19	16	22	19	25	22	32
	2100 to 2700 excl	14	22	17	24	21	29	25	35
	2700 and over	16	25	19	29	22	32	29	35
6 000 to 9 000 excl	to 1500 excl	10	25	13	29	16	32	19	38
	1500 to 2100 excl	13	25	16	29	19	32	22	38
	2100 to 2700 excl	14	25	17	32	22	35	25	38
	2700 and over	17	29	22	32	25	35	32	44
9 000 to 12 000 excl	to 1500 excl	11	29	13	32	16	35	19	41
	1500 to 2100 excl	13	32	16	35	19	38	22	41
	2100 to 2700 excl	14	32	19	35	22	38	25	48
	2700 and over	19	35	22	38	25	41	32	48
12 000 to 15 000 excl	to 1500 excl	11	32	13	38	16	41	19	48
	1500 to 2100 excl	13	35	16	38	19	41	22	48
	2100 to 2700 excl	16	35	19	38	22	41	25	48
	2700 and over	19	38	22	41	25	44	32	48
15 000 to 18 000 excl	to 1500 excl	13	44	16	48	19	48	22	57
	1500 to 2100 excl	16	44	19	48	22	48	25	57
	2100 to 2700 excl	16	44	19	48	22	48	29	57
	2700 and over	22	44	25	51	29	57	32	64
18 000 and over	to 1500 excl	14	51	19	54	22	57	25	70
	1500 to 2100 excl	19	51	22	54	25	57	29	70
	2100 to 2700 excl	19	51	22	54	25	57	32	70
	2700 and over	25	51	29	60	32	64	35	76

^A Permissible variation under specified width and length: 6 mm. By agreement, these permitted variations may be taken all over, in which case the sum of these permitted variations applies.

^B Permissible variations in length apply also to Universal Mill plates up to 300 mm in width for thicknesses over 50 to 65 mm, incl, except for alloy steel up to 50 mm thick.

TABLE A2.3 Permissible Variations in Rolled Width for Universal Mill Carbon Steel, High-Strength Low-Alloy Steel Plates, and Alloy Steel Plates 400 mm and under in Thickness

NOTE 1—Permissible variation under specified width shall be 3 mm.

Specified Width, mm	Variations Over Specified Width for Thickness Given, mm					
	To 10, excl	10 to 16, excl	16 to 25, excl	25 to 50, excl	Over 50 to 250, incl	Over 250 to 400, incl
Over 200 to 500, excl	3	3	5	6	10	13
500 to 900, excl	5	6	8	10	11	14
900 and over	8	10	11	13	14	16

TABLE A2.4 Permissible Variations in Diameter for Sheared Circular Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Plates 25 mm and under in Thickness

NOTE 1—No permissible variations under specified diameter.

Specified Diameters, mm	Permissible Variations Over Specified Diameter for Thicknesses Given, mm		
	To 10, excl	10 to 16, excl	16 to 25, incl
To 800, excl	6	10	13
800 to 2100, excl	8	11	14
2100 to 2700, excl	10	13	16
2700 to 3300, excl	11	14	17
3300 and over	13	16	19

TABLE A2.5 Permissible Variations in Width and Length for Rectangular Carbon Steel and High-Strength Low-Alloy Steel Plates when Gas Cutting is Specified or Required

NOTE 1—These variations may be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, mm	Variations Over for All Specified Widths or Lengths, mm
To 50, excl	13
50 to 100, excl	16
100 to 150, excl	19
150 to 200, excl	22
200 to 400, incl	25

TABLE A2.6 Permissible Variations in Diameter for Gas-Cut Circular Carbon Steel and High-Strength Low-Alloy Steel Plates

NOTE 1—No permissible variations under specified diameter.

Specified Diameters, mm	Variations Over Specified Diameter for Thicknesses Given, mm					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, excl
To 800, excl	10	10	13	13	16	19
800 to 2100, excl	10	13	13	16	19	22
2100 to 2700, excl	13	14	16	19	22	25
2700 to 3300, excl	13	14	17	22	25	29
3300 and over	16	19	22	25	29	32

TABLE A2.7 Permissible Camber for Carbon Steel Sheared or Gas-Cut Rectangular Plates all Thicknesses

NOTE 1—Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

Maximum permissible camber, mm = length in millimetres/500
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TABLE A2.8 Permissible Camber for Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared or Gas-Cut Rectangular Plates

NOTE 1—Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

Width, mm	Camber for Width Given, mm
To 750, incl	Length/300
Over 750 to 1500	Length/250

TABLE A2.9 Permissible Variations from Flatness for Carbon Steel Plates

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4—The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 415 MPa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the limits given in the table are increased to 1½ times the amounts in the above table.

NOTE 5—This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 6—Plates shall be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Permissible Variations from a Flat Surface for Specified Widths, mm										
	To 900, excl	900 to 1200	1200 to 1500	1500 to 1800	1800 to 2100	2100 to 2400	2400 to 2700	2700 to 3000	3000 to 3600	3600 to 4200	4200 and Over
To 6, excl	14	19	24	32	35	38	41	44	48	...	...
6 to 10, excl	13	16	19	24	29	32	35	38	41	...	...
10 to 12, excl	13	14	16	16	19	22	25	29	32	48	54
12 to 20, excl	11	13	14	16	16	19	25	25	29	38	51
20 to 25, excl	11	13	14	16	16	16	19	22	25	35	44
25 to 50, excl	10	13	13	14	14	16	16	16	18	29	38
50 to 100, excl	8	10	11	13	13	13	13	14	16	22	29
100 to 150, excl	10	11	13	13	14	14	16	19	22	22	25
150 to 200, excl	11	13	13	16	18	19	22	22	25	25	25
200 to 250, excl	13	13	16	18	19	21	22	24	25	25	25
250 to 300, excl	13	16	19	21	22	24	25	25	25	25	25
300 to 400, incl	16	19	21	22	24	25	25	25	25	25	...

TABLE A2.10 Permissible Variations in Width and Length for Rectangular Alloy Steel Plates when Gas Cutting is Specified or Required

NOTE 1—These variations may be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, mm	Variations Over for All Specified Widths and Lengths, mm
To 50, excl	19
50 to 100, excl	25
100 to 150, excl	29
150 to 200, excl	33
200 to 400, incl	38

TABLE A2.11 Permissible Variations in Diameter for Gas Cut Circular Alloy Steel Plates

NOTE 1—No permissible variations under specified diameter.

Specified Diameter, mm	Variations Over Specified Diameter for Thicknesses Given, mm					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	13	13	19	19	25	25
800 to 2100, excl	13	16	22	25	29	32
2100 to 2700, excl	16	19	25	29	32	35
2700 to 3300, incl	22	25	29	32	35	38

TABLE A2.12 Permissible Variations from Flatness for High-Strength Low-Alloy Steel and Alloy Steel PlatesNOTE 1—*Flatness Tolerances for Length*—The longer dimension specified is considered the length and variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.NOTE 2—*Flatness Tolerances for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation shall not exceed 10 mm. When the larger dimension is from 900 to 1800 mm, incl, the variation shall not exceed 75 % of the tabular amount for the specified width.

NOTE 4—This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 5—Plates shall be in a horizontal position on a flat surface when flatness is measured.

Specified Thickness, mm	Flatness Tolerances for Specified Widths, mm										
	To 900, excl	900 to 1200	1200 to 1500	1500 to 1800	1800 to 2100	2100 to 2400	2400 to 2700	2700 to 3000	3000 to 3600	3600 to 4200	4200 and over
To 6, excl	21	29	35	48	51	57	60	67	70	...	...
6 to 10, excl	19	24	29	35	44	48	51	57	60	...	...
10 to 12, excl	19	22	24	24	29	33	38	41	48	70	79
12 to 20, excl	16	19	21	22	25	29	32	35	41	57	76
20 to 25, excl	16	19	22	22	24	25	29	33	38	51	67
25 to 50, excl	14	16	19	21	22	24	25	25	25	41	57
50 to 100, excl	13	14	18	19	19	19	19	22	25	32	41
100 to 150, excl	14	18	19	19	22	22	24	29	32	32	38
150 to 200, excl	16	19	19	24	25	29	32	33	38	38	38
200 to 250, excl	19	21	24	25	29	32	33	35	38	38	38
250 to 300, excl	19	24	29	32	33	35	38	38	38	38	38
300 to 400, incl	22	25	30	33	35	38	38	38	38	38	38

TABLE A2.13 Waviness Tolerances for Rectangular Plates, Universal Mill Plates, Circular Plates, and Sketch Plates

NOTE 1—Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 4000 mm of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A 2.9 and A 2.12.

Flatness Tolerance from Tables A2.9 and A2.12	When Number of Waves in 4000 mm is:						
	1	2	3	4	5	6	7
8	8	6	5	3	3	2	2
10	10	8	5	5	3	2	2
11	11	8	6	5	3	3	2
13	13	10	8	5	5	3	2
14	14	11	8	6	5	3	2
16	16	13	10	6	5	3	2
17	17	13	10	8	5	5	2
19	19	14	11	8	6	5	2
21	21	16	11	8	6	5	2
22	22	17	13	10	6	5	2
24	24	17	13	10	8	6	5
25	25	19	14	11	8	6	5
29	29	22	16	13	10	6	5
32	32	24	17	13	10	8	6
35	35	27	19	14	11	8	6
38	38	29	22	16	13	10	6
41	41	32	24	17	13	10	8
44	44	33	25	19	14	11	8
48	48	37	27	21	14	11	8
51	51	38	29	22	16	13	10
54	54	41	30	22	17	13	10
57	57	43	32	24	17	14	10
60	60	46	33	25	19	14	11
64	64	48	37	27	21	14	11
67	67	51	38	29	21	16	11
70	70	52	40	29	22	16	13
73	73	56	41	30	24	17	13
76	76	57	43	32	24	17	14
79	79	60	44	33	25	19	14

TABLE A2.14 Visible Edge Indications Extending Approximately Parallel to Rolled Surfaces

Plate Specification and Thickness	Acceptable		Remove by Grinding		Acceptable on Edges Cut in Fabrication	
	Depth	Length ^A	Depth	Length ^A	Depth	Length ^A
Column	1	2	3	4	5	6
Other than killed, ^B to 50 mm, incl	3 mm, max	any	over 3 to 6 mm, incl	over 25 mm	6 mm max	any
Killed, ^C to 150 mm, incl	2 mm, max	any	over 2 to 3 mm, incl	over 25 mm	3 mm max	any
Killed, ^C over 150 mm	3 mm, max	any	over 3 to 13 mm, incl	over 25 mm	13 mm max	any

^A Lamellar-type discontinuities 25 mm and less in length are acceptable and do not require exploration.

^B Specifications: A285; A433; A442 in thicknesses to 25 mm, incl; or A455.

^C The specifications in 1.1 of this standard, other than those listed in the above Table Footnote B.

TABLE A2.15 Generally Available Grade-Thickness-Minimum Test Temperature Combinations Meeting Charpy V-Notch Requirements Indicated (Normalized or Quenched and Tempered Condition)

NOTE 1—The minimum temperatures listed are for longitudinal tests. For transverse tests, the available minimum temperature may be somewhat higher.

Acceptance Criteria Charpy V-Notch Energy Absorption			Specification and Grade	Test Temperature, °C for Plate Thicknesses (Unless Otherwise Agreed Upon)						
Class ^A	Minimum Average For 3 Specimens ^B , J	Minimum For 1 Specimen ^B , J		25 mm and Under	Over 25 mm to 50 mm, incl.	Over 50 mm to 75 mm, incl.	Over 75 mm to 125 mm, incl.			
I	14	10	A285 Grade A	+4	+16	...	...	
			A285 Grade B	+10	+21	...	...	
			A285 Grade C	+16	+27	...	...	
II	18	14	A455	-4	...	...	...
III	18	14	A203 Grade A	-68	-68	-60	...			
			A203 Grade D	-101	-101	-87	...			
			A442 Grade 55 (38 mm max thickness)	...	-29	...	...	
			A442 Grade 60 (38 mm max thickness)	...	-26	...	...	
			A516 Grade 55	-51	-51	-46	-46			
			A516 Grade 60	-51	-46	-46	-46			
			A516 Grade 65	-51	-46	-40	-32			
			A537 Class 1 (Over 64–100 mm)	...	...	-60	-46	
			A662 Grade A	-60	-60	...	...	
			A662 Grade B	-51	-51	...	...	
			IV	20	16	A203 Grade B	-68	-68	-60	...
						A203 Grade E	-101	-101	-87	...
						A203 Grade F (100 mm max)	-107	-107
A299	-7	-1				-1	+4			
A516 Grade 70	-46	-40				-35	-29			
A537 Class 1 (64 mm max)	-62	-60				-60	...			
A537 Class 2 (Over 64–100 mm)	...	...				-60	-46	
V	27	20	A662 Grade C	-46	-46	...	...	
			A203 Grade F	-107	-107	...	...	
			A537 Class 2 (64 mm max)	-68	-68	-68	...			
			A612	-46	...	...	...
			A724 Grade A	-46	...	...	...
Lateral Expansion mm, Minimum Each Specimen Transverse Test										
VI	0.38		A353	-196	-196	...	...	
			A553 Type I	-196	-196	...	...	
			A553 Type II	-170	-170	...	...	
			A645	-170	-170	...	...	
			A517 all (64 mm max thickness)	^C	^C	...	...	
			A724 Grade B	-46	...	...	...

^A Class I is *Other Than Killed* with a specified minimum tensile strength of 450 MPa or lower.
 Class II is *Other Than Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.
 Class III is *Killed* with a specified minimum tensile strength of 450 MPa or lower.
 Class IV is *Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.
 Class V is *Killed* with a specified minimum tensile strength of over 520 MPa to but not including 655 MPa.
 Class VI is *Killed* with a specified minimum tensile strength of 655 MPa or over.
^B Full size (10 by 10 mm) specimens.
^C Testing temperature as specified in the purchase order, but no higher than 0°C.

TABLE A2.16 Permissible Variations in Width for Mill Edge Carbon Steel and High-Strength Low-Alloy Steel Plates Produced on Strip Mills

NOTE 1—Applies to plates produced from coil and plates produced from plate-as-rolled.

Specified Width, mm	Variations Over Specified Width, mm ^A
To 360, excl	11
360 to 430, excl	13
430 to 480, excl	14
480 to 530, excl	16
530 to 610, excl	17
610 to 660, excl	21
660 to 710, excl	24
710 to 890, excl	29
890 to 1270, excl	32
1270 to 1520, excl	38
1520 to 1650, excl	41
1650 to 1780, excl	44
1780 to 2030, excl	47
2030 and over	51

^A No permissible variation under specified width.

A3. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A3.1 Proposals for the introduction of new plate materials to be covered by the general requirements in this specification, either by the addition of new grades within existing specifications, or by the creation of a new specification shall be subject to the following conditions:

A3.1.1 The application for the addition of a new grade to a specification or a new specification shall be made to the chair of the subcommittee. Applications for new specifications remain subject to the approval of Committee A01. Revisions to existing specifications for such reasons as chemistry or thickness limitation are not subject to this annex.

A3.1.2 The application shall contain documentation citing the requisite need for the new material and its intended use as outlined in *Form and Style for ASTM Standards*, B5. Scope.³ That documentation may be in the form of a letter from a user, fabricator, another standards development organization, or producer stating the purpose and intended use for said new material. The Subcommittee may consider other evidence of need for the proposal. Additional background information as may be pertinent to the introduction of the new material may also be presented with the proposal.

A3.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished and shall include:

A3.1.3.1 Chemical data reflecting a suitable representation of the required chemistry range requested.

A3.1.3.2 Mechanical property data representing the proposed requirements in the delivered condition from each of the heats supplied.

NOTE A3.1—To assist the balloting process, data from plates representing the maximum proposed thickness should be provided recognizing that in some cases the standard may be “limited only by the capacity of the composition to meet the specified mechanical property requirements.”

A3.1.3.3 Mechanical property data in the simulated Post-Weld Heat Treatment (PWHT) condition if the product specification lists Supplementary Requirement S3.

A3.1.3.4 Evidence of weldability if the material is intended for welded construction as may be referenced in the Scope section of the new or existing standard.

NOTE A3.2—Such evidence is at the discretion of the submitter. Common methodology may include but not be limited to a single ASME Section IX qualification such as is referenced in 9.4 of this specification.

A3.1.4 Other properties that are not specification requirements that further describe the material, including physical properties, are not mandatory. However, to the extent that such information may assist the Subcommittee in evaluating the proposal they may be included. Omission of such non-essential documentation shall not be a cause for rejection of the application by the subcommittee.

A3.1.5 The application shall state whether or not a patent covers the new material.

APPENDIXES

(Nonmandatory Information)

X1. COILED STEEL

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, such temperatures are higher as the steel thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The differ-

ence in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength, and increased percent elongation, for the product with slower cooling rates from the coiling temperature to ambient. Such differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

X2. VARIATION OF TENSILE PROPERTIES IN PLATE-AS-ROLLED

X2.1 The tension requirements of this general requirements specification are intended only to characterize the tensile properties of a plate-as-rolled for determination of conformance to the requirements of the applicable product specifications. Such testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a plate-as-rolled. It is well known and documented that tensile properties vary within a plate-as-rolled or individual piece of steel as a function of chemical composition, processing, testing procedure, and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results shown on mill test reports. The testing procedures of this general requirements specification have been found to provide plate adequate for normal pressure vessel design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was conducted by the American Iron and Steel Institute (AISI).⁷

The results of this survey are contained in a *Contributions to the Metallurgy of Steel* entitled "The Variation of Product Analysis and Tensile Properties—Carbon Steel Plates, and Wide Flange Shapes" (SU/18, SU/19, and SU/20), published in September 1974. The data are presented in tables of probability that tensile properties at other than the official location may differ from those of the reported test location.

X2.3 This general requirements specification contains no requirements applicable to product tension tests; conformance to the applicable product specification is determined on the basis of tests performed at the place of manufacture or processing prior to shipment, unless otherwise specified.

X2.4 A Task Group of ASTM Subcommittee A01.11 has determined, based on review of the AISI data (SU20), that the variation in tensile properties within a plate-as-rolled can be expressed as a function of specified requirements; one standard deviation equals approximately 3 % of required tensile strength, 5 % of required yield strength, and 3 percentage points of required elongation.

X3. VARIATION IN CHARPY V-NOTCH TESTS

X3.1 A survey of the variation to be expected in Charpy V-Notch test results obtained from three common fine grain plate steels was conducted by the American Iron and Steel Institute (AISI). The results of the survey are contained in a *Contributions to the Metallurgy of Steel* entitled, "The Variations of Charpy V-Notch Impact Test Properties in Steel Plates," (SU/24), published January 1979. The survey data consists of test values obtained from six locations in addition to the locations specified in 12.1.3 of this specification. The plate

conditions tested involved as-rolled, normalized, and quench and tempered. Sufficient full-size specimens were taken from each sample so that three longitudinal and three transverse specimens could be broken at three test temperatures defined for each grade. The data is presented in tables of probability that impact properties at other than the official location which may differ from those of the reported test location. Additional data of the same type, but utilizing samples from thicker plates, was published by AISI as SU/27.

X4. RADIUS FOR COLD BENDING

X4.1 Suggested minimum inside bend radii for cold forming are referenced to group Designations A through F as defined in Table X4.1. The suggested radii listed in Table X4.2 should be used as minimums in typical shop fabrication. Material that does not form satisfactorily when fabricated in accordance with Table X4.2 may be subject to rejection pending negotiation with the steel supplier. When tighter bends are required, the manufacturer should be consulted.

X4.2 The bend radius and the radius of the male die should be as liberal as the finished part will permit. The width across the shoulders of the female die should be at least 8 times the plate thickness. Higher strength steels require larger die openings. The surface of the dies in the area of radius should be smooth.

X4.3 Since cracks in cold bending commonly originate from the outside edges, shear burrs and gas cut edges should be removed by grinding. Sharp corners on edges and on punched or gas cut holes should be removed by chamfering or grinding to a radius.

X4.4 If possible, parts should be formed such that the bend line is perpendicular to the direction of final rolling. If it is necessary to bend with the bend line parallel to the direction of final rolling, a more generous radius is suggested (1½ times applicable value given in Table X4.2 for bend lines perpendicular to the direction of rolling).

X4.5 References

X4.5.1 Both of these references are available from American Iron and Steel Institute (AISI):⁷

Holt, G. E., et al. "Minimum Cold Bend Radii Project - Final Report," Concurrent Technologies Corporation, January 27, 1997.

Brockenbrough, R. L., "Fabrication Guidelines for Cold Bending," R. L. Brockenbrough & Associates, June 28, 1998.

TABLE X4.1 Group Designations for Cold Bending

Specification	Class Where Applicable	Grade Where Applicable	Group Designation ^A
A203/A203M		A, D B, E F	B C D
A204/A204M		A B C	B C D
A225/A225M		C, D	D
A285/A285M		A, B, C	A
A299/A299M		A, B	D
A302/A302M		A, C, D B	D E
A353/A353M			D
A387/A387M	1, 2	2, 11, 12	C
	1	5, 9, 21, 21L, 22, 22L	E
	2	5, 9, 21, 22, 91	E
A455/A455M			C
A515/A515M		60 or 65 70	B C
A516/A516M		55 60, 65 70	A B C
A517/A517M		A, B, E, F, H, P, Q, S	F
A533/A533M	1, 2, 3	A, B, C, D, E	E
A537/A537M	1, 2 ^B , 3 ^B 2 ^C , 3 ^C		C D
A542/A542M ^D	1, 2 3, 4 4a		F D E
A543/A543M	1, 2, 3	B, C	F
A553/A553M ^D			D
A562/A562M			A
A612/A612M			C
A645/A645M			D
A662/A662M		A, B C	B C
A724/A724M		A, C B	D E
A736/A736M	1, 2, 3	A, C	D
A737/A737M		B, C	B
A738/A738M		A, B C ^B C ^C	D C D
A832/A832M		21V, 22V, 23V	E
A841/A841M	1, 2 3	A, B, C D	C F
A844/A844M			D
A1017/A1017M		23, 122 92, 911	D E

^A Steels in Groups A to E inclusive are grouped on the basis of similar specified values for minimum elongation in 2 in. [50 mm]; Group F includes steels that have a specified minimum elongation in 2 in. [50 mm] of 16 or less, and steels that have a ratio of specified minimum tensile strength to specified minimum yield strength of 1.15 or less.

^B For thicknesses of 4 in. [100 mm] and less.

^C For thicknesses over 4 in. [100 mm].

^D For any type.

TABLE X4.2 Suggested Minimum Inside Radii for Cold Bending^A

Group Designation ^B	Thickness (t), in. [mm]			
	Up to ¾ in. [20 mm]	Over ¾ in. [20 mm] to 1 in. [25 mm], incl	Over 1 in. [25 mm] to 2 in. [50 mm], incl	Over 2 in. [50 mm]
A	1.5t	1.5t	1.5t	1.5t
B	1.5t	1.5t	1.5t	2.0t
C	1.5t	1.5t	2.0t	2.5t
D	1.5t	1.5t	2.5t	3.0t
E	1.5t	1.5t	3.0t	3.5t
F	1.75t	2.25t	4.5t	5.5t

^A Values are for bend lines perpendicular to the direction of final rolling. These radii apply when the precautions listed in X4.2 are followed. If bend lines are parallel to the direction of final rolling, multiply values by 1.5.

^B Steels specifications included in the group designations may not include the entire thickness range shown in this table.

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SPECIFICATION FOR STEEL BARS, CARBON AND ALLOY, HOT-WROUGHT, GENERAL REQUIREMENTS FOR



SA-29/SA-29M



(Identical with ASTM Specification A29/A29M-05.)

SPECIFICATION FOR STEEL BARS, CARBON AND ALLOY, HOT-WROUGHT, GENERAL REQUIREMENTS FOR



SA-29/SA-29M



(Identical with ASTM Specification A 29/A 29M-05.)

1. Scope

1.1 This specification covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, shall apply to carbon and alloy steel bars under each of the following ASTM specifications (or under any other ASTM specification which invokes this specification or portions thereof):

Title of Specification	ASTM Designation ^A
<i>Hot-Rolled Carbon Steel Bars:</i>	
Steel Bars, Carbon, Quenched and Tempered	A 321
Steel Bars and Shapes, Carbon Rolled from "T" Rails	A 499
Steel Bars, Carbon, Merchant Quality, M-Grades	A 575
Steel Bars, Carbon, Hot-Wrought, Special Quality	A 576
Steel Bars, Carbon, Merchant Quality, Mechanical Properties	A 663/A 663M
Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	A 675/A 675M
Steel Bars for Springs, Carbon and Alloy	A 689
<i>Cold-Finished Carbon Steel Bars:</i>	
Steel Bars, Carbon and Alloy, Cold-Finished	A 108
Cold-Drawn Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements	A 311/A 311M
<i>Hot-Rolled Alloy Steel Bars:</i>	
Steel Bars, Alloy, Standard Grades	A 322
Carbon and Alloy Steel Bars Subject to End-Quench Hardenability Requirements	A 304
Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered	A 434
Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both	A 739
<i>Cold-Finished Alloy Steel Bars:</i>	
Steel Bars, Alloy, Hot-Rolled or Cold-Finished, Quenched and Tempered	A 434

Title of Specification	ASTM Designation ^A
Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components	A 696

^AThese designations refer to the latest issue of the respective specifications, which appear either in the *Annual Book of ASTM Standards*, Vol 01.05, or as reprints obtainable from ASTM.

1.2 In case of any conflict in requirements, the requirements of the purchase order, the individual material specification, and this general specification shall prevail in the sequence named.

1.3 The values stated in inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 For purposes of determining conformance to this specification and the various material specifications referenced in 1.1, dimensional values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

NOTE 1 — Specification A 29 previously listed dimensional tolerances for cold-finished bars; these are now found in Specification A 108.

2. Referenced Documents

2.1 ASTM Standards:

A 108 Specification for Steel Bars, Carbon and Alloy, Cold-Finished

- A 304 Specification for Carbon and Alloy Steel Bars Subject to End-Quench Hardenability Requirements
- A 311/A 311M Specification for Cold-Drawn, Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements
- A 321 Specification for Steel Bars, Carbon, Quenched and Tempered
- A 322 Specification for Steel Bars, Alloy, Standard Grades
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 434 Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered
- A 499 Specification for Steel Bars and Shapes, Carbon Rolled from “T” Rails
- A 575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
- A 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
- A 663/A 663M Specification for Steel Bars, Carbon, Merchant Quality, Mechanical Properties
- A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties
- A 689 Specification for Carbon and Alloy Steel Bars for Springs
- A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality for Pressure Piping Components
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 112 Test Methods for Determining Average Grain Size
- 2.2 Federal Standards:**
- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
- Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products
- 2.3 Military Standard:**
- MIL-STD-163 Steel Mill Products—Preparation for Shipment and Storage
- 2.4 Other Standards:**
- AIAG B-1 Bar Code Symbolology Standard for 3-of-9 Bar Codes
- AIAG B-5 02.00 Primary Metals Tag Application Standard

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 Hot-Wrought Steel Bars — Steel bars produced by hot forming ingots, blooms, billets, or other semifinished

forms to yield straight lengths (or coils, depending upon size, section, and mill equipment) in sections that are uniform throughout their length, and in the following sections and sizes:

3.1.1.1 Rounds — $\frac{7}{32}$ to 10.0 in. [5.5 to 250 mm], inclusive,

3.1.1.2 Squares — $\frac{7}{32}$ to 6.0 in. [6 to 160 mm], inclusive,

3.1.1.3 Round-Cornered Squares — $\frac{7}{32}$ to 8.0 in. [6 to 200 mm], inclusive,

3.1.1.4 Flats — $\frac{1}{4}$ to 8 in. inclusive, in width: $\frac{13}{64}$ in. in minimum thickness up to 6 in. in width; and 0.230 in. in minimum thickness for over 6 to 8 in. in width, inclusive [over 5 mm in thickness up to 150 mm in width; and over 6 mm in thickness for over 150 mm through 200 mm in width]. Maximum thickness for all widths is 4 in. [100 mm].

3.1.1.5 Hexagons and Octagons — $\frac{1}{4}$ to $4\frac{1}{16}$ in. [6 to 103 mm], inclusive, between parallel surfaces,

3.1.1.6 Bar Size Shapes — Angles, channels, tees, zees, when their greatest cross-sectional dimension is under 3 in. [75 mm], and

3.1.1.7 Special Bar Sections — Half-rounds, ovals, half-ovals, other special bar size sections.

3.1.2 Cold-Finished Steel Bars — Steel bars produced by cold finishing previously hot-wrought bars by means of cold drawing, cold forming, turning, grinding, or polishing (singly or in combination) to yield straight lengths or coils in sections that are uniform throughout their length and in the following sections and sizes:

3.1.2.1 Rounds — 9 in. [230 mm] and under in diameter,

3.1.2.2 Squares — 6 in. [150 mm] and under between parallel surfaces,

3.1.2.3 Hexagons — 4 in. [100 mm] and under between parallel surfaces,

3.1.2.4 Flats — $\frac{1}{8}$ in. [3 mm] and over in thickness and not over 12 in. [300 mm] in width, and

3.1.2.5 Special Bar Sections:

3.1.3 Lot — Unless otherwise specified in the contract or order, a lot shall consist of all bars submitted for inspection at the same time of the same heat, condition, finish, size, or shape. For bars specified in the quenched and tempered condition, when heat treated in batch-type furnaces, a lot shall consist of all bars from the same heat, of the same prior condition, the same size, and subjected to the same heat treatment in one tempering charge. For bars specified in the quenched and tempered condition, when heat treated without interruption in a continuous-type furnace, a lot shall consist of all bars from the same

heat, of the same prior condition, of the same size, and subjected to the same heat treatment.

4. Chemical Composition

4.1 Limits:

4.1.1 The chemical composition shall conform to the requirements specified in the purchase order or the individual product specifications. For convenience the grades commonly specified for carbon steel bars are shown in Tables 1 and 2. Bars may be ordered to these grade designations and when so ordered shall conform to the specified limits by heat analysis.

4.1.2 When compositions other than those shown in Tables 1 and 2 are required, the composition limits shall be prepared using the ranges and limits shown in Table 3 for carbon steel and Table 4 for alloy steel.

4.2 Heat or Cast Analysis:

4.2.1 The chemical composition of each heat or cast shall be determined by the manufacturer in accordance with Test Methods, Practices, and Terminology A 751.

4.2.2 The heat or cast analysis shall conform to the requirements specified in the product specification or purchase order. These can be the heat chemical range and limit for a grade designated in Tables 1 and 2, or another range and limit in accordance with 4.1.2, or with requirements of the product specification.

NOTE 2 — Heat analysis for lead is not determinable since lead is added to the ladle stream while each ingot is poured. When specified as an added element to a standard steel, the percentage of lead is reported as 0.15 to 0.35 incl, which is the range commonly specified for this element.

4.2.3 If requested or required, the heat analysis shall be reported to the purchaser or his representative.

4.2.4 Reporting of significant figures and rounding shall be in accordance with Test Methods, Practices, and Terminology A 751.

4.3 Product Analysis:

4.3.1 Merchant quality carbon bar steel is not subject to rejection for product analysis unless misapplication of a heat is clearly indicated.

4.3.2 Analyses may be made by the purchaser from finished bars other than merchant quality representing each heat of open-hearth, basic-oxygen, or electric-furnace steel. The chemical composition thus determined shall not vary from the limits specified in the applicable specification by more than the amounts prescribed in Table 5 and Table 6, but the several determinations of any element, excluding lead, in a heat may not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur; therefore,

when rimmed or capped steel is specified or required, the limitations for these elements shall not be applicable. Because of the degree to which phosphorus and sulfur segregate, the limitations for these elements shall not be applicable to rephosphorized or resulfurized steels.

4.3.3 Samples for product analysis shall be taken by one of the following methods:

4.3.3.1 Applicable to small sections whose cross-sectional area does not exceed 0.75 in.² [500 mm²] such as rounds, squares, hexagons, and the like. Chips are taken by milling or machining the full cross section of the piece. Drilling is not a feasible method for sampling sizes 0.75 in.² and smaller.

4.3.3.2 Applicable to products where the width of the cross section greatly exceeds the thickness, such as bar size shapes and light flat bars. Chips are taken by drilling entirely through the steel at a point midway between the edge and the middle of the section, or by milling or machining the entire cross section.

4.3.3.3 Applicable to large rounds, squares semi-finished, etc. Chips are taken at any point midway between the outside and the center of the piece by drilling parallel to the axis or by milling or machining the full cross section. In cases where these methods are not practicable, the piece may be drilled on the side, but chips are not taken until they represent the portion midway between the outside and the center.

4.3.3.4 When the steel is subject to tension test requirements, the tension test specimen can also be used for product analysis. In that case, chips for product analysis can be taken by drilling entirely through the tension test specimens or by the method described in 4.3.3.1.

4.3.4 When chips are taken by drilling, the diameter of the drill used shall conform to the following:

Area of Sample Cross Section, in. ² (cm ²)	Approximate Drill Diameter, in. (mm)
16 [100] or less	½ [12.5]
Over 16 [100]	1 [25.0]

4.3.5 The minimum number of samples to be taken from material representing the same heat or lot before rejection by the purchaser shall be as follows:

	Minimum Number of Samples
15 tons [15 Mg] and under	4
Over 15 tons [15 Mg]	6

4.3.6 In case the number of pieces in a heat is less than the number of samples required, one sample from each piece shall be considered sufficient.

4.3.7 In the event that product analysis determinations are outside the permissible limits as prescribed in

4.3.2, additional samples shall be analyzed and the acceptability of the heat negotiated between the purchaser and the producer.

4.4 Referee Analysis — In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the referee analysis shall be performed in accordance with the latest issue of Test Methods, Practices, and Terminology A 751, unless otherwise agreed upon between the manufacturer and the purchaser.

5. Grain Size Requirement

5.1 Austenitic Grain Size:

5.1.1 When a coarse austenitic grain size is specified, the steel shall have a grain size number of 1 to 5 exclusive as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the grains in the area examined shall constitute the basis of acceptance. One test per heat shall be made.

5.1.2 When a fine austenitic grain size is specified, the steel shall have a grain size number of 5 or higher as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the area examined shall constitute the basis of acceptance. One test per heat shall be made unless the provisions of 5.1.2.1 or 5.1.2.2 are exercised.

5.1.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020% total aluminum or, alternately, 0.015% acid soluble aluminum. The aluminum content shall be reported. The grain size test specified in 5.1.2 shall be the referee test.

5.1.2.2 By agreement between purchaser and supplier, columbium or vanadium or both may be used for grain refining instead of or with aluminum. When columbium or vanadium is used as a grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the columbium or vanadium content is as follows (the content of the elements shall be reported with the heat analysis):

Steels having 0.25% carbon or less:

Cb	0.025 min
V	0.05 min

Steels having over 0.25% carbon:

Cb	0.015 max
V	0.02 min

The maximum contents shall be:

Cb	0.05 max
V	0.08 max
Cb + V	0.06 max

5.1.2.3 When provisions of 5.1.2.1 or 5.1.2.2 are exercised, a grain size test is not required unless specified by the purchaser. Unless otherwise specified, fine austenitic grain size shall be certified using the analysis of grain refining element(s).

5.1.2.4 Referee Test — In the event that the chemical analysis of columbium or vanadium does not meet the requirements of 5.1.2.2, the grain size test shown in 5.1.2 shall be the referee test unless an alternative test method is agreed upon between the manufacturer and the purchaser.

6. Mechanical Property Requirements

6.1 Test Specimens:

6.1.1 Selection — Test specimens shall be selected in accordance with the requirements of the applicable product specification or in accordance with Supplement I of the latest issue of Test Methods and Definitions A 370, in the sequence named.

6.1.2 Preparation — Unless otherwise specified in the applicable product specification, test specimens shall be prepared in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof.

6.2 Methods of Mechanical Testing — All mechanical tests shall be conducted in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof, on steel bar products.

6.3 Retests:

6.3.1 If any test specimen shows defective machining or develops flaws, the specimen may be discarded and another substituted.

6.3.2 If the percentage elongation of any tension specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of a 2 in. [50 mm] specimen, or is outside the middle half of the gage length of an 8 in. [200 mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

6.3.3 For “as-wrought” material, if the results for any original tension specimen are within 2000 psi [14 MPa] of the required tensile strength, within 1000 psi [7 MPa] of the required yield point, or within 2% of the required elongation, retesting shall be permitted. If the original testing required only one test, the retest shall consist of two random tests from the heat or lot involved. If the original testing required two tests of which one failed by the amounts listed in this paragraph, the retest shall be made on one random test from the heat or lot. If the results on the retest specimen or specimens meet the specified requirements, the heat or test lot will be accepted. If the results of one retest specimen do not meet the specified requirements, the material is subject to rejection.

6.3.4 For thermally treated bars, if the results of the mechanical tests do not conform to the requirements specified, two more tests may be selected for each bar failing, and each of these retests shall conform to the requirements of the product specification.

6.3.5 If a bend specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted from the heat or test lot involved for which one random specimen for each original specimen showing failure shall be used. If the results on the retest specimen meet the requirements of the specification, the heat or test lot will be accepted.

7. Dimensions, Mass, and Permissible Variations

7.1 Hot-Wrought Bars — The permissible variations for dimensions of hot-wrought carbon and alloy steel bars shall not exceed the applicable limits stated in Annex A1 for inch-pound values and Annex A2 for metric values.

8. Workmanship, Finish, and Appearance

8.1 The material shall be free of injurious defects and shall have a workmanlike finish.

9. Rework and Retreatment

9.1 For thermally treated bars only, the manufacturer may retreat a lot one or more times, and retests shall be made in the same manner as the original tests. Each such retest shall conform to the requirements specified.

10. Inspection

10.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

10.2 All required tests and inspection shall be made by the manufacturer prior to shipment.

11. Rejection

11.1 Unless otherwise specified, any rejection because of noncompliance to the requirements of the specification shall be reported by the purchaser to the manufacturer within 30 working days after receipt of samples.

11.2 Material that shows imperfections capable of adversely affecting processibility subsequent to its acceptance at the purchaser's works will be rejected, and the manufacturer shall be notified.

12. Rehearing

12.1 Samples that represent rejected material shall be preserved for two weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

13. Product Marking

13.1 Civilian Procurement — Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer, purchaser's name and order number, the ASTM designation (year date is not required), grade number where appropriate, size and length, weight of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer's option and may be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars.

13.1.1 Bar code marking may be used as an auxiliary method of identification. Such bar-code markings shall be of the 3-of-9 type and shall conform to AIAG B1. When barcoded tags are used, they shall conform to AIAG B5.

13.2 Government Procurement:

13.2.1 Marking for shipment shall be in accordance with the requirements specified in the contract or order and shall be in accordance with MIL-STD-163 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

13.2.2 For government procurement by the Defense Supply Agency, the bars shall be continuously marked for identification in accordance with Fed. Std. No. 183.

14. Packaging

14.1 Civilian Procurement — Unless otherwise specified, the bars shall be packaged and loaded in accordance with Practices A 700.

14.2 Government Procurement — MIL-STD-163 shall apply when packaging is specified in the contract or order, or when Level A for preservation, packaging, and packing is specified for direct procurement by or direct shipment to the government.

15. Keywords

15.1 alloy steel bars; carbon steel bars; cold finished steel bars; general delivery requirements; hot wrought steel bars; steel bars

**TABLE 1
GRADE DESIGNATIONS AND CHEMICAL
COMPOSITIONS OF CARBON STEEL BARS**

Grade Designation	Heat Chemical Ranges and Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max ^A
Nonresulfurized Carbon Steels ^{B,C,D,E,F}				
1005	0.06 max	0.35 max	0.040	0.050
1006	0.08 max	0.25–0.40	0.040	0.050
1008	0.10 max	0.30–0.50	0.040	0.050
1010	0.08–0.13	0.30–0.60	0.040	0.050
1011	0.08–0.13	0.60–0.90	0.040	0.050
1012	0.10–0.15	0.30–0.60	0.040	0.050
1013	0.11–0.16	0.50–0.80	0.040	0.050
1015	0.13–0.18	0.30–0.60	0.040	0.050
1016	0.13–0.18	0.60–0.90	0.040	0.050
1017	0.15–0.20	0.30–0.60	0.040	0.050
1018	0.15–0.20	0.60–0.90	0.040	0.050
1019	0.15–0.20	0.70–1.00	0.040	0.050
1020	0.18–0.23	0.30–0.60	0.040	0.050
1021	0.18–0.23	0.60–0.90	0.040	0.050
1022	0.18–0.23	0.70–1.00	0.040	0.050
1023	0.20–0.25	0.30–0.60	0.040	0.050
1025	0.22–0.28	0.30–0.60	0.040	0.050
1026	0.22–0.28	0.60–0.90	0.040	0.050
1029	0.25–0.31	0.60–0.90	0.040	0.050
1030	0.28–0.34	0.60–0.90	0.040	0.050
1034	0.32–0.38	0.50–0.80	0.040	0.050
1035	0.32–0.38	0.60–0.90	0.040	0.050
1037	0.32–0.38	0.70–1.00	0.040	0.050
1038	0.35–0.42	0.60–0.90	0.040	0.050
1039	0.37–0.44	0.70–1.00	0.040	0.050
1040	0.37–0.44	0.60–0.90	0.040	0.050
1042	0.40–0.47	0.60–0.90	0.040	0.050
1043	0.40–0.47	0.70–1.00	0.040	0.050
1044	0.43–0.50	0.30–0.60	0.040	0.050
1045	0.43–0.50	0.60–0.90	0.040	0.050
1046	0.43–0.50	0.70–1.00	0.040	0.050
1049	0.46–0.53	0.60–0.90	0.040	0.050
1050	0.48–0.55	0.60–0.90	0.040	0.050
1053	0.48–0.55	0.70–1.00	0.040	0.050
1055	0.50–0.60	0.60–0.90	0.040	0.050
1059	0.55–0.65	0.50–0.80	0.040	0.050
1060	0.55–0.65	0.60–0.90	0.040	0.050
1064	0.60–0.70	0.50–0.80	0.040	0.050
1065	0.60–0.70	0.60–0.90	0.040	0.050
1069	0.65–0.75	0.40–0.70	0.040	0.050
1070	0.65–0.75	0.60–0.90	0.040	0.050
1071	0.65–0.70	0.75–1.05	0.040	0.050
1074	0.70–0.80	0.50–0.80	0.040	0.050
1075	0.70–0.80	0.40–0.70	0.040	0.050
1078	0.72–0.85	0.30–0.60	0.040	0.050
1080	0.75–0.88	0.60–0.90	0.040	0.050
1084	0.80–0.93	0.60–0.90	0.040	0.050
1086	0.80–0.93	0.30–0.50	0.040	0.050
1090	0.85–0.98	0.60–0.90	0.040	0.050
1095	0.90–1.03	0.30–0.50	0.040	0.050

**TABLE 1
GRADE DESIGNATIONS AND CHEMICAL
COMPOSITIONS OF CARBON STEEL BARS (CONT'D)**

Grade Designation	Heat Chemical Ranges and Limits, %				
	Carbon	Manganese	Phosphorus, max	Sulfur, max ^A	
Resulfurized Carbon Steels ^{B,D,F}					
1108	0.08–0.13	0.60–0.80	0.040	0.08–0.13	
1109	0.08–0.13	0.60–0.90	0.040	0.08–0.13	
1110	0.08–0.13	0.30–0.60	0.040	0.08–0.13	
1116	0.14–0.20	1.10–1.40	0.040	0.16–0.23	
1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13	
1118	0.14–0.20	1.30–1.60	0.040	0.08–0.13	
1119	0.14–0.20	1.00–1.30	0.040	0.24–0.33	
1132	0.27–0.34	1.35–1.65	0.040	0.08–0.13	
1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13	
1139	0.35–0.43	1.35–1.65	0.040	0.13–0.20	
1140	0.37–0.44	0.70–1.00	0.040	0.08–0.13	
1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13	
1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33	
1145	0.42–0.49	0.70–1.00	0.040	0.04–0.07	
1146	0.42–0.49	0.70–1.00	0.040	0.08–0.13	
1151	0.48–0.55	0.70–1.00	0.040	0.08–0.13	
Rephosphorized and Resulfurized Carbon Steels ^{D,F}					
Grade Designation	Carbon	Manganese	Phosphorus	Sulfur	Lead
1211	0.13 max	0.60–0.90	0.07–0.12	0.10–0.15	...
1212	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23	...
1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	...
1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	...
12L13	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	0.15–0.35
12L14	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35
12L15	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	0.15–0.35
High-Manganese Carbon Steels ^{B,C,D,E,F}					
Grade Designation	Former Designation	Carbon	Manganese	Phosphorus, max	Sulfur, max
1513	...	0.10–0.16	1.10–1.40	0.040	0.050
1518	...	0.15–0.21	1.10–1.40	0.040	0.050
1522	...	0.18–0.24	1.10–1.40	0.040	0.050
1524	1024	0.19–0.25	1.35–1.65	0.040	0.050
1525	...	0.23–0.29	0.80–1.10	0.040	0.050
1526	...	0.22–0.29	1.10–1.40	0.040	0.050
1527	1027	0.22–0.29	1.20–1.50	0.040	0.050
1536	1036	0.30–0.37	1.20–1.50	0.040	0.050
1541	1041	0.36–0.44	1.35–1.65	0.040	0.050
1547	...	0.43–0.51	1.35–1.65	0.040	0.050
1548	1048	0.44–0.52	1.10–1.40	0.040	0.050
1551	1051	0.45–0.56	0.85–1.15	0.040	0.050
1552	1052	0.47–0.55	1.20–1.50	0.040	0.050
1561	1061	0.55–0.65	0.75–1.05	0.040	0.050
1566	1066	0.60–0.71	0.85–1.15	0.040	0.050
1572	1072	0.65–0.76	1.00–1.30	0.040	0.050

TABLE 1
GRADE DESIGNATIONS AND CHEMICAL
COMPOSITIONS OF CARBON STEEL BARS (CONT'D)

Grade Designation	Heat Chemical Ranges and Limits, percent			
	Merchant Quality M Series Carbon Steel Bars			
	Carbon	Manganese ^G	Phosphorus, max	Sulfur, max
M 1008	0.10 max	0.25–0.60	0.04	0.05
M 1010	0.07–0.14	0.25–0.60	0.04	0.05
M 1012	0.09–0.16	0.25–0.60	0.04	0.05
M 1015	0.12–0.19	0.25–0.60	0.04	0.05
M 1017	0.14–0.21	0.25–0.60	0.04	0.05
M 1020	0.17–0.24	0.25–0.60	0.04	0.05
M 1023	0.19–0.27	0.25–0.60	0.04	0.05
M 1025	0.20–0.30	0.25–0.60	0.04	0.05
M 1031	0.26–0.36	0.25–0.60	0.04	0.05
M 1044	0.40–0.50	0.25–0.60	0.04	0.05

^A Maximum unless otherwise indicated.

^B When silicon is required, the following ranges and limits are commonly specified: 0.10%, max, 0.10% to 0.20%, 0.15% to 0.35%, 0.20% to 0.40%, or 0.30% to 0.60%.

^C Copper can be specified when required as 0.20% minimum.

^D When lead is required as an added element to a standard steel, a range of 0.15 to 0.35% inclusive is specified. Such a steel is identified by inserting the letter "L" between the second and third numerals of the grade designation, for example, 10 L 45. A cast or heat analysis is not determinable when lead is added to the ladle stream.

^E When boron treatment for killed steels is specified, the steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

^F The elements bismuth, calcium, selenium, or tellurium may be added as agreed upon between purchaser and supplier.

^G Unless prohibited by the purchaser, the manganese content may exceed 0.60% on heat analysis to a maximum of 0.75%, provided the carbon range on heat analysis has the minimum and maximum reduced by 0.01% for each 0.05% manganese over 0.60%.

TABLE 2
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon ^A	Nickel	Chromium	Molybdenum
1330	0.28–0.33	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
1335	0.33–0.38	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
1345	0.43–0.48	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
4012	0.09–0.14	0.75–1.00	0.035	0.040	0.15 to 0.35	...	...	0.15–0.25
4023	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4024	0.20–0.25	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	...	...	0.20–0.30
4027	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4028	0.25–0.30	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	...	...	0.20–0.30
4032	0.30–0.35	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4037	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4042	0.40–0.45	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4047	0.45–0.50	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.40–0.60	0.08–0.15
4120	0.18–0.23	0.90–1.20	0.035	0.040	0.15 to 0.35	...	0.40–0.60	0.13–0.20
4121	0.18–0.23	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.45–0.65	0.20–0.30
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4135	0.33–0.38	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4137	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4142	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4145	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4147	0.45–0.50	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4150	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4161	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.70–0.90	0.25–0.35
4320	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	0.40–0.60	0.20–0.30
4340	0.38–0.43	0.60–0.80	0.035	0.040	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
E4340	0.38–0.43	0.65–0.85	0.025	0.025	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
4419	0.18–0.23	0.45–0.65	0.035	0.040	0.15 to 0.35	...	...	0.45–0.60
4422	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.35–0.45
4427	0.24–0.29	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.35–0.45
4615	0.13–0.18	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	...	0.20–0.30
4620	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	...	0.20–0.30
4621	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	1.65–2.00	...	0.20–0.30
4626	0.24–0.29	0.45–0.65	0.035	0.040	0.15 to 0.35	0.70–1.00	...	0.15–0.25
4715	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.70–1.00	0.45–0.65	0.45–0.60
4718	0.16–0.21	0.70–0.90	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.30–0.40
4720	0.17–0.22	0.50–0.70	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.15–0.25
4815	0.13–0.18	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	...	0.20–0.30
4817	0.15–0.20	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	...	0.20–0.30
4820	0.18–0.23	0.50–0.70	0.035	0.040	0.15 to 0.35	3.25–3.75	...	0.20–0.30
5015	0.12–0.17	0.30–0.50	0.035	0.040	0.15 to 0.35	...	0.30–0.50	...
5046	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.20–0.35	...
5115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5120	0.17–0.22	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	...
5132	0.30–0.35	0.60–0.80	0.035	0.040	0.15 to 0.35	...	0.75–1.00	...
5135	0.33–0.38	0.60–0.80	0.035	0.040	0.15 to 0.35	...	0.80–1.05	...
5140	0.38–0.43	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5145	0.43–0.48	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5147	0.46–0.51	0.70–0.95	0.035	0.040	0.15 to 0.35	...	0.85–1.15	...
5150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5155	0.51–0.59	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5160	0.56–0.61	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...

TABLE 2
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS (CONT'D)

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon ^A	Nickel	Chromium	Molybdenum
E50100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	...	0.40–0.60	...
E51100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	...	0.90–1.15	...
E52100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	...	1.30–1.60	...
52100 ^B	0.93–1.05	0.25–0.45	0.025	0.015	0.15 to 0.35	...	1.35–1.60	...
6118	0.16–0.21	0.50–0.70	0.035	0.040	0.15 to 0.35	...	0.50–0.70	(0.10–0.15 V)
6150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	(0.15 min V)
8115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.20–0.40	0.30–0.50	0.08–0.15
8615	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8617	0.15–0.20	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8622	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8625	0.23–0.28	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8627	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8637	0.35–0.40	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8640	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8642	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8645	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8650	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8655	0.51–0.59	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8660	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8720	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8740	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8822	0.20–0.25	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.30–0.40
9254	0.51–0.59	0.60–0.80	0.035	0.040	1.20–1.60	...	0.60–0.80	...
9255	0.51–0.59	0.70–0.95	0.035	0.040	1.80–2.20	...	...	...
9259	0.56–0.64	0.75–1.00	0.035	0.040	0.70–1.10	...	0.45–0.65	...
9260	0.56–0.64	0.75–1.00	0.035	0.040	1.80–2.20	...	...	...
E9310	0.08–0.13	0.45–0.65	0.025	0.025	0.15 to 0.30	3.00–3.50	1.00–1.40	0.08–0.15
Standard Boron Steels ^C								
50B44	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.20–0.60	...
50B46	0.44–0.49	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.20–0.35	...
50B50	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.40–0.60	...
50B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.40–0.60	...
51B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
81B45	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.20–0.40	0.35–0.55	0.08–0.15
94B17	0.15–0.20	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.08–0.15
94B30	0.28–0.33	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.08–0.15

^A Silicon may be specified by the purchaser as 0.10% maximum. The need for 0.10% maximum generally relates to severe cold-formed parts.

^B The purchaser may also require the following maximums: copper 0.30%; aluminum 0.050%; oxygen 0.0015%.

^C These steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

Note 1 — Small quantities of certain elements are present in alloy steels, which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35%; nickel, 0.25%; chromium, 0.20%; and molybdenum, 0.06%.

Note 2 — Where minimum and maximum sulfur content is shown it is indicative of resulfurized steel.

Note 3 — The chemical ranges and limits shown in Table 2 are produced to product analysis tolerances shown in Table 6.

Note 4 — Standard alloy steels can be produced with a lead range of 0.15–0.35%. Such steels are identified by inserting the letter "L" between the second and third numerals of the AISI number, for example, 41 L 40. A cast or heat analysis is not determinable when lead is added to the ladle stream.

TABLE 3
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF
CARBON STEEL BARS

Element	Chemical Ranges and Limits, %		
	When Maximum of Specified Elements is:	Range	Lowest Maximum
Carbon ^A	...	...	0.06
	to 0.12, incl	...	...
	over 0.12 to 0.25, incl	0.05	...
	over 0.25 to 0.40, incl	0.06	...
	over 0.40 to 0.55, incl	0.07	...
	over 0.55 to 0.80, incl	0.10	...
Manganese	over 0.80	0.13	...
	...	...	0.35
	to 0.40, incl	0.15	...
Phosphorus	over 0.40 to 0.50, incl	0.20	...
	over 0.50 to 1.65, incl	0.30	...
	to 0.040, incl	...	0.040 ^B
Sulfur	over 0.040 to 0.08, incl	0.03	...
	over 0.08 to 0.13, incl	0.05	...
	to 0.050, incl	...	0.050 ^B
	over 0.050 to 0.09, incl	0.03	...
Silicon ^C	over 0.09 to 0.15, incl	0.05	...
	over 0.15 to 0.23, incl	0.07	...
	over 0.23 to 0.50, incl	0.09	...
	...	...	0.10
	to 0.10, incl	...	...
Copper	over 0.10 to 0.15, incl	0.08	...
	over 0.15 to 0.20, incl	0.10	...
	over 0.20 to 0.30, incl	0.15	...
Lead ^D	over 0.30 to 0.60, incl	0.20	...
	When copper is required 0.20 min is generally used		
Bismuth ^E	When lead is required, a range of 0.15 to 0.35 is specified		
Calcium ^E			
Selenium ^E			
Tellurium ^E			

^A The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.10%. When the maximum manganese limit exceeds 1.10%, add 0.01 to the carbon ranges shown above.

^B For steels produced in merchant quality the phosphorus maximum is 0.04% and the sulfur maximum is 0.05%.

^C It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.

^D A cast or heat analysis is not determinable when lead is added to the ladle stream.

^E Element specification range as agreed upon between purchaser and supplier.

TABLE 4
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF
ALLOY STEEL BARS

Element	Chemical Ranges and Limits, %			
	When Maximum of Specified Element is:	Open-Hearth or Basic-Oxygen Steel	Electric Furnace Steel	Maximum Limit, % ^A
Carbon	To 0.55, incl	0.05	0.05	
	Over 0.55–0.70, incl	0.08	0.07	
	Over 0.70 to 0.80, incl	0.10	0.09	
	Over 0.80–0.95, incl	0.12	0.11	
	Over 0.95–1.35, incl	0.13	0.12	
Manganese	To 0.60, incl	0.20	0.15	
	Over 0.60–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.90, incl	0.30	0.30	
Phosphorus	Over 1.90–2.10, incl	0.40	0.35	
	Basic open-hearth or basic-oxygen steel			0.035
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
Sulfur	Acid electric-furnace steel			0.050
	To 0.050, incl	0.015	0.015	
	Over 0.050–0.07, incl	0.02	0.02	
	Over 0.07–0.10, incl	0.04	0.04	
	Over 0.10–0.14, incl	0.05	0.05	
Silicon	Basic open-hearth or basic-oxygen steel			0.040
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
	Acid electric-furnace steel			0.050
Nickel	To 0.20, incl	0.08	0.08	
	Over 0.20–0.30, incl	0.15	0.15	
	Over 0.30–0.60, incl	0.20	0.20	
	Over 0.60–1.00, incl	0.30	0.30	
	Over 1.00–2.20, incl	0.40	0.35	
	Acid steels ^B			
Chromium	To 0.50, incl	0.20	0.20	
	Over 0.50–1.50, incl	0.30	0.30	
	Over 1.50–2.00, incl	0.35	0.35	
	Over 2.00–3.00, incl	0.40	0.40	
	Over 3.00–5.30, incl	0.50	0.50	
	Over 5.30–10.00, incl	1.00	1.00	
	To 0.40, incl	0.15	0.15	
Molybdenum	Over 0.40–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.60, incl	0.30	0.30	
	Over 1.60–1.75, incl	^C	0.35	
	Over 1.75–2.10, incl	^C	0.40	
	Over 2.10–3.99, incl	^C	0.50	
	To 0.10, incl	0.05	0.05	
Tungsten	Over 0.10–0.20, incl	0.07	0.07	
	Over 0.20–0.50, incl	0.10	0.10	
	Over 0.50–0.80, incl	0.15	0.15	
	Over 0.80–1.15, incl	0.20	0.20	
Tungsten	To 0.50, incl	0.20	0.20	
	Over 0.50–1.00, incl	0.30	0.30	
	Over 1.00–2.00, incl	0.50	0.50	
	Over 2.00–4.00, incl	0.60	0.60	

TABLE 4
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF
ALLOY STEEL BARS (CONT'D)

Element	Chemical Ranges and Limits, %		
	When Maximum of Specified Element is:	Open-Hearth or Basic-Oxygen Steel	Electric Furnace Steel
Vanadium	To 0.25, incl	0.05	0.05
	Over 0.25–0.50, incl	0.10	0.10
Aluminum	Up to 0.10, incl	0.05	0.05
	Over 0.10–0.20, incl	0.10	0.10
	Over 0.20–0.30, incl	0.15	0.15
	Over 0.30–0.80, incl	0.25	0.25
	Over 0.80–1.30, incl	0.35	0.35
Copper	Over 1.30–1.80, incl	0.45	0.45
	To 0.60, incl	0.20	0.20
	Over 0.60–1.50, incl	0.30	0.30
	Over 1.50–2.00, incl	0.35	0.35

Note 1 — Boron steels can be expected to have 0.0005% minimum boron content.

Note 2 — Alloy steels can be produced with a lead range of 0.15–0.35%. A cast or heat analysis is not determinable when lead is added to the ladle stream.

^A Applies to only nonrephosphorized and nonresulfurized steels.

^B Minimum silicon limit for acid open-hearth or acid electric-furnace alloy steels is 0.15%.

^C Not normally produced in open-hearth.

TABLE 5
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS
OF CARBON STEEL

Element	Limit, or Maximum of Specified Range, %	Over Maximum Limit, %	Under Minimum Limit, %
Carbon ^A	0.25 and under	0.02	0.02
	over 0.25 to 0.55, incl	0.03	0.03
	over 0.55	0.04	0.04
Manganese	0.90 and under	0.03	0.03
	over 0.90 to 1.65, incl	0.06	0.06
Phosphorus ^{A,B}	basic steels	0.008	...
	acid bessemer steel	0.01	0.01
Sulfur ^{A,B}		0.008	...
Silicon	0.35 and under	0.02	0.02
	over 0.35 to 0.60, incl	0.05	0.05
Copper	under minimum only	...	0.02
Lead ^C	0.15 to 0.35, incl	0.03	0.03

^A Rimmed and capped steels are not subject to rejection on product analysis unless misapplication is clearly indicated.

^B Resulfurized or rephosphorized steels are not subject to rejection on product analysis for these elements unless misapplication is clearly indicated.

^C Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

TABLE 6
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS
OF ALLOY STEEL

Elements	Limit, or Maximum of Specified Range, %	Permissible Variations Over Maximum Limit or Under Minimum Limit, %
Carbon	0.30 and under	0.01
	over 0.30 to 0.75, incl	0.02
	over 0.75	0.03
Manganese	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.04
Phosphorus	over maximum only	0.005
Sulfur	0.060 and under	0.005
Silicon	0.40 and under	0.02
	over 0.40 to 2.20, incl	0.05
Nickel	1.00 and under	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.30, incl	0.07
	over 5.30 to 10.00, incl	0.10
Chromium	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.05
	over 2.10 to 3.99, incl	0.10
Molybdenum	0.20 and under	0.01
	over 0.20 to 0.40, incl	0.02
	over 0.40 to 1.15, incl	0.03
Vanadium	0.10 and under	0.01
	over 0.10 to 0.25, incl	0.02
	over 0.25 to 0.50, incl	0.03
	minimum value specified, under minimum limit only	0.01
Tungsten	1.00 and under	0.04
	over 1.00 to 4.00, incl	0.08
Aluminum	0.10 and under	0.03
	over 0.10 to 0.20, incl	0.04
	over 0.20 to 0.30, incl	0.05
	over 0.30 to 0.80, incl	0.07
	over 0.80 to 1.80, incl	0.10
Lead ^A	0.15 to 0.35, incl	0.03
Copper	to 1.00 incl	0.03
	over 1.00 to 2.00, incl	0.05

^A Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Flat Bar Thickness Tolerances

S1.1 When flat bars are specified in metric units to a thickness under tolerance of 0.3 mm, the thickness tolerance of Table S1.1 shall apply.

TABLE S1.1
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS
ORDERED TO 0.3 MM UNDER TOLERANCE⁴

Specified Width, mm	Tolerances over Specified Thickness for Thickness Given, mm					Tolerance from Specified Width, mm	
	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75, incl	Over 75	Over	Under
To 25, incl	...	...	...	...	...	0.5	0.5
Over 25 to 50, incl	...	0.5	1.3	...	...	1.0	1.0
Over 50 to 100, incl	0.5	0.7	1.3	2.1	2.1	1.5	1.0
Over 100 to 150, incl	0.5	0.7	1.3	2.1	2.1	2.5	1.5
Over 150 to 200, incl	0.5	1.0	1.3	2.1	2.9	3.0	2.5

Note — Tolerance under specified thickness 0.3 mm.

⁴ When a square is held against a face and an edge of a square-edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions expressed in inch-pound units of measurement.

TABLE A1.1
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR
HOT-WROUGHT ROUND, SQUARE, AND ROUND-
CORNERED SQUARE BARS OF STEEL

Specified Size, in.	Permissible Variation from Specified Size, in. ^A		Out-of-Round or Out-of-Square, in. ^B
	Over	Under	
To $\frac{5}{16}$, incl	0.005	0.005	0.008
Over $\frac{5}{16}$ to $\frac{7}{16}$, incl	0.006	0.006	0.009
Over $\frac{7}{16}$ to $\frac{5}{8}$, incl	0.007	0.007	0.010
Over $\frac{5}{8}$ to $\frac{7}{8}$, incl	0.008	0.008	0.012
Over $\frac{7}{8}$ to 1, incl	0.009	0.009	0.013
Over 1 to $1\frac{1}{8}$, incl	0.010	0.010	0.015
Over $1\frac{1}{8}$ to $1\frac{1}{4}$, incl	0.011	0.011	0.016
Over $1\frac{1}{4}$ to $1\frac{3}{8}$, incl	0.012	0.012	0.018
Over $1\frac{3}{8}$ to $1\frac{1}{2}$, incl	0.014	0.014	0.021
Over $1\frac{1}{2}$ to 2, incl	$\frac{1}{64}$	$\frac{1}{64}$	0.023
Over 2 to $2\frac{1}{2}$, incl	$\frac{1}{32}$	0	0.023
Over $2\frac{1}{2}$ to $3\frac{1}{2}$, incl	$\frac{3}{64}$	0	0.035
Over $3\frac{1}{2}$ to $4\frac{1}{2}$, incl	$\frac{1}{16}$	0	0.046
Over $4\frac{1}{2}$ to $5\frac{1}{2}$, incl	$\frac{5}{64}$	0	0.058
Over $5\frac{1}{2}$ to $6\frac{1}{2}$, incl	$\frac{1}{8}$	0	0.070
Over $6\frac{1}{2}$ to $8\frac{1}{4}$, incl	$\frac{5}{32}$	0	0.085
Over $8\frac{1}{4}$ to $9\frac{1}{2}$, incl	$\frac{3}{16}$	0	0.100
Over $9\frac{1}{2}$ to 10, incl	$\frac{1}{4}$	0	0.120

^A Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

^B Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

TABLE A1.2
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR
HOT-WROUGHT HEXAGONAL BARS OF STEEL

Specified Sizes Between Opposite Sides, in.	Permissible Variations from Specified Size, in. ^A		Out-of-Hexagon (Carbon Steel and Alloy Steel) or Out-of-Octagon (Alloy Steel), in. ^B
	Over	Under	
To $\frac{1}{2}$, incl	0.007	0.007	0.011
Over $\frac{1}{2}$ to 1, incl	0.010	0.010	0.015
Over 1 to $1\frac{1}{2}$, incl	0.021	0.013	0.025
Over $1\frac{1}{2}$ to 2, incl	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{32}$
Over 2 to $2\frac{1}{2}$, incl	$\frac{3}{64}$	$\frac{1}{64}$	$\frac{3}{64}$
Over $2\frac{1}{2}$ to $3\frac{1}{2}$, incl	$\frac{1}{16}$	$\frac{1}{64}$	$\frac{1}{16}$
Over $3\frac{1}{2}$ to $4\frac{1}{2}$, incl	$\frac{5}{64}$	$\frac{1}{64}$	$\frac{5}{64}$

^A Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

^B Out-of-hexagon or out-of-octagon is the greatest difference between any two dimensions at the same cross section between opposite faces.

TABLE A1.3
PERMISSIBLE VARIATIONS IN THICKNESS AND WIDTH FOR HOT-WROUGHT SQUARE EDGE AND ROUND EDGE FLAT BARS^A

Specified Width, in.	Permissible Variations in Thickness, for Thickness Given, Over and Under, in. ^B							Permissible Variations in Width, in.	
	0.203 to 0.230, excl	0.230 to 1/4, excl	1/4 to 1/2, incl	Over 1/2 to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl	Over 3	Over	Under
	To 1, incl	0.007	0.007	0.008	0.010	1/64	1/64
Over 1 to 2, incl	0.007	0.007	0.012	0.015	1/32	...	...	1/32	1/32
Over 2 to 4, incl	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl	0.009	0.009	0.015	0.020	1/32	3/64	3/64	3/32	1/16
Over 6 to 8, incl	^C	0.015	0.016	0.025	1/32	3/64	1/16	1/8	3/32

^A When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

^B Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

^C Flats over 6 to 8 in., incl, in width, are not available as hot-wrought steel bars in thickness under 0.230 in.

TABLE A1.4
PERMISSIBLE VARIATIONS IN THICKNESS, LENGTH, AND OUT-OF-SQUARE FOR HOT-WROUGHT BAR SIZE ANGLES OF CARBON STEEL

Specified Length of Leg, in. ^A	Permissible Variations in Thickness, for Thicknesses Given, Over and Under, in.			Permissible Variations for Length of Leg, Over and Under, in.
	To 3/16, incl	Over 3/16 to 3/8, incl	Over 3/8	
	To 1, incl	0.008	0.010		...	1/32
Over 1 to 2, incl	0.010	0.010	0.012	3/64
Over 2 to 3, excl	0.012	0.015	0.015	1/16

^A The longer leg of an unequal angle determines the size for tolerance. The out-of-square tolerance in either direction is 1 1/2°.

TABLE A1.6
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE TEES OF CARBON STEEL

Specified Size of Tee, in. ^A	Permissible Variations in Size, in.						Stem out-of-Square ^C
	Width or Depth ^B		Thickness of Flange		Thickness of Stem		
	Over	Under	Over	Under	Over	Under	
To 1 1/4, incl	3/64	3/64	0.010	0.010	0.005	0.020	1/32
Over 1 1/4 to 2, incl	1/16	1/16	0.012	0.012	0.010	0.020	1/16
Over 2 to 3, excl	3/32	3/32	0.015	0.015	0.015	0.020	3/32

^A The longer member of the unequal tee determines the size for tolerances.

^B Measurements for both width and depth are overall.

^C Stem out-of-square is the variation from its true position of the center line of the stem measured at the point.

TABLE A1.5
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE CHANNELS OF CARBON STEEL

Specified Size of Channel, in.	Permissible Variations in Size, Over and Under, in.				Out-of-Square ^A if Either Flange, in./in. of Flange Width
	Depth of Section ^B	Width of Flanges ^B	Thickness of Web for Thickness Given		
			To 3/16, incl	Over 3/16	
To 1 1/2, incl	1/32	1/32	0.010	0.015	1/32
Over 1 1/2 to 3, excl	1/16	1/16	0.015	0.020	1/32

^A For channels 5/8 in. and under in depth, the out-of-square tolerance is 3/64 in./in. of depth.

^B Measurements for depth of section and width of flanges are overall.

TABLE A1.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HALF-ROUNDS, OVALS, HALF-OVALS, AND OTHER SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, half-ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A1.8
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, FLATS, AND BAR
SIZE SECTIONS OF STEEL

Specified Size of Rounds, Squares, and Hexagons, in.	Specified Size of Flats, in.		Permissible Variations Over Specified Length, in. ^A				
	Thickness	Width	5 to 10 ft, excl	10 to 20 ft, excl	20 to 30 ft, excl	30 to 40 ft, excl	40 to 60 ft, excl
Mill Shearing							
To 1, incl	to 1, incl	to 3, incl	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$
Over 1 to 2, incl	over 1	to 3, incl	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
	to 1, incl	over 3 to 6, incl	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Over 2 to 5, incl	over 1	over 3 to 6, incl	1	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$
Over 5 to 10, incl	...	...	2	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$
	0.230 to 1, incl	over 6 to 8, incl	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$3\frac{1}{2}$	4
	over 1 to 3, incl	over 6 to 8, incl	$1\frac{1}{4}$	$1\frac{3}{4}$	2	$3\frac{1}{2}$	4
Bar Size Sections	...	...	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Hot Sawing							
2 to $3\frac{1}{2}$, incl	1 and over	3 and over	^B	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$
Over $3\frac{1}{2}$ to 5, incl				2	$2\frac{1}{4}$	$2\frac{5}{8}$	3
Over 5 to 10, incl	...	...	^B	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$

^A No permissible variations under.

^B Smaller sizes and shorter lengths are not hot sawed.

TABLE A1.9
PERMISSIBLE VARIATIONS IN LENGTH FOR
RECUTTING OF BARS MEETING SPECIAL
STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in. ^A	Tolerances Over Specified Length, in. ^A	
	To 12 ft, incl	Over 12 ft
To 3, incl	$\frac{1}{4}$	$\frac{5}{16}$
Over 3 to 6, incl	$\frac{5}{16}$	$\frac{7}{16}$
Over 6 to 8, incl	$\frac{7}{16}$	$\frac{9}{16}$
Rounds over 8 to 10, incl	$\frac{9}{16}$	$\frac{11}{16}$

^A No tolerance under.

TABLE A1.10
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR
HOT-WROUGHT BARS AND BAR SIZE SECTIONS OF
STEEL^A

Standard tolerances	$\frac{1}{4}$ in. in any 5 ft and ($\frac{1}{4}$ in. \times length in ft)/5
Special tolerances	$\frac{1}{8}$ in. in any 5 ft and ($\frac{1}{8}$ in. \times length in ft)/5

^A Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.

A2. DIMENSIONAL TOLERANCES — SI UNITS

A2.1 Listed below are permissible variations in dimensions expressed in SI units of measurement.

**TABLE A2.1
TOLERANCES IN SECTIONAL DIMENSIONS FOR
ROUND AND SQUARE BARS AND ROUND-CORNERED
SQUARE BARS**

Size, mm	Tolerance from Specified Size, Over and Under, mm or % ^A	Out-of-Round, or Out-of-Square Section, ^B mm or % ^A
Over 7 to 11, incl	0.15 mm	0.22 mm
Over 11 to 15, incl	0.18 mm	0.27 mm
Over 15 to 19, incl	0.20 mm	0.30 mm
Over 19 to 250, incl	1%	1.5%

^A The tolerance shall be rounded to the nearest tenth of a millimetre after calculation.

^B Out-of-round is the difference between the maximum and the minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

**TABLE A2.2
TOLERANCES IN CROSS SECTION FOR HOT-WROUGHT
HEXAGONAL AND OCTAGONAL STEEL BARS**

Specified Size Between Opposite Sides, mm	Tolerance from Specified Size, mm		Out of Hexagon or Out of Octagon, mm ^A
	Over	Under	
To 13, incl	0.18	0.18	0.3
Over 13 to 25, incl	0.25	0.25	0.4
Over 25 to 40, incl	0.55	0.35	0.6
Over 40 to 50, incl	0.8	0.40	0.8
Over 50 to 65, incl	1.2	0.40	1.2
Over 65 to 80, incl	1.6	0.40	1.6
Over 80 to 100, incl	2.0	0.40	2.0

^A Out of hexagon or out of octagon is the greatest difference between any two dimensions at the cross section between opposite faces.

**TABLE A2.3
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS^{A,B}**

Specified Width, mm	Tolerances from Specified Thickness for Thickness Given Over and Under, mm						Tolerances from Specified Width, mm	
	Over 5 to 6, incl	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75	Over 75	Over	Under
	To 25, incl	0.18	0.20	0.25	0.5	0.5
Over 25 to 50, incl	0.18	0.30	0.40	0.8	...	...	1.0	1.0
Over 50 to 100, incl	0.20	0.40	0.50	0.8	1.2	1.2	1.5	1.0
Over 100 to 150, incl	0.25	0.40	0.50	0.8	1.2	1.2	2.5	1.5
Over 150 to 200, incl	^A	0.40	0.65	0.8	1.2	1.6	3.0	2.5

^A When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

^B Flats over 150 to 200 mm, incl in width are not available as hot-wrought bars in thickness 6 mm and under.

TABLE A2.4
THICKNESS, LENGTH, AND OUT-OF-SQUARE
TOLERANCES FOR HOT-WROUGHT BAR SIZE ANGLES

Specified Length of Leg, mm ^{A,B}	Tolerances in Thickness for Thickness Given, Over and Under, mm			Tolerances for Length of Leg Over and Under, mm
	To 5, incl	Over 5 to 10, incl	Over 10	
Over 50 to 75, excl	0.3	0.4	0.4	2

^A The longer leg of an unequal angle determines the size for tolerance.

^B Out of square tolerances in either direction is $1\frac{1}{2}^\circ = 0.026$ mm/mm.

TABLE A2.5
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR
SIZE CHANNELS

Specified Size of Channel, mm	Tolerances in Size, Over and Under, mm				Out of Square of Either Flange per mm of Flange Width, ^B mm
	Depth of Section ^A	Width of Flanges ^A	Thickness of Web		
			To 5, incl	Over 5	
To 40, incl	1	1	0.2	0.4	0.03
Over 40 to 75, excl	2	2	0.4	0.5	0.03

^A Measurements for depth of section and width of flanges are overall.

^B For channels 16 mm and under in depth, out of square tolerance is 0.05 mm/mm.

TABLE A2.6
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR
SIZE TEES

Specified Size of Tee, ^A mm	Tolerances in Size, mm						Stem Out of Square ^C
	Width or Depth, ^B		Thickness of Flange		Thickness of Stem		
	Over	Under	Over	Under	Over	Under	
To 30, incl	1	1	0.2	0.2	0.1	0.5	1
Over 30 to 50, incl	2	2	0.3	0.3	0.2	0.5	2
Over 50 to 75, excl	2	2	0.4	0.4	0.4	0.5	2

^A The longer member of the unequal tee determines the size for tolerances.

^B Measurements for width and depth are overall.

^C Stem out of square is the tolerance from its true position of the center line of the stem measured at the point.

TABLE A2.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR
HALF-ROUNDS, OVALS, HALF-OVALS, AND OTHER
SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A2.8
LENGTH TOLERANCES FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, OCTAGONS, FLATS,
AND BAR SIZE SECTIONS

Specified Size of Rounds, Squares, Hexagons and Octagons, mm	Specified Size of Flats, mm		Tolerances over Specified Length, mm ^A				
	Thickness	Width	1500 to 3000, excl	3000 to 6000, excl	6000 to 9000, excl	9000 to 12 000, excl	12 000 to 18 000, excl
Hot Shearing							
To 25, incl	to 25, incl	to 75, incl	15	20	35	45	60
Over 25 to 50, incl	over 25	to 75, incl	15	25	40	50	65
	to 25, incl	over 75 to 150, incl	15	25	40	50	65
Over 50 to 125, incl	over 25	over 75 to 150, incl	25	40	45	60	70
Over 125 to 250, incl	...	...	50	65	70	75	85
Bar Size Sections	over 6 to 25, incl	over 150 to 200, incl	20	30	45	90	100
	over 25 to 75, incl	over 150 to 200, incl	30	45	50	90	100
	...	...	15	25	40	50	65
Hot Sawing							
50 to 90, incl	25 and over	75 and over	^B	40	45	60	70
Over 90 to 125, incl				50	60	65	75
Over 125 to 250, incl	...	...	^B	65	70	75	85

^A No tolerance under.

^B Smaller sizes and shorter lengths are not hot sawed.

TABLE A2.9
LENGTH TOLERANCES FOR RECUTTING OF BARS
MEETING SPECIAL STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Octagons, Widths of Flats and Maximum Dimensions of Other Sections, mm	Tolerances over Specified Length, mm ^A	
	To 3700 mm, incl	Over 3700 mm
To 75, incl	6	8
Over 75 to 150, incl	8	11
Over 150 to 200, incl	11	14
Rounds over 200 to 250, incl	14	18

^A No tolerance under.

TABLE A2.10
STRAIGHTNESS TOLERANCES FOR HOT-WROUGHT
BARS AND
BAR SIZE SECTIONS^A

Standard tolerances	6 mm in any 1500 mm and (length in mm/250) ^B
Special tolerances	3 mm in any 1500 mm and (length in mm/500) ^B

^A Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.

^B Round to the nearest whole millimetre.

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SPECIFICATION FOR STEEL RIVETS AND BARS FOR RIVETS, PRESSURE VESSELS



SA-31

(Identical with ASTM Specification A31-14 except that 3.1.7 has been deleted, Note 1 has been revised for ASME and certification is mandatory in 14.)

SPECIFICATION FOR STEEL RIVETS AND BARS FOR RIVETS, PRESSURE VESSELS



SA-31

1. Scope

1.1 This specification covers steel rivets for use in boilers and pressure vessels and steel bars for use in the manufacture of rivets.

1.2 Two grades are covered:

1.2.1 Grade A — Bars having a yield point of 23 000 psi (160 MPa) minimum with no controls on carbon content.

1.2.2 Grade B — Bars having a yield point of 29 000 psi (200 MPa) minimum with carbon 0.28% maximum.

1.2.3 Rivets are manufactured from the applicable bar grade.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

- A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ASME Standards:

- B18.1.1 Small Solid Rivets $\frac{7}{16}$ Inch Nominal Diameter and Smaller
- B18.1.2 Large Rivets $\frac{1}{2}$ Inch Nominal Diameter and Larger
- B18.24 Part Identifying Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for rivets and bars under this specification shall include:

3.1.1 Specification designation and date of issue,

3.1.2 Quantity — Number of pieces for rivets and weight for bars,

3.1.3 Name of product and grade (A or B),

3.1.4 Size (diameter and length),

3.1.5 Rivet head type,

3.1.6 If inspection at point of manufacture is required,

3.1.7 DELETED

3.1.8 Additional testing or special requirements, if required.

3.1.9 For establishment of a part identifying system, see ASME B18.24.

NOTE 1 — A typical ordering description is: ASME SA-31, 2015 edition, 10 000 pieces, steel rivets Grade A, button head.

4. Materials and Manufacture

4.1 The steel shall be made by any of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 Rivets shall be manufactured from rivet bars conforming to the applicable grade ordered.

4.3 Rivets shall be manufactured by hot- or cold-heading.

4.4 Bars shall be furnished as rolled and not pickled, blast cleaned, or oiled. At producer's option, bars may be cleaned for inspection or cold drawn.

5. Chemical Composition

5.1 The steel shall conform to chemical composition prescribed in Table 1.

5.2 Heat Analysis — An analysis of each heat of steel shall be made by the bar manufacturer to determine for Grades A and B the percentages of carbon, manganese, phosphorus, and sulfur. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements for heat analysis in accordance with Table 1.

5.3 Product Analysis — An analysis may be made by the purchaser from finished materials representing each heat. The chemical composition thus determined shall conform to the requirements for product analysis prescribed in Table 1.

5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Rivet Bend Tests:

6.1.1 The rivet shank of Grade A steel shall stand being bent cold through 180° flat on itself, as shown in Fig. 1, without cracking on the outside of the bent portion.

6.1.2 The rivet shank of Grade B steel shall stand being bent cold through 180° without cracking on the outside of the bent portion in accordance with Table 2.

6.2 Rivet Flattening Tests — The rivet head shall stand being flattened, while hot, to a diameter $2\frac{1}{2}$ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges.

6.3 Bar Tensile Properties — Bars shall conform to the tensile requirements in accordance with Table 3.

6.4 Bar Bend Tests:

6.4.1 The test specimen for Grade A steel bars shall stand being bent cold through 180° flat on itself without cracking on the outside of the bent portion.

6.4.2 The test specimen for Grade B steel bars shall stand being bent cold through 180° without cracking on the outside of the bent portion to an inside diameter which shall have a relation to the diameter of the specimen in accordance with Table 4.

7. Dimensions, Mass, and Permissible Variations

7.1 Rivets:

7.1.1 The dimensions of rivets shall conform to B18.1.2 for nominal diameters in. and larger and B18.1.1 for nominal diameters $\frac{7}{16}$ in. and less.

7.1.2 Snap gage measurement shall be made at the point of minimum diameter, but it is not required that the rivet shall turn completely in the gage. Measurements of the maximum tolerance shall be made with a ring gage, all rivets to slip full to the head in the gage of the required size for the various diameters.

7.2 Bars — The diameter of hot-finished rivet bars shall not vary from the size specified by more than the amounts in accordance with Table 5.

8. Workmanship, Finish, and Appearance

8.1 Rivets — The finished rivets shall be true to form, concentric, and free of injurious defects.

8.2 Bars:

8.2.1 Bars shall be free of visible pipe, undue segregation, and injurious surface imperfections.

8.2.2 Surface Finish — The bars shall have a commercial hot-wrought finish obtained by conventional hot rolling. See 4.4 for producer's descaling option.

9. Number of Tests and Retests

9.1 Rivets — Sampling for rivet bend and rivet flattening tests shall be in accordance with Guide F 1470, detection process.

9.2 Bars:

9.2.1 Two tension tests shall be made from each heat, unless the finished material from a heat is less than 50 tons (45 Mg), when one tension test will be sufficient. However, for material 2 in. (51 mm) and under in thickness, when the material from one heat differs $\frac{3}{8}$ in. (9.5 mm) or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled regardless of the weight represented. Each test shall conform to the specified requirements.

9.2.2 Retests on bars may be made in accordance with Specification A 29/A 29M.

10. Specimen Preparation

10.1 Rivets — Rivets shall be tested in their full-size finished condition.

10.2 Bars:

10.2.1 Test specimen selection and preparation shall be in accordance with Specification A 29/A 29M and Test Methods and Definitions A 370.

10.2.2 Tension and bend test specimens for rivet bars which have been cold drawn shall be normalized before testing.

11. Test Methods

11.1 Rivets — Rivet bend and flattening tests shall be in accordance with the manufacturers standard test procedures.

11.2 Bars — Tension and bend tests shall be conducted in accordance with Test Methods and Definitions A 370, and especially Supplement I thereof, on steel bar products.

12. Inspection

12.1 If the testing described in Section 9 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Rivets — Rivets that fail to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13.2 Bars — Rejection and rehearing shall be in accordance with Specification A 29/A 29M.

14. Certification

14.1 The manufacturer shall furnish certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis (5.2) and mechanical property test results (Section 6) as applicable to the product ordered. The report shall include the manufacturer's name, ASTM designation, grade, heat number (bars only), and authorized signature.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

16. Packaging and Package Marking

16.1 Rivets — Rivets shall be properly packed and marked to prevent damage and loss during shipment.

16.2 Bars — Bars shall be packed and marked in accordance with Specification A 29/A 29M.

17. Keywords

17.1 bars; carbon steel; pressure vessel rivets; rivets; steel

FIG. 1 BEND TEST OF RIVET

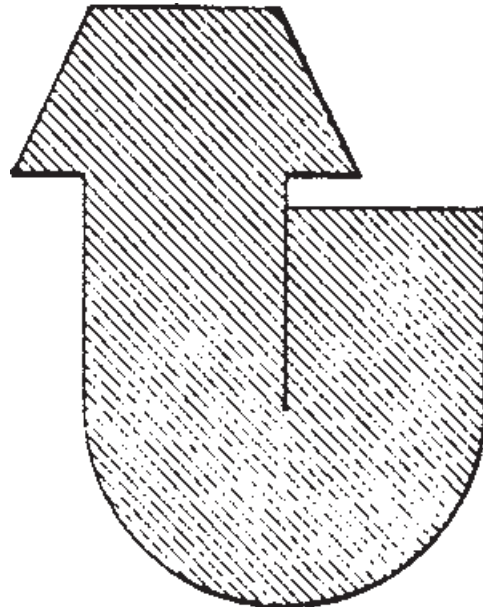


FIG. 2 FLATTENING TEST OF RIVET

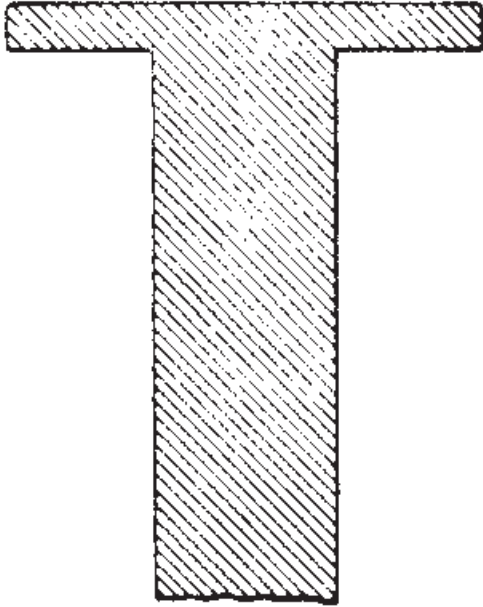


TABLE 1
CHEMICAL REQUIREMENTS

	Grade A		Grade B	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max., %	...	...	0.28	0.31
Manganese, %	0.30-0.60	0.27-0.63	0.30-0.80	0.27-0.83
Phosphorus, max., %	0.040	0.048	0.040	0.048
Sulfur, max., %	0.050	0.058	0.050	0.058

TABLE 2
BEND REQUIREMENTS, RIVETS

Diameter of Rivet Shank, in.	Ratio of Bend Diameter to Diameter of Rivet Shank	
	Grade A	Grade B
$\frac{3}{4}$ and under	flat	1
Over $\frac{3}{4}$	flat	$1\frac{1}{2}$

TABLE 3
TENSILE REQUIREMENTS, BARS

	Grade A	Grade B
Tensile strength, psi (MPa)	45 000-55 000 (310-380)	58 000-68 000 (400-470)
Yield point, min., psi (MPa)	23 000 (160)	29 000 (200)
Elongation in 8 in. or 200 mm, min., %	27	22
Elongation in 2 in. or 50 mm, min., %	33	25

TABLE 4
BEND REQUIREMENTS, BARS

Specimen Diameter, in.	Ratio of Bend Diameter to Diameter of Specimen	
	Grade A	Grade B
$\frac{3}{4}$ and under	flat	$\frac{1}{2}$
Over $\frac{3}{4}$	flat	1

TABLE 5
PERMISSIBLE VARIATIONS IN THE SIZE OF HOT-ROLLED ROUNDS

Specified Size, in.	Variations from Size, in.		Out-of-Round, ⁴ in.
	Over	Under	
$\frac{5}{16}$ and under	0.005	0.005	0.008
Over $\frac{5}{16}$ to $\frac{7}{16}$, incl	0.006	0.006	0.009
Over $\frac{7}{16}$ to $\frac{5}{8}$, incl	0.007	0.007	0.010
Over $\frac{5}{8}$ to $\frac{7}{8}$, incl	0.008	0.008	0.012
Over $\frac{7}{8}$ to 1, incl	0.009	0.009	0.013
Over 1 to $1\frac{1}{8}$, incl	0.010	0.010	0.015
Over $1\frac{1}{8}$ to $1\frac{1}{4}$, incl	0.011	0.011	0.016
Over $1\frac{1}{4}$ to $1\frac{3}{8}$, incl	0.012	0.012	0.018
Over $1\frac{3}{8}$ to $1\frac{1}{2}$, incl	0.014	0.014	0.021

⁴ Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross-section.

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SPECIFICATION FOR CARBON STRUCTURAL STEEL



SA-36/SA-36M



(Identical with ASTM Specification A36/A36M-14.)

Standard Specification for Carbon Structural Steel

1. Scope

1.1 This specification covers carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction of bridges and buildings, and for general structural purposes.

1.2 Supplementary requirements are provided for use where additional testing or additional restrictions are required by the purchaser. Such requirements apply only when specified in the purchase order.

1.3 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A6/A6M for information on weldability.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.5 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.6 For structural products produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of A6/A6M apply.

2. Referenced Documents

2.1 *ASTM Standards:*

- A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A27/A27M Specification for Steel Castings, Carbon, for General Application
- A307 Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
- A325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
- A325M Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength (Metric)
- A500 Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
- A501 Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
- A502 Specification for Rivets, Steel, Structural
- A563 Specification for Carbon and Alloy Steel Nuts
- A563M Specification for Carbon and Alloy Steel Nuts (Metric)
- A668/A668M Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use
- A1011/A1011M Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
- A1018/A1018M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Commercial, Drawing, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
- F568M Specification for Carbon and Alloy Steel Externally

TABLE 1 Appurtenant Material Specifications

NOTE 1—The specifier should be satisfied of the suitability of these materials for the intended application. Chemical composition or mechanical properties, or both, may be different than specified in A36/A36M.

Material	ASTM Designation
Steel rivets	A502, Grade 1
Bolts	A307, Grade A or F568M, Class 4.6
High-strength bolts	A325 or A325M
Steel nuts	A563 or A563M
Cast steel	A27/A27M, Grade 65–35 [450–240]
Forgings (carbon steel)	A668/A668M, Class D
Hot-rolled sheets and strip	A1011/A1011M, SS Grade 36 [250] Type 1 or Type 2 or A1018/A1018M, SS Grade 36 [250]
Cold-formed tubing	A500, Grade B
Hot-formed tubing	A501
Anchor bolts	F1554, Grade 36

Threaded Metric Fasteners (Metric) (Withdrawn 2012)
F1554 Specification for Anchor Bolts, Steel, 36, 55, and
105-ksi Yield Strength

3. Appurtenant Materials

3.1 When components of a steel structure are identified with this ASTM designation but the product form is not listed in the scope of this specification, the material shall conform to one of the standards listed in Table 1 unless otherwise specified by the purchaser.

4. General Requirements for Delivery

4.1 Structural products furnished under this specification shall conform to the requirements of the current edition of Specification A6/A6M, for the specific structural product ordered, unless a conflict exists in which case this specification shall prevail.

4.2 Coils are excluded from qualification to this specification until they are processed into a finished structural product. Structural products produced from coil means structural products that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operations involved in the processing of a coil into a finished structural product. Such operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For structural products produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding structural products produced from coil are described in Specification A6/A6M.

5. Bearing Plates

5.1 Unless otherwise specified, plates used as bearing plates for bridges shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 8.

5.2 Unless otherwise specified, mechanical tests shall not be required for plates over 1½ in. [40 mm] in thickness used as bearing plates in structures other than bridges, subject to the requirement that they shall contain 0.20 to 0.33 % carbon by heat analysis, that the chemical composition shall conform to the requirements of Table 3 in phosphorus and sulfur content, and that a sufficient discard shall be made to secure sound plates.

6. Materials and Manufacture

6.1 The steel shall be killed

7. Chemical Composition

7.1 The heat analysis shall conform to the requirements prescribed in Table 3, except as specified in 5.2.

7.2 The steel shall conform on product analysis to the requirements prescribed in Table 3, subject to the product analysis tolerances in Specification A6/A6M.

8. Tension Test

8.1 The material as represented by the test specimen, except as specified in 5.2 and 8.2, shall conform to the requirements as to the tensile properties prescribed in Table 2.

8.2 Shapes less than 1 in.² [645 mm²] in cross section and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer, provided that the chemical composition used is appropriate for obtaining the tensile properties in Table 2.

9. Keywords

9.1 bars; bolted construction; bridges; buildings; carbon; plates; riveted construction; shapes; steel; structural steel; welded construction

TABLE 2 Tensile Requirements^A

Plates, Shapes, ^B and Bars:	
Tensile strength, ksi [MPa]	58–80 [400–550]
Yield point, min, ksi [MPa]	36 [250] ^C
Plates and Bars: ^{D,E}	
Elongation in 8 in. [200 mm], min, %	20
Elongation in 2 in. [50 mm], min, %	23
Shapes:	
Elongation in 8 in. [200 mm], min, %	20
Elongation in 2 in. [50 mm], min, %	21 ^B

^A See the Orientation subsection in the Tension Tests section of Specification A6/A6M.

^B For wide flange shapes with flange thickness over 3 in. [75 mm], the 80 ksi [550 MPa] maximum tensile strength does not apply and a minimum elongation in 2 in. [50 mm] of 19 % applies.

^C Yield point 32 ksi [220 MPa] for plates over 8 in. [200 mm] in thickness.

^D Elongation not required to be determined for floor plate.

^E For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See the Elongation Requirement Adjustments subsection under the Tension Tests section of Specification A6/A6M.

TABLE 3 Chemical Requirements

NOTE 1—Where “. . .” appears in this table, there is no requirement. The heat analysis for manganese shall be determined and reported as described in the heat analysis section of Specification A6/A6M.

Product	Shapes ^A	Plates > 15-in. [380 mm] Width ^B					Bars; Plates ≤ 15-in. [380 mm] Width ^B			
		To ¾ [20], incl	Over ¾ to 1½, incl	Over 1½ to 2½, incl	Over 2½ to 4 [65 to 100], incl	Over 4 [100]	To ¾ [20], incl	Over ¾ to 1½, [20 to 40], incl	Over 1½ to 4 [100], incl	Over 4 [100]
Thickness, in. [mm]	All									
Carbon, max, %	0.26	0.25	0.25	0.26	0.27	0.29	0.26	0.27	0.28	0.29
Manganese, %	...	...	0.80–1.20	0.80–1.20	0.85–1.20	0.85–1.20	...	0.60–0.90	0.60–0.90	0.60–0.90
Phosphorus, max, %	0.04	0.030	0.030	0.030	0.030	0.030	0.04	0.04	0.04	0.04
Sulfur, max, %	0.05	0.030	0.030	0.030	0.030	0.030	0.05	0.05	0.05	0.05
Silicon, %	0.40 max	0.40 max	0.40 max	0.15–0.40	0.15–0.40	0.15–0.40	0.40 max	0.40 max	0.40 max	0.40 max
Copper, min, % when cop per steel is specified	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

^A Manganese content of 0.85–1.35 % and silicon content of 0.15–0.40 % is required for shapes with flange thickness over 3 in. [75 mm].

^B For each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage point manganese above the specified maximum will be permitted, up to the maximum of 1.35 %.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order.

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A6/A6M. Those that are considered suitable for use with this specification are listed by title:

S5. Charpy V-Notch Impact Test.

S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location

S32. Single Heat Bundles

S32.1 Bundles containing shapes or bars shall be from a single heat of steel.

SPECIFICATION FOR FERRITIC MALLEABLE IRON CASTINGS



SA-47/SA-47M

(21)

(Identical with ASTM Specification A47/A47M-99(2018)^{E1} except for the deletion of welded repair references in 11.2 and 11.3, and mandatory certification in 14.1.)

SPECIFICATION FOR FERRITIC MALLEABLE IRON CASTINGS



SA-47/SA-47M

[Identical with ASTM Specification A 47/A 47M-99(2018)^{e1}, except for the deletion of welded repair references in 11.2 and 11.3, and mandatory certification in 14.1.]

1. Scope

1.1 This specification covers ferritic malleable castings for general engineering usage at temperatures from normal ambient to approximately 400°C (750°F).

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings
- A 644 Terminology Relating to Iron Castings
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 140 Hardness Conversion Tables for Metals

2.2 Military Standard:

MIL-STD-129 Marking for Shipment and Storage

2.3 Federal Standard:

Fed. Std. No. 123 Marking for Domestic Shipment (Civilian Agencies)

3. Terminology

3.1 Definitions — Definitions for many terms common to iron are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced under this specification are classified under the following grades based on tests on separately cast test bars. Separately cast test bars shall be poured from the same lot of iron as the castings they represent and shall be heat treated with those castings except as provided in 7.2.3.

4.1.1 Grade 32510 [Grade 22010]:

4.1.1.1 The first three digits of the grade designation indicate the minimum yield strength ($\times 100$ psi [MPa]) and the last two digits indicate the minimum elongation (% in 2 in. [50 mm]).

5. Ordering Information

5.1 The purchase order for castings ordered under this specification shall state the specification designation, the year in which the specification was issued, and the grade of malleable iron to be supplied. Any option or special additions to the basic requirements of this specification shall be clearly and fully stipulated.

6. Chemical Composition

6.1 The chemical composition of the iron shall be such as to produce the structural and mechanical properties required by this specification.

7. Mechanical Properties

7.1 Factors influencing the properties of castings and their relationship to those of test specimens and separate test castings are discussed in Appendix X1.

7.2 Tension Test Specimens:

7.2.1 The tension test specimens shall be cast to the form and dimensions shown in Fig. 1 or Fig. 2, in the same kind of molding material used for the production castings. At least three such specimens shall be cast from a representative ladle of iron either from each batch-melted heat or, in continuous melting, from each 4 h pour period during which the purchaser's castings were poured, or as otherwise agreed upon between manufacturer and purchaser.

7.2.2 All test specimens shall be suitably identified with the designation of either the batch-melted heat or the pour period of a continuous heat.

7.2.3 All test specimens shall be heat treated in the same production furnaces and in the same cycles as the castings they represent. However, in those instances wherein the critical sections of the production castings differ appreciably from that of the central portion of the test specimens, the time cycle for tempering the test specimens may be altered from that of the production lot in order to obtain similar microstructures or hardness, or both, in both specimen and castings. In such cases the hardness of the specimens shall be tested and reported along with the tensile test results.

7.2.4 The tension test is usually performed on unmachined specimens. However, for referee work, the specimen may be machined from the standard cast bar to the dimensions shown in Fig. 3.

7.3 Tension Test Method:

7.3.1 The gage length of the standard tension specimen shall be 2.00 ± 0.01 in. [50.0 ± 0.3 mm].

7.3.2 The diameter used to compute the cross-sectional area shall be the average between the largest and smallest diameters in that section of the 2 in. [50 mm] gage length having the smallest diameter and shall be measured to the nearest 0.001 in. [0.2 mm]. No cast bar having a mean diameter less than 0.590 in. [15.0 mm] shall be accepted for test.

7.3.3 After reaching a stress equivalent to approximately half of the anticipated yield stress, the speed of the moving head of the testing machine shall not exceed 0.50 in./min [12.5 mm/min] through the breaking load.

7.3.4 While the values for yield point and yield strength are not identical, they are sufficiently close for most applications of ferritic malleable irons to be used interchangeably. They may be determined by any of the approved techniques described in the paragraphs on Determination of Yield Strength and Yield Point of Test Methods E 8. If determined as yield strength, that stress producing an extension under load of 0.01 in. [0.25 mm] over the 2 in. [50 mm] gage length (for example, 0.5% extension) or an offset of 0.2% shall be taken as the yield stress, which shall be converted to yield strength by dividing by

the original cross-sectional area of the gage length found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa]. In referee work, yield strength shall be determined as the stress that produces an extension under load of 0.5% of the gage length.

7.3.5 The tensile strength shall be the maximum load carried by the specimen during the test divided by the original cross-sectional area of the gage length, as found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa].

7.3.6 The elongation is the increase in gage length after fracture of a tensile specimen, measured to the nearest 0.01 in. [0.25 mm], expressed as a percentage of the original gage length. It shall be reported to the nearest 0.5%.

7.4 Retesting:

7.4.1 If, after testing, a specimen shows evidence of a defect, another tension test may be made on a companion specimen. Also, a retest shall be permitted whenever fracture occurs outside the central 50% of the gage length.

7.4.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification, the castings represented by these test specimens shall be rejected. A valid test is one wherein the test specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

7.4.3 If sufficient companion test bars are unavailable, the manufacturer shall have the option of testing a specimen cut from a representative casting. Therefore, as stated in X1.3, the mechanical properties of such tension test specimen removed from a production casting will not necessarily correspond to those of a standard separately cast test specimen, the values in Table 1 do not apply. Instead, the mechanical properties of the test specimen from the casting must equal or exceed the average of those from similar test specimens removed from the same location from two castings of the same design where separately cast test bars meet the requirements of Table 1.

7.4.4 If the first test results indicate that a reheat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be reheat treated together. Testing shall then be repeated in accordance with 7.4.1–7.4.3.

7.4.5 The results of all tests, including retests, shall be posted in permanent record, which shall state any abnormalities observed during the test and in the fractured ends. Such records shall be kept for at least 1 year after shipment of the production castings and shall be available for examination by the purchaser or by his authorized representative.

7.4.6 If not covered in the purchase agreement, the frequency of tension testing shall be in accordance with 7.2.1 and sufficiently often to ensure uniformity of product and compliance with minimum test requirements.

7.4.7 Tension test results, obtained in accordance with the above subsections, must conform to the values of Table 1 for acceptance under this specification except as provided in 7.4.3.

7.4.8 When agreed upon between manufacturer and purchaser, tested specimens or unbroken test bars shall be preserved by the manufacturer for a period of three months after the date of the test report.

7.5 Hardness Test— If the purchase agreement requires hardness testing, the acceptable hardness range shall be stated and a test location clearly shown on the covering drawing(s).

7.5.1 Hardness Test Method — The Brinell method of hardness testing in accordance with Test Method E 10 shall be employed whenever possible.

7.5.2 For castings of such size or shape that do not permit Brinell testing with the standard 3000-kgf load, the 500 kgf may be employed, the hardness number being reported as HB 10/500/15. In very unusual cases where it is impossible to use the Brinell method, the Rockwell test may be substituted, using Test Methods E 18 with an appropriate Rockwell scale. Conversions of hardness values from one method to another according to Standard E 140, which does not specifically cover cast irons, are approximate only and, therefore, are generally inadvisable.

7.5.3 Sufficient material shall be removed from the cast surface to ensure that the measured surface is representative.

7.5.4 Sampling procedures and the frequency of hardness testing shall be fully detailed on the purchase agreement. Otherwise, hardness tests shall be performed at the discretion of the producer.

7.5.5 Castings failing to conform to the required hardness range may be reheat treated and retested. If after reheat treating they still fail the hardness requirements, they shall be rejected.

7.5.6 Typical hardness maximums for this grade of malleable iron are listed in Table 2.

8. Microstructure Requirements

8.1 The microstructure of the malleable iron shall consist of temper carbon nodules distributed through a ferritic matrix and shall be free of excessive pearlite, massive carbides, and primary graphite.

8.2 When agreed upon by the purchaser and producer, the maximum decarburization at any as-cast surface after heat treatment may be stipulated in writing, as measured by visual depletion of combined carbon after polishing, etching in nital, and viewing at 100×.

8.3 In reference work, the metallographic practice recommended in Test Method A 247 shall be followed.

9. Soundness Requirements

9.1 All castings, on visual examination, shall be sound and free of obvious shrinkage and porosity.

9.2 If the purchaser requires soundness tests to be performed, it shall be so stated in the purchase agreement, and the method and soundness requirements shall be detailed.

10. Dimensional Requirements

10.1 The castings shall conform to the dimensions given on drawings furnished by the purchaser, or to the dimensions established by the pattern equipment supplied by the purchaser, or as agreed upon in specific cases to gages supplied by the purchaser. Variations in any solid dimensions will be permitted, as shown in Table 3, unless otherwise agreed upon by the foundry and purchaser.

11. Workmanship, Finish and Appearance

11.1 The surface of the casting shall be inspected visually, particularly in critical areas, for such surface defects as cracks, hot tears, adhering sand and scale, cold shuts, and gas holes.

11.2 No repairing or plugging of any kind shall be permitted unless written permission is granted by the purchaser. Welding or brazing is not permitted under any circumstances.

11.3 DELETED

12. Responsibility for Inspection

12.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

12.2 The purchaser reserves the right to perform any inspection set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

13. Rejection and Rehearing

13.1 Any casting or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the

tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

13.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly his basis for rejection. In case of dissatisfaction with the purchaser's claim, the manufacturer may apply for a hearing before final rejection of the shipment.

14. Certification

14.1 A manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results signed by an authorized agent of the manufacturer, shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

**TABLE 1
TENSION TEST REQUIREMENTS**

Inch-Pound Grades			
English Grade	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 2 in., min, %
32510	50 000	32 500	10
Metric Grades			
Metric Grade	Tensile Strength, min, MPa	Yield Strength, min, MPa	Elongation in 50 mm, min, %
22010	340	220	10

15. Product Marking

15.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing and, if not shown on the drawing, at such a location at the discretion of the producer that the identification will not interfere with subsequent processing and service of the casting.

16. Packaging and Package Marking

16.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

16.2 U.S. Government Procurement — When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 and MIL-STD-129.

**TABLE 2
TYPICAL HARDNESS**

Inch-Pound Grade [Metric Grade]	Hardness, Maximum HB	Indentation Value Diameters, mm
325 10 [22010]	156	4.8

**TABLE 3
PERMISSIBLE VARIATION IN ANY
SOLID DIMENSION**

Size, in. [mm]	Tolerance, ± in. [mm]
Up to 1 [Up to 25]	0.03 [0.8]
1 to 6 [25 to 150]	0.06 [1.6]
6 to 12 [151 to 300]	0.12 [3.2]
12 to 18 [301 to 460]	0.15 [3.8]
18 to 24 [461 to 600]	0.19 [4.8]
24 to 36 [601 to 900]	0.22 [5.6]

FIG. 1 TENSION TEST SPECIMEN

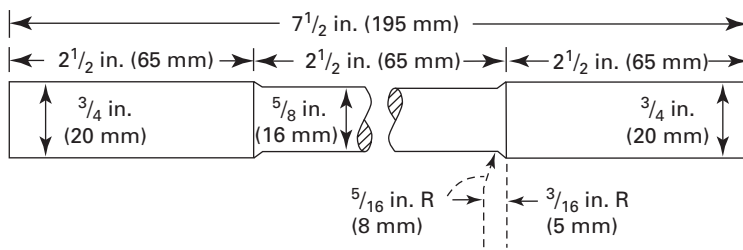
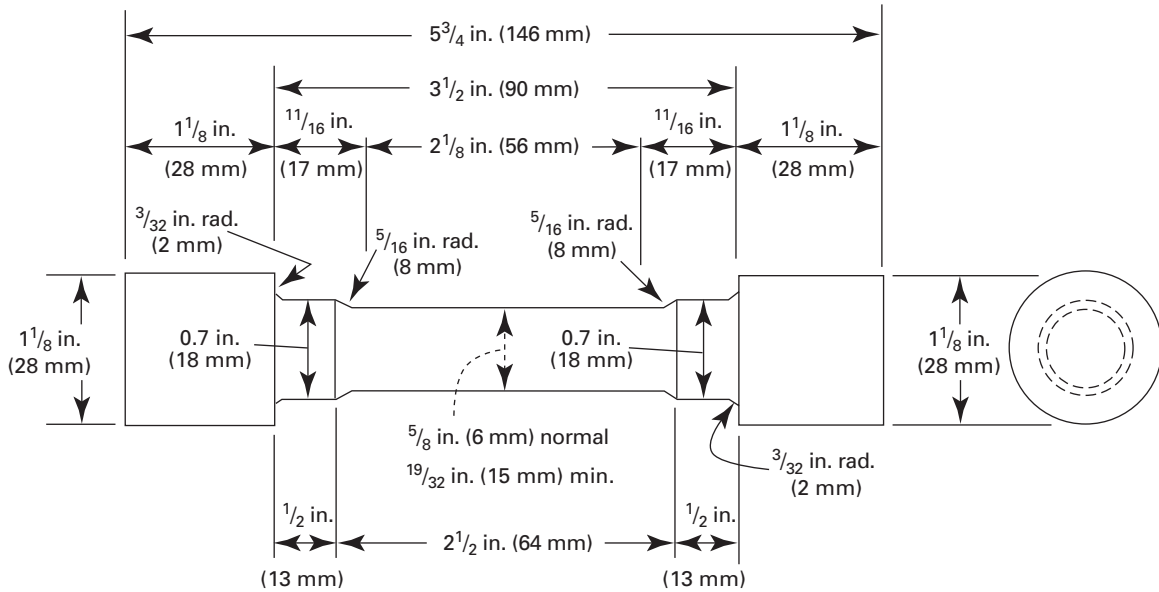
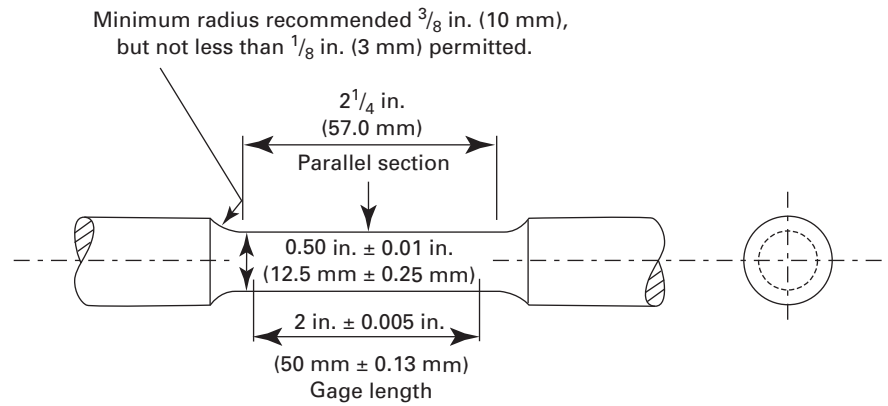


FIG. 2 ALTERNATIVE UNMACHINED TENSION TEST SPECIMEN



NOTE 1 — Modifications may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

FIG. 3 MACHINED TENSION TEST SPECIMEN



NOTE 1 — The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08 to 0.13 mm] larger in diameter than the center.

SUPPLEMENTARY REQUIREMENTS

S1. Special Conditions

S1.1 If agreed upon in writing by the foundry and purchaser, the malleable iron castings may be required to meet special conditions, hardness or other property dimensions, surface quality, or a combination of conditions.

S2. Test Lugs

S2.1 If requested in writing or if included on the pattern(s) or pattern drawing(s), test lugs may be cast on all castings of sufficient size to permit their incorporation. The size of such lugs shall be proportional to the thickness of the casting. On castings over 24 in. [600 mm] in length, a test lug shall be cast near each end such as not to interfere with any subsequent processing of the castings. The purchase order shall stipulate whether the foundry's inspector or the purchaser's inspector shall break, inspect, and pass judgment on the fracture quality of these test lugs.

S3. Destructive Tests

S3.1 At the option of the purchaser or his representative, a casting of each design ordered may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition that might be detrimental to the serviceability of the casting.

S4. Special Tension Specimens

S4.1 If tension specimens are to be machined from castings, their location in the casting, the specimen dimensions, and the required properties shall be agreed upon in writing by the foundry and purchaser.

S5. Zinc-Coated Castings

S5.1 When specified in the contract or purchase order, castings shall be zinc-coated by the hot-dip process in accordance with Specification A 153. Castings shall be of a composition that will preclude the possibility of galvanizing embrittlement, or shall be either cooled from the anneal or subsequently heat treated so as to be immunized against such embrittlement. If regalvanizing is required, procedures for regalvanizing castings and determining the effect on the casting performance must be agreed upon between the purchaser and the seller.

S6. Marking of Casting for Government Procurement

S6.1 When castings are specified for government procurement, the location of the permanent markings specified in 15.1, as well as any special marking for mechanical or physical properties (either permanent or temporary), shall be as indicated on the government drawings or sketches.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of malleable iron castings are influenced by a number of factors, including the cooling rate during solidification, chemical composition, the heat treatment, the design of the casting, section thickness, and the location and effectiveness of gates, risers, and chills.

X1.2 Because of the complexity of these factors in influencing the properties of the final product, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

X1.3 The specimen specified in 7.2.1 as the standard tensile test bar for malleable iron has a $\frac{5}{8}$ in. [16 mm] diameter test section that reasonably represents a typical

section of the general run of malleable iron castings. Furthermore, the initial freezing of malleable irons as homogeneous white iron, together with the heat treatment that is inherent in the manufacture of malleable iron, tends to reduce the section-sensitivity effect. Therefore, where experimentation into precise properties within a given casting would be infeasible, this standard test bar, made like any typical casting, should provide a practical approximation of the properties that can be expected in average sound malleable iron casting.

X1.4 If malleable iron castings are welded, the microstructure of the iron is markedly affected, particularly in the heat-affected zone. Therefore, since this may adversely affect the properties of the casting, the welding of malleable iron castings should be done under strict metallurgical control, followed by appropriate post-weld heat treatment, to minimize the substantial reductions in ductility, impact resistance, and machinability that could result, particularly in the vicinity of the weldment. Nevertheless, it is generally considered inadvisable to join castings to similar castings or to other materials, by fusion welding out in the field, or in manufactured assemblies, without fully testing the entire completed part.

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SPECIFICATION FOR PIPE, STEEL, BLACK AND HOT-DIPPED, ZINC-COATED, WELDED AND SEAMLESS



SA-53/SA-53M

(Identical with ASTM Specification A53/A53M-01 except for the insertion of test practices in 11.1.1, and editorial correction to Table X4.1.)

SPECIFICATION FOR PIPE, STEEL, BLACK AND HOT-DIPPED, ZINC-COATED, WELDED AND SEAMLESS



SA-53/SA-53M

(Identical with ASTM Specification A 53/A 53M-01 except for the insertion of test practices in 11.1.1, and editorial correction to Table X4.1.)

1. Scope

1.1 This specification covers seamless and welded black and hot-dipped galvanized steel pipe in NPS $\frac{1}{8}$ to NPS 26 [DN 6 to DN 650] (Note 1), inclusive, with nominal wall thickness (Note 2) as given in Table X2.2 and Table X2.3. It shall be permissible to furnish pipe having other dimensions (Note 2) provided such pipe complies with all other requirements of this specification.

NOTE 1 — The dimensionless designators NPS (nominal pipe size) [DN (diameter nominal)] have been substituted in this specification for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

NOTE 2 — The term nominal wall thickness has been assigned for the purpose of convenient designation, existing in name only, and is used to distinguish it from the actual wall thickness, which may vary over or under the nominal wall thickness.

1.2 This specification covers the following types and grades:

1.2.1 *Type F* — Furnace-butt welded, continuous welded Grade A,

1.2.2 *Type E* — Electric-resistance welded, Grades A and B, and

1.2.3 *Type S* — Seamless, Grades A and B.

NOTE 3 — See Appendix X1 for definitions of types of pipe.

1.3 Pipe ordered under this specification is intended for mechanical and pressure applications and is also acceptable for ordinary uses in steam, water, gas, and air lines. It is suitable for welding, and suitable for forming operations involving coiling, bending, and flanging, subject to the following qualifications:

1.3.1 Type F is not intended for flanging.

1.3.2 When Types S and E are required for close coiling or cold bending, Grade A is the preferred grade. This provision is not intended to prohibit the cold bending of Grade B pipe.

1.3.3 Type E is furnished either nonexpanded or cold expanded at the option of the manufacturer.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 The following precautionary caveat pertains only to the test method portion, Sections 9, 10, 11, 15, 16, and 17 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

2. Referenced Documents

2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A 865 Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints

- B 6 Specification for Zinc
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
- E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products
- E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 ANSI Standards:

ASC X12

B1.20.1 Pipe Threads, General Purpose

2.3 ASME Standard:

B36.10 Welded and Seamless Wrought Steel Pipe

2.4 Military Standards:

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.5 Federal Standards:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.6 API Standard:

5L Specification for Line Pipe

3. Ordering Information

3.1 Information items to be considered, if appropriate, for inclusion in the purchase order are as follows:

3.1.1 Specification designation (A 53 or A 53M, including year of issue),

3.1.2 Quantity (feet, metres, or number of lengths),

3.1.3 Grade (see Table 1),

3.1.4 Type (see 1.2 and Table 2),

3.1.5 Finish (black or galvanized),

3.1.6 Size (either nominal (NPS) [DN] and weight class or schedule number, or both; or outside diameter and nominal wall thickness, Table X2.2 and Table X2.3),

3.1.7 Length (specific or random, Section 18),

3.1.8 End finish (plain end or threaded, Section 13),

3.1.8.1 Threaded and coupled, if desired,

3.1.8.2 Threads only (no couplings), if desired,

3.1.8.3 Plain end, if desired,

3.1.8.4 Couplings power tight, if desired,

3.1.8.5 Taper tapped couplings for NPS 2 [DN 50] and smaller, if desired,

3.1.9 Close coiling, if required (see 8.2),

3.1.10 Skelp for tension tests, if permitted (see 17.2),

3.1.11 Certification (see Section 22),

3.1.12 End use of material,

3.1.13 Special requirements, and

3.1.14 Selection of applicable level of preservation and packaging and level of packing required, if other than as specified or if MIL-STD-163 applies (see 21.2).

4. Materials and Manufacture

4.1 The steel for both seamless and welded pipe shall be made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 The weld seam of electric-resistance welded pipe in Grade B shall be heat treated after welding to a minimum of 1000°F [540°C] so that no untempered martensite remains, or otherwise processed in such a manner that no untempered martensite remains.

4.4 When pipe is cold expanded, the amount of expansion shall not exceed 1½% of the outside diameter pipe size.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition in Table 1 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

6. Product Analysis

6.1 The purchaser is permitted to perform an analysis of two pipes from each lot of 500 lengths, or fraction thereof. Samples for chemical analysis, except for spectrographic analysis, shall be taken in accordance with Practice E 1806. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.2 If the analysis of either pipe does not conform to the requirements specified in Table 1, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

7.2 The yield strength corresponding to a permanent offset of 0.2% of the gage length of the specimen or to a total extension of 0.5% of the gage length under load shall be determined.

7.3 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8 [DN 200].

7.4 Transverse tension test specimens for electric-welded pipe NPS 8 [DN 200] and larger shall be taken opposite the weld. All transverse test specimens shall be approximately 1½ in. [40 mm] wide in the gage length, and shall represent the full wall thickness of the pipe from which the specimen was cut. This test is required for NPS 8 [DN 200] and larger.

8. Bending Requirements

8.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall be capable of being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter of the pipe, without developing cracks at any portion and without opening the weld.

8.2 When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter of the pipe, without failure.

8.3 Double-extra-strong pipe over NPS 1¼ [DN 32] need not be subjected to the bend test.

9. Flattening Test

9.1 The flattening test shall be made on pipe over NPS 2 [DN 50] with all thicknesses extra strong and lighter.

9.2 Seamless Pipe:

9.2.1 For seamless pipe, a test specimen at least 2½ in. [60 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 9.7, shall occur until the distance between the plates is less than the value of H calculated as follows:

$$H = (1 + e)t/(e + tD)$$

where:

H = distance between flattening plates, in. [mm]
(Note 4),

e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, and 0.07 for Grade B),

t = nominal wall thickness, in. [mm], and

D = specified outside diameter, in. [mm]

9.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite sides of the pipe meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

NOTE 4 — The H values have been calculated for standard and extra-heavy weight sizes from NPS 2½ to NPS 24 [DN 65 to DN 600], inclusive, and are shown in Table X2.1.

9.3 Electric-Resistance-Welded Pipe — A test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps, with the weld located either 0° or 90° from the line of direction of force as required in 9.3.1 or 9.3.2, whichever is applicable. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces at the weld shall occur until the distance between the plates is less than two thirds of the specified diameter of the pipe. As a second step, the flattening shall be continued as a test for ductility away from the weld. During the second step, no cracks or breaks on the inside or outside surfaces away from the weld, except as provided for in 9.7, shall occur until the distance between the plates is less than one third of the specified outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed by the flattening test shall be cause for rejection.

9.3.1 For pipe produced in single lengths, the flattening test specified in 9.3 shall be made using a test specimen taken from each end of each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force.

9.3.2 For pipe produced in multiple lengths, the flattening test specified in 9.3 shall be made as follows:

9.3.2.1 Test specimens taken from, and representative of, the front end of the first pipe intended to be supplied from each coil, the back end of the last pipe intended to be supplied from each coil, and each side of any intermediate weld stop location shall be flattened with the weld located at 90° from the line of direction of force.

9.3.2.2 Test specimens taken from pipe at any two locations intermediate to the front end of the first pipe and the back end of the last pipe intended to be supplied from each coil shall be flattened with the weld located at 0° from the line of direction of force.

9.3.3 For pipe that is to be subsequently reheated throughout its cross section and hot formed by a reducing process, the manufacturer shall have the option of obtaining

the flattening test specimens required by 9.3.1 or 9.3.2, whichever is applicable, either prior to or after such hot reducing.

9.4 Continuous-Welded Pipe — A test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps. The weld shall be located at 90° from the line of direction of force. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside, outside, or end surfaces at the weld shall occur until the distance between the plates is less than three fourths of the specified diameter of the pipe. As a second step, the flattening shall be continued as a test for ductility away from the weld. During the second step, no cracks or breaks on the inside, outside, or end surfaces away from the weld, except as provided for in 9.7, shall occur until the distance between the plates is less than 60% of the specified outside diameter of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed by the flattening test shall be cause for rejection.

9.5 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 14.

9.6 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

9.7 When low D -to- t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the D -to- t ratio is less than 10.

10. Hydrostatic Test

10.1 The hydrostatic test shall be applied, without leakage through the pipe wall, to each length of pipe except as provided in 11.2 for seamless pipe.

10.2 Each length of plain-end pipe shall be hydrostatically tested to the pressures prescribed in Table X2.2, and each threaded-and-coupled length shall be hydrostatically tested to the pressures prescribed in Table X2.3. It shall be permissible, at the discretion of the manufacturer, to perform the hydrostatic test on pipe with plain ends, with threads only, or with threads and couplings and also shall be permissible to test pipe in either single lengths or multiple lengths.

NOTE 5 — The hydrostatic test pressures given herein are inspection test pressures, are not intended as a basis for design, and do not have any direct relationship to working pressures.

10.3 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17 200 kPa] for NPS 3 [DN 80] and under, nor 2800 psi [19 300 kPa] for all sizes over NPS 3 [DN 80]. This does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic pressure shall be maintained for not less than 5 s for all sizes of seamless and electric-welded pipe.

11. Nondestructive Electric Test

11.1 Type E Pipe:

11.1.1 The weld seam of each length of ERW pipe NPS 2 [DN 50] and larger shall be tested with a nondestructive electric test in accordance with Practice E 213, E 309, or E 570 as follows:

11.1.2 Ultrasonic and Electromagnetic Inspection — Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 11.1.3 at least once every working turn or not more than 8 h to demonstrate its effectiveness and the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product.

11.1.3 Reference Standards — The length of the reference standards shall be determined by the pipe manufacturer, and they shall have the same specified diameter and thickness as the product being inspected. Reference standards shall contain machined notches, one on the inside surface and one on the outside surface, or a drilled hole, as shown in Fig. 1, at the option of the pipe manufacturer. The notches shall be parallel to the weld seam, and shall be separated by a distance sufficient to produce two separate and distinguishable signals. The $\frac{1}{8}$ -in. [3.2-mm] hole shall be drilled through the wall and perpendicular to the surface of the reference standard as shown in Fig. 1. Care shall be taken in the preparation of the reference standard to ensure freedom from fins or other edge roughness, or distortion of the pipe.

NOTE 6 — The calibration standards defined in 11.1.3 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

11.1.4 Acceptance Limits — Table 3 gives the height of acceptance limit signals in percent of the height of signals produced by reference standards. Imperfections in the weld seam that produce a signal greater than the acceptance limit signal given in Table 3 shall be considered a defect unless the pipe manufacturer can demonstrate that

the imperfection does not reduce the effective wall thickness beyond 12½% of the specified wall thickness.

11.2 Seamless Pipe — As an alternative to the hydrostatic test, and when specified by the purchaser, the full body of each seamless pipe shall be tested with a nondestructive electric test in accordance with Practices E 213, E 309, or E 570. In this case each length so furnished shall include the mandatory marking of the letters “NDE.” Except as provided in 11.2.6.2 it is the intent of this test to reject pipe with imperfections which produce test signals equal to or greater than that of the calibration standard.

11.2.1 When the nondestructive electric test is performed, the lengths shall be marked with the letters “NDE.” The certification, when required, shall state Nondestructive Electric Tested and shall indicate which of the tests was applied. Also, the letters NDE shall be appended to the product specification number and material grade shown on the certification.

11.2.2 The following information is intended to facilitate the use of this specification.

11.2.2.1 The calibration standards defined in 11.2.3 through 11.2.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

11.2.2.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections; however, different techniques need to be employed for the detection of differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

11.2.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type.

11.2.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only require longitudinal calibration for flux leakage. Different techniques need to be employed for the detection of differently oriented imperfections.

11.2.2.5 The hydrostatic test referred to in 10.2 has the capability of finding imperfections of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

11.2.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that are capable of being detected in the specific application of these examinations is directed to discuss this with the manufacturer of the tubular product.

11.2.3 For ultrasonic testing, the calibration reference notches shall be at the option of the producer, and shall be any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12.5% of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

11.2.4 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following calibration standards to establish a minimum sensitivity level for rejection.

11.2.4.1 Drilled Hole — Depending upon the pipe diameter the calibration pipe shall contain three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

NPS	DN	Diameter of Drilled Hole
≤ ½	≤ 15	0.039 in. (1 mm)
> ½ ≤ 1¼	> 15 ≤ 32	0.055 in. (1.4 mm)
> 1¼ ≤ 2	> 32 ≤ 50	0.071 in. (1.8 mm)
> 2 ≤ 5	> 50 ≤ 125	0.087 in. (2.2 mm)
> 5	> 125	0.106 in. (2.7 mm)

11.2.4.2 Transverse Tangential Notch — Using a round tool or file with a ¼ in. [6 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding 12.5% of the specified wall thickness of the pipe or 0.012 in. [0.3 mm], whichever is greater.

11.2.4.3 Longitudinal Notch — A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12.5% of the specified wall thickness of the tube or 0.012 in. [0.3 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

11.2.4.4 Compatibility — The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

11.2.5 For flux leakage testing, the longitudinal calibration reference notches shall be straight sided notches machined in a radial plane parallel to the pipe axis. For wall thickness under 0.500 in. [12.7 mm], outside and inside notches shall be used. For wall thickness equal and above 0.500 in. [12.7 mm], only an outside notch shall be

used. Notch depth shall not exceed 12.5% of the specified wall thickness, or 0.012 in. [0.3 mm], whichever is greater. Notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

11.2.6 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be rejected.

11.2.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like imperfections, shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by the specification. It shall be permissible to reduce the outside diameter at the point of grinding by the amount so removed.

11.2.6.2 It shall be permissible to evaluate test signals produced by visual imperfections in accordance with provisions of Section 14. A few examples of these imperfections would be straightener marks, cutting chips, scratches, steel die stamps, stop marks, or pipe reducer ripple.

11.2.7 The test methods described in this section are not necessarily capable of inspecting the end portion of pipes. This condition is referred to as end effect. The length of the end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

12. Permissible Variations in Weight and Dimensions

12.1 Weight — The weight of the pipe as specified in Table X2.2 and Table X2.3 or as calculated from the relevant equation in ASME B36.10M shall not vary by more than $\pm 10\%$.

NOTE 7 — The weight tolerance is determined from the weights of the customary lifts of pipe as produced for shipment by the mill, divided by the number of feet of pipe in the lift. On pipe sizes over NPS 4 [DN 100], where individual lengths are weighed, the weight tolerance is applicable to the individual length.

12.2 Diameter — For pipe NPS $1\frac{1}{2}$ [DN 40] and under, the outside diameter at any point shall not vary more than $\pm \frac{1}{64}$ in. [0.4 mm] from the standard specified. For pipe NPS 2 [DN 50] and over, the outside diameter shall not vary more than $\pm 1\%$ from the standard specified.

12.3 Thickness — The minimum wall thickness at any point shall be not more than 12.5% under the nominal wall thickness specified. The minimum wall thickness on

inspection shall conform to the requirements in Table X2.4.

13. End Finish

13.1 When ordered with plain ends, the pipe shall be furnished to the following practice, unless otherwise specified.

13.1.1 NPS $1\frac{1}{2}$ [DN 40] and Smaller — Unless otherwise specified on the purchase order, end finish shall be at the option of the manufacturer.

13.1.2 NPS 2 [DN 50] and Larger:

13.1.2.1 Pipe of standard or extra strong weights, or in wall thickness less than 0.500 in. [12.7 mm], other than double extra strong pipe, shall be plain-end beveled with ends beveled to an angle of 30° , $+5^\circ$, -0° , measured from a line drawn perpendicular to the axis of the pipe, and with a root face of $\frac{1}{16}$ in. $\pm \frac{1}{32}$ in. [1.6 mm \pm 0.8 mm].

13.1.2.2 Pipe with wall thicknesses over 0.500 in. [12.7 mm], and all double extra strong, shall be plain-end square cut.

13.2 When ordered with threaded ends, the pipe ends shall be provided with a thread in accordance with the gaging practice and tolerances of ANSI B1.20.1. For standard-weight pipe NPS 6 [DN 150] and smaller, refer to Table X3.1 for threading data. For standard-weight pipe NPS 8 [DN 200] and larger and all sizes of extra-strong weight and double extra-strong weight, refer to Table X3.2 for threading data. Threaded pipe NPS 4 [DN 100] and larger shall have thread protectors on the ends not protected by a coupling.

13.3 When ordered with couplings, one end of each length of pipe shall be provided with a coupling manufactured in accordance with Specification A 865. The coupling threads shall be in accordance with the gaging practice of ANSI B1.20.1. The coupling shall be applied handling-tight, unless power-tight is specified on the order. Couplings are to be made of steel. Taper-tapped couplings shall be furnished on all weights of threaded pipe sizes NPS $2\frac{1}{2}$ [DN 65] and larger. For pipe NPS 2 [DN 50] and smaller, it is regular practice to furnish straight-tapped couplings for standard-weight pipe and taper-tapped couplings for extra-strong and double extra-strong pipe. If taper-tapped couplings are required for pipe NPS 2 [DN 50] and smaller on standard-weight pipe, it is recommended that line pipe threads in accordance with API Specification 5L be ordered. The taper-tapped couplings provided on line pipe in these sizes may be used on mill-threaded standard-weight pipe of the same size.

14. Workmanship, Finish and Appearance

14.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth.

14.2 Surface imperfections that penetrate more than $12\frac{1}{2}\%$ of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with defects shall be given one of the following dispositions:

14.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within specified limits,

14.2.2 Type S pipe and the parent metal of Type E pipe, except within $\frac{1}{2}$ in. [13 mm] of the fusion line of the electric resistance seam, are permitted to be repaired in accordance with the welding provisions of 14.5. Repair welding of Type F pipe and the weld seam of Type E is prohibited.

14.2.3 The section of pipe containing the defect may be cut off within the limits of requirement on length, or

14.2.4 Rejected.

14.3 At the purchaser's discretion, pipe shall be subjected to rejection if surface defects repaired in accordance with 14.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

14.4 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. It shall be permissible to reduce the outside diameter at the point of grinding by the amount so removed.

14.4.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In the case of a dispute, the measurement determined by use of the mechanical caliper shall govern.

14.5 Weld repair shall be permitted only subject to approval of the purchaser and in accordance with Specification A 530/A 530M.

14.6 The finished pipe shall be reasonably straight.

14.7 The pipe shall contain no dents greater than 10% of the pipe diameter or $\frac{1}{4}$ in. [6 mm], whichever is smaller, measured as a gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold-formed dents deeper than $\frac{1}{8}$ in. [3 mm] shall be free of sharp bottom gouges; it shall be permissible to remove the gouges by grinding, provided that the remaining wall

thickness is within specified limits. The length of the dent in any direction shall not exceed one half the pipe diameter.

15. Number of Tests

15.1 Except as required by 15.2, one of each of the tests specified in Section 7, 8.2, and Section 9 shall be made on test specimens taken from one length of pipe from each lot of each pipe size. For continuous-welded pipe, a lot shall contain no more than 25 tons [23 Mg] of pipe for pipe sizes NPS $1\frac{1}{2}$ [DN 40] and smaller, and no more than 50 tons [45 Mg] of pipe for pipe sizes NPS 2 [DN 50] and larger. For seamless and electric-resistance-welded pipe, a lot shall contain no more than one heat, and at the option of the manufacturer shall contain no more than 500 lengths of pipe (as initially cut after the final pipe-forming operation, prior to any further cutting to the required ordered lengths) or 50 tons [45 Mg] of pipe.

15.2 The number of flattening tests for electric-resistance-welded pipe shall be in accordance with 9.3.1 or 9.3.2, whichever is applicable.

15.3 Except as allowed by 11.2, each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

16. Retests

16.1 If the results of the mechanical tests of any lot do not conform to the requirements specified in Sections 7, 8, and 9, retests are permitted to be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

16.2 For pipe produced in single lengths, if any section of the pipe fails to comply with the requirements of 9.3, it shall be permissible to cut other sections from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80% of its length after the original cropping; otherwise the length shall be rejected. For pipe produced in multiple lengths, it shall be permissible to cut retests from each end of each individual length in the multiple. Such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

17. Test Methods

17.1 The test specimens and the tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

17.2 The longitudinal tension test specimen shall be taken from the end of the pipe or, for continuous-welded pipe, it shall be permissible to be taken from the skelp, at

a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. If desired, the tension tests are permitted to be made on the full section of pipe. When impracticable to pull a test specimen in full section, the standard 2-in. [50-mm] gage length tension test specimen shown in Fig. A2.3 of Test Methods and Definitions A 370 is acceptable.

17.3 Transverse weld test specimens from electric-resistance-welded pipe shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately 1½ in. [40 mm] wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

17.4 Test specimens for the bend and flattening tests shall be taken from pipe. Test specimens for the flattening test shall be smooth on the ends and free from burrs.

17.5 All specimens shall be tested at room temperature.

18. Lengths

18.1 Unless otherwise specified, pipe lengths shall be in accordance with the following regular practice.

18.1.1 Pipe of weights lighter than extra strong shall be in single-random lengths of 16 to 22 ft [4.88 to 6.71 m], but not more than 5% of the total number of threaded lengths are permitted to be jointers (two pieces coupled together). When ordered with plain ends, 5% are permitted to be in lengths of 12 to 16 ft [3.66 to 4.88 m].

18.1.2 Pipe of extra-strong and heavier weights shall be in random lengths of 12 to 22 ft [3.66 to 6.71 m]. Five percent are permitted to be in lengths of 6 to 12 ft [1.83 to 3.66 m].

18.1.3 When extra-strong or lighter pipe is ordered in double-random lengths, the minimum lengths shall be not less than 22 ft [6.71 m], with a minimum average for the order of 35 ft [10.67 m].

18.1.4 When lengths longer than single random are required for wall thicknesses heavier than extra-strong, the length shall be subject to negotiation.

18.1.5 When pipe is furnished with threads and couplings, the length shall be measured to the outer face of the coupling.

19. Galvanized Pipe

19.1 Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

19.2 *Weight of Coating* — The weight of zinc coating shall be not less than 1.8 oz/ft² [0.55 kg/m²] as determined

from the average results of the two specimens taken for test in the manner prescribed in 19.5 and not less than 1.6 oz/ft² [0.49 kg/m²] for either of these specimens. The weight of coating expressed in ounces per square foot shall be calculated by dividing the total weight of zinc, inside plus outside, by the total area, inside plus outside, of the surface coated. Each specimen shall have not less than 1.3 oz/ft² [0.40 kg/m²] of zinc coating on each surface, calculated by dividing the total weight of zinc on the given surface (outside or inside) by the area of the surface coated (outside or inside).

19.3 *Weight of Coating Test* — The weight of zinc coating shall be determined by a stripping test in accordance with Test Method A 90/A 90M. The total zinc on each specimen shall be determined in a single stripping operation.

19.4 *Test Specimens* — Test specimens for determination of weight of coating shall be cut approximately 4 in. [100 mm] in length.

19.5 *Number of Tests* — Two test specimens for the determination of weight of coating shall be taken, one from each end of one length of galvanized pipe selected at random from each lot of 500 lengths or fraction thereof, of each size.

19.6 *Retests* — If the weight of coating of any lot does not conform to the requirements specified in 19.2, retests of two additional pipes from the same lot shall be made, each of which shall conform to the requirements specified.

19.7 When pipe ordered under this specification is to be galvanized, the tension, flattening, and bend tests shall be made on the base material before galvanizing. When specified, results of the mechanical tests on the base material shall be reported to the purchaser. If it is impracticable to make the mechanical tests on the base material before galvanizing, it shall be permissible to make such tests on galvanized samples, and any flaking or cracking of the zinc coating shall not be considered cause for rejection. When galvanized pipe is bent or otherwise fabricated to a degree that causes the zinc coating to stretch or compress beyond the limit of elasticity, some flaking of the coating is acceptable.

20. Inspection

20.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at

the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

21. Rejection

21.1 The purchaser is permitted to inspect each length of pipe received from the manufacturer and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length shall be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

21.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, shall be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

22. Certification

22.1 The producer or supplier shall, upon request, furnish to the purchaser a certificate of inspection stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification (including year of issue), and has been found to meet the requirements.

22.2 Report — For Types E and S, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

22.3 EDI — A certificate of inspection or chemical analysis report printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The use and format of the EDI document are subject to agreement between the purchaser and the supplier.

NOTE 8 — EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

22.4 Notwithstanding the absence of a signature, the organization submitting the certificate of inspection or chemical analysis report is responsible for its content.

23. Product Marking

23.1 Except as allowed by 23.5 and 23.6, each length of pipe shall be legibly marked in the following sequence by rolling, stamping, or stenciling to show:

23.1.1 Manufacturer's name or mark,

23.1.2 Specification number (year of issue not required),

NOTE 9 — Pipe that complies with multiple compatible specifications may be marked with the appropriate designation for each specification.

23.1.3 Size (NPS and weight class, schedule number, or nominal wall thickness; or specified outside diameter and nominal wall thickness),

23.1.4 Grade (A or B),

23.1.5 Type of pipe (F, E, or S),

23.1.6 Test pressure, seamless pipe only (if applicable, in accordance with Table 4),

23.1.7 Nondestructive electric test, seamless pipe only (if applicable, in accordance with Table 4),

23.2 Unless another marking format is specified in the purchase order, length shall be marked in feet and tenths of a foot, or metres to two decimal places, dependent upon the units to which the pipe was ordered. The location of such marking shall be at the option of the manufacturer.

23.3 Heat number, lot number, run number, or a combination thereof shall be marked at the option of the manufacturer, unless specific marking is specified in the purchase order. The location of such marking shall be at the option of the manufacturer.

23.4 Any additional information desired by the manufacturer or specified in the purchase order.

23.5 For pipe NPS 1½ [DN 40] and smaller that is bundled, it shall be permissible to mark this information on a tag securely attached to each bundle.

23.6 When pipe sections are cut into shorter lengths by a subsequent producer for resale as material, the processor shall transfer complete identification including the name or brand of the manufacturer, to each unmarked cut length, or to metal tags securely attached to unmarked pipe bundled in accordance with the requirements of 23.5. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

23.7 Bar Coding — In addition to the requirements in 23.1, 23.5, and 23.6, bar coding is acceptable as a supplementary identification method. It is recommended that bar coding be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

24. Government Procurement

24.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of

such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Federal Std. No. 183 if continuous marking is required, for military agencies.

24.2 Inspection — Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the manufacturer shall use its own or any other suitable facilities for performing the inspection and test requirements specified herein, unless otherwise disapproved by the purchaser in the contract or purchase order. The purchaser shall have the right to perform any of the inspections and tests set forth

in this specification where deemed necessary to ensure that the material conforms to prescribed requirements.

25. Packaging and Package Marking

25.1 When specified on the purchase order, packaging, marking, and loading or shipment shall be in accordance with those procedures recommended by Practices A 700.

26. Keywords

26.1 black steel pipe; seamless steel pipe; steel pipe; welded steel pipe; zinc coated steel pipe

FIG. 1 CALIBRATION STANDARDS

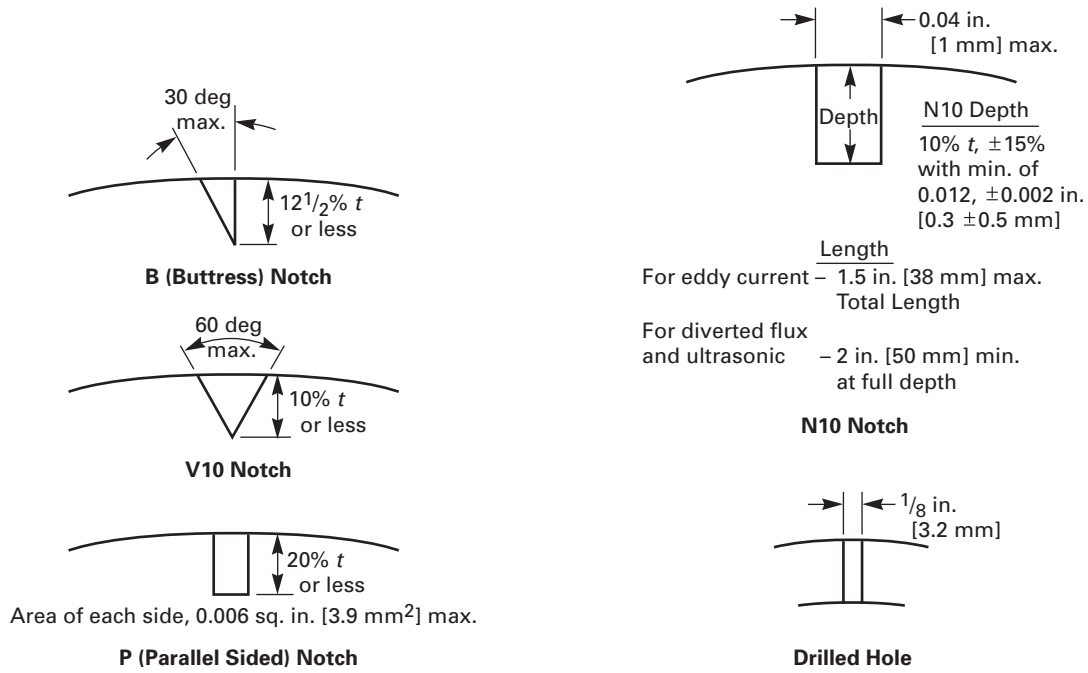


TABLE 1
 CHEMICAL REQUIREMENTS

	Composition, max, %								
	Carbon	Manganese	Phosphorus	Sulfur	Copper ^A	Nickel ^A	Chromium ^A	Molybdenum ^A	Vanadium ^A
Type S (seamless pipe)									
Open-hearth, electric-furnace, or basic-oxygen:									
Grade A	0.25	0.95	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Type E (electric-resistance-welded)									
Open-hearth, electric-furnace, or basic-oxygen:									
Grade A	0.25	0.95	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Type F (furnace-welded pipe)									
Open-hearth, electric-furnace, or basic oxygen									
Grade A	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08

^A The combination of these five elements shall not exceed 1.00%.

TABLE 2
TENSILE REQUIREMENTS

	Type F	Types E and S	
	Open-Hearth, Basic Oxygen, or Electric- Furnace, Grade A	Grade A	Grade B
Tensile strength, min, psi [MPa]	48 000 [330]	48 000 [330]	60 000 [415]
Yield strength, min, psi [MPa]	30 000 [205]	30 000 [205]	35 000 [240]
Elongation in 2 in. [50 mm]	<i>A,B</i>	<i>A,B</i>	<i>A,B</i>

^A The minimum elongation in 2 in. [50 mm] shall be that determined by the following equation:

$$e = 625\,000 [1940] A^{0.2}/U^{0.9}$$

where:

- e = minimum elongation in 2 in. [50 mm] in percent rounded to the nearest percent
- A = cross-sectional area of the tension specimen, rounded to the nearest 0.01 in.² [1 mm²], based on the specified outside diameter or the nominal specimen width and specified wall thickness. If the area calculated is equal to or greater than 0.75 in.² [500 mm²], then the value 0.75 in.² [500 mm²] shall be used, and
- U = specified tensile strength, psi [MPa]

^B See Table X4.1 or Table X4.2, whichever is applicable, for minimum elongation values for various size tension specimens and grades.

TABLE 3
ACCEPTANCE LIMITS

Type Notch	Size of Hole		Acceptance Limit Signal, %
	in.	mm	
N10, V10	1/8	3.2	100
B.P.	...	...	80

TABLE 4
MARKING OF SEAMLESS PIPE

Hydro	NDE	Marking
Yes	No	Test pressure
No	Yes	NDE
Yes	Yes	Test pressure/NDE

APPENDICES

(Nonmandatory Information)

X1. DEFINITIONS OF TYPES OF PIPE

X1.1 *Type F, Furnace-Butt-Welded Pipe, Continuous-Welded* — Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

X1.2 *Type E, Electric-Resistance-Welded Pipe* — Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which

the pipe is a part, and by the application of pressure.

X1.3 *Type S, Wrought Steel Seamless Pipe* — Wrought steel seamless pipe is a tubular product made without a welded seam. It is manufactured by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

X2. TABLES FOR DIMENSIONAL AND CERTAIN MECHANICAL REQUIREMENTS

X2.1 Tables X2.1–X2.4 address dimensional and certain mechanical requirements.

TABLE X2.1
CALCULATED *H* VALUES FOR SEAMLESS PIPE

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Distance, in. [mm], Between Plates " <i>H</i> " by Formula: $H = (1 + e)t/(e + t/D)$	
				Grade A	Grade B
2½	65	2.875 [73.0]	0.203 [5.16]	1.378 [35.0]	1.545 [39.2]
			0.276 [7.01]	1.618 [41.1]	1.779 [45.2]
3	80	3.500 [88.9]	0.216 [5.49]	1.552 [39.4]	1.755 [44.6]
			0.300 [7.62]	1.861 [47.3]	2.062 [52.4]
3½	90	4.000 [101.6]	0.226 [5.74]	1.682 [42.7]	1.912 [48.6]
			0.318 [8.08]	2.045 [51.9]	2.276 [57.8]
4	100	4.500 [114.3]	0.237 [6.02]	1.811 [46.0]	2.067 [52.5]
			0.337 [8.56]	2.228 [56.6]	2.489 [63.2]
5	125	5.563 [141.3]	0.258 [6.55]	2.062 [52.4]	2.372 [60.2]
			0.375 [9.52]	2.597 [66.0]	2.920 [74.2]
6	150	6.625 [168.3]	0.280 [7.11]	2.308 [58.6]	2.669 [67.8]
			0.432 [10.97]	3.034 [77.1]	3.419 [86.8]
8	200	8.625 [219.1]	0.277 [7.04]	2.473 [62.8]	2.902 [73.7]
			0.322 [8.18]	2.757 [70.0]	3.210 [81.5]
			0.500 [12.70]	3.683 [93.5]	4.181 [106.2]
			0.279 [7.09] ^A	2.623 [66.6]	3.111 [79.0]
10	250	10.750 [273.0]	0.307 [7.80]	2.823 [71.7]	3.333 [84.7]
			0.365 [9.27]	3.210 [81.5]	3.757 [95.4]
			0.500 [12.70]	3.993 [101.4]	4.592 [116.6]
			0.300 [7.62]	3.105 [78.9]	3.683 [93.5]
12	300	12.750 [323.8]	0.375 [9.52]	3.423 [86.9]	4.037 [102.5]
			0.500 [12.70]	4.218 [107.1]	4.899 [124.4]
			0.375 [9.52]	3.500 [88.9]	4.146 [105.3]
14	350	14.000 [355.6]	0.500 [12.70]	4.336 [110.1]	5.061 [128.5]
			0.375 [9.52]	3.603 [91.5]	4.294 [109.1]
16	400	16.000 [406.4]	0.500 [12.70]	4.494 [114.1]	5.284 [134.2]
			0.375 [9.52]	3.688 [93.7]	4.417 [112.2]
18	450	18.000 [457]	0.500 [12.70]	4.628 [117.6]	5.472 [139.0]
			0.375 [9.52]	3.758 [95.5]	4.521 [114.8]
20	500	20.000 [508]	0.500 [12.70]	4.740 [120.4]	5.632 [143.1]
			0.375 [9.52]	3.869 [98.3]	4.686 [119.0]
24	600	24.000 [610]	0.500 [12.70]	4.918 [124.9]	5.890 [149.6]
			0.375 [9.52]	3.869 [98.3]	4.686 [119.0]

^A Special order only.

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ^A psi [kPa]	
							Grade A	Grade B
1/8	6	0.405 [10.3]	0.068 [1.73]	0.24 [0.37]	STD	40	700 [4800]	700 [4800]
			0.095 [2.41]	0.31 [0.47]	XS	80	850 [5900]	850 [5900]
1/4	8	0.540 [13.7]	0.088 [2.24]	0.43 [0.63]	STD	40	700 [4800]	700 [4800]
			0.119 [3.02]	0.54 [0.80]	XS	80	850 [5900]	850 [5900]
3/8	10	0.675 [17.1]	0.091 [2.31]	0.57 [0.84]	STD	40	700 [4800]	700 [4800]
			0.126 [3.20]	0.74 [1.10]	XS	80	850 [5900]	850 [5900]
1/2	15	0.840 [21.3]	0.109 [2.77]	0.85 [1.27]	STD	40	700 [4800]	700 [4800]
			0.147 [3.73]	1.09 [1.62]	XS	80	850 [5900]	850 [5900]
			0.188 [4.78]	1.31 [1.95]	...	160	900 [6200]	900 [6200]
			0.294 [7.47]	1.72 [2.55]	XXS	...	1000 [6900]	1000 [6900]
3/4	20	1.050 [26.7]	0.113 [2.87]	1.13 [1.69]	STD	40	700 [4800]	700 [4800]
			0.154 [3.91]	1.48 [2.20]	XS	80	850 [5900]	850 [5900]
			0.219 [5.56]	1.95 [2.90]	...	160	950 [6500]	950 [6500]
			0.308 [7.82]	2.44 [3.64]	XXS	...	1000 [6900]	1000 [6900]
1	25	1.315 [33.4]	0.133 [3.38]	1.68 [2.50]	STD	40	700 [4800]	700 [4800]
			0.179 [4.55]	2.17 [3.24]	XS	80	850 [5900]	850 [5900]
			0.250 [6.35]	2.85 [4.24]	...	160	950 [6500]	950 [6500]
			0.358 [9.09]	3.66 [5.45]	XXS	...	1000 [6900]	1000 [6900]
1 1/4	32	1.660 [42.2]	0.140 [3.56]	2.27 [3.39]	STD	40	1200 [8300]	1300 [9000]
			0.191 [4.85]	3.00 [4.47]	XS	80	1800 [12 400]	1900 [13 100]
			0.250 [6.35]	3.77 [5.61]	...	160	1900 [13 100]	2000 [13 800]
			0.382 [9.70]	5.22 [7.77]	XXS	...	2200 [15 200]	2300 [15 900]
1 1/2	40	1.900 [48.3]	0.145 [3.68]	2.72 [4.05]	STD	40	1200 [8300]	1300 [9000]
			0.200 [5.08]	3.63 [5.41]	XS	80	1800 [12 400]	1900 [13 100]
			0.281 [7.14]	4.86 [7.25]	...	160	1950 [13 400]	2050 [14 100]
			0.400 [10.16]	6.41 [9.56]	XXS	...	2200 [15 200]	2300 [15 900]
2	50	2.375 [60.3]	0.154 [3.91]	3.66 [5.44]	STD	40	2300 [15 900]	2500 [17 200]
			0.218 [5.54]	5.03 [7.48]	XS	80	2500 [17 200]	2500 [17 200]
			0.344 [8.74]	7.47 [11.11]	...	160	2500 [17 200]	2500 [17 200]
			0.436 [11.07]	9.04 [13.44]	XXS	...	2500 [17 200]	2500 [17 200]
2 1/2	65	2.875 [73.0]	0.203 [5.16]	5.80 [8.63]	STD	40	2500 [17 200]	2500 [17 200]
			0.276 [7.01]	7.67 [11.41]	XS	80	2500 [17 200]	2500 [17 200]
			0.375 [9.52]	10.02 [14.90]	...	160	2500 [17 200]	2500 [17 200]
			0.552 [14.02]	13.71 [20.39]	XXS	...	2500 [17 200]	2500 [17 200]
3	80	3.500 [88.9]	0.125 [3.18]	4.51 [6.72]	...	...	1290 [8900]	1500 [1000]
			0.156 [3.96]	5.58 [8.29]	...	...	1600 [11 000]	1870 [12 900]
			0.188 [4.78]	6.66 [9.92]	...	...	1930 [13 330]	2260 [15 600]
			0.216 [5.49]	7.58 [11.29]	STD	40	2220 [15 300]	2500 [17 200]
			0.250 [6.35]	8.69 [12.93]	...	...	2500 [17 200]	2500 [17 200]
			0.281 [7.14]	9.67 [14.40]	...	...	2500 [17 200]	2500 [17 200]
			0.300 [7.62]	10.26 [15.27]	XS	80	2500 [17 200]	2500 [17 200]
			0.438 [11.13]	14.34 [21.35]	...	160	2500 [17 200]	2500 [17 200]
3 1/2	90	4.000 [101.6]	0.125 [3.18]	5.18 [7.72]	...	...	1120 [7700]	1310 [19 000]
			0.156 [3.96]	6.41 [9.53]	...	...	1400 [6700]	1640 [11 300]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ^A psi [kPa]	
							Grade A	Grade B
			0.188 [4.78]	7.66 [11.41]	...	...	1690 [11 700]	1970 [13 600]
			0.226 [5.74]	9.12 [13.57]	STD	40	2030 [14 000]	2370 [16 300]
			0.250 [6.35]	10.02 [14.92]	...	...	2250 [15 500]	2500 [17 200]
			0.281 [7.14]	11.17 [16.63]	...	...	2500 [17 200]	2500 [17 200]
			0.318 [8.08]	12.52 [18.63]	XS	80	2800 [19 300]	2800 [19 300]
4	100	4.500 [114.3]	0.125 [3.18]	5.85 [8.71]	...	...	1000 [6900]	1170 [8100]
			0.156 [3.96]	7.24 [10.78]	...	...	1250 [8600]	1460 [10 100]
			0.188 [4.78]	8.67 [12.91]	...	...	1500 [10 300]	1750 [12 100]
			0.219 [5.56]	10.02 [14.91]	...	...	1750 [12 100]	2040 [14 100]
			0.237 [6.02]	10.80 [16.07]	STD	40	1900 [13 100]	2210 [15 200]
			0.250 [6.35]	11.36 [16.90]	...	...	2000 [13 800]	2330 [16 100]
			0.281 [7.14]	12.67 [18.87]	...	...	2250 [15 100]	2620 [18 100]
			0.312 [7.92]	13.97 [20.78]	...	...	2500 [17 200]	2800 [19 300]
			0.337 [8.56]	15.00 [22.32]	XS	80	2700 [18 600]	2800 [19 300]
			0.438 [11.13]	19.02 [28.32]	...	120	2800 [19 300]	2800 [19 300]
			0.531 [13.49]	22.53 [33.54]	...	160	2800 [19 300]	2800 [19 300]
			0.674 [17.12]	27.57 [41.03]	XXS	...	2800 [19 300]	2800 [19 300]
5	125	5.563 [141.3]	0.156 [3.96]	9.02 [13.41]	...	...	1010 [7000]	1180 [8100]
			0.188 [4.78]	10.80 [16.09]	...	...	1220 [8400]	1420 [9800]
			0.219 [5.56]	12.51 [18.61]	...	...	1420 [9800]	1650 [11 400]
			0.258 [6.55]	14.63 [21.77]	STD	40	1670 [11 500]	1950 [13 400]
			0.281 [7.14]	15.87 [23.62]	...	...	1820 [12 500]	2120 [14 600]
			0.312 [7.92]	17.51 [26.05]	...	...	2020 [13 900]	2360 [16 300]
			0.344 [8.74]	19.19 [28.57]	...	...	2230 [15 400]	2600 [17 900]
			0.375 [9.52]	20.80 [30.94]	XS	80	2430 [16 800]	2800 [19 300]
			0.500 [12.70]	27.06 [40.28]	...	120	2800 [19 300]	2800 [19 300]
			0.625 [15.88]	32.99 [49.11]	...	160	2800 [19 300]	2800 [19 300]
						0.750 [19.05]	38.59 [57.43]	XXS	...	2800 [19 300]	2800 [19 300]
6	150	6.625 [168.3]	0.188 [4.78]	12.94 [19.27]	...	...	1020 [7000]	1190 [8200]
			0.219 [5.56]	15.00 [22.31]	...	...	1190 [8200]	1390 [9600]
			0.250 [6.35]	17.04 [25.36]	...	...	1360 [9400]	1580 [10 900]
			0.280 [7.11]	18.99 [28.26]	STD	40	1520 [10 500]	1780 [12 300]
			0.312 [7.92]	21.06 [31.32]	...	...	1700 [11 700]	1980 [13 700]
			0.344 [8.74]	23.10 [34.39]	...	...	1870 [12 900]	2180 [15 000]
			0.375 [9.52]	25.05 [37.28]	...	...	2040 [14 100]	2380 [16 400]
			0.432 [10.97]	28.60 [42.56]	XS	80	2350 [16 200]	2740 [18 900]
			0.562 [14.27]	36.43 [54.20]	...	120	2800 [19 300]	2800 [19 300]
			0.719 [18.26]	45.39 [67.56]	...	160	2800 [19 300]	2800 [19 300]
						0.864 [21.95]	53.21 [79.22]	XXS	...	2800 [19 300]	2800 [19 300]
8	200	8.625 [219.1]	0.188 [4.78]	16.96 [25.26]	...	...	780 [5400]	920 [6300]
			0.203 [5.16]	18.28 [27.22]	...	...	850 [5900]	1000 [6900]
			0.219 [5.56]	19.68 [29.28]	...	...	910 [6300]	1070 [7400]
			0.250 [6.35]	22.38 [33.31]	...	20	1040 [7200]	1220 [8400]
			0.277 [7.04]	24.72 [36.31]	...	30	1160 [7800]	1350 [9300]
			0.312 [7.92]	27.73 [41.24]	...	...	1300 [9000]	1520 [10 500]
			0.322 [8.18]	28.58 [42.55]	STD	40	1340 [9200]	1570 [10 800]
			0.344 [8.74]	30.45 [45.34]	...	...	1440 [9900]	1680 [11 600]
			0.375 [9.52]	33.07 [49.20]	...	...	1570 [10 800]	1830 [12 600]
			0.406 [10.31]	35.67 [53.08]	...	60	1700 [11 700]	2000 [13 800]
			0.438 [11.13]	38.33 [57.08]	...	...	1830 [12 600]	2130 [14 700]
0.500 [12.70]	43.43 [64.64]	XS	80	2090 [14 400]	2430 [16 800]			
			0.594 [15.09]	51.00 [75.92]	...	100	2500 [17 200]	2800 [19 300]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ⁴ psi [kPa]	
							Grade A	Grade B
			0.719 [18.26]	60.77 [90.44]	...	120	2800 [19 300]	2800 [19 300]
			0.812 [20.62]	67.82 [100.92]	...	140	2800 [19 300]	2800 [19 300]
			0.875 [22.22]	72.49 [107.88]	XXS	...	2800 [19 300]	2800 [19 300]
			0.906 [23.01]	74.76 [111.27]	...	160	2800 [19 300]	2800 [19 300]
10	250	10.750 [273.0]	0.188 [4.78]	21.23 [31.62]	...	...	630 [4300]	730 [5000]
			0.203 [5.16]	22.89 [34.08]	...	...	680 [4700]	800 [5500]
			0.219 [5.56]	24.65 [36.67]	...	...	730 [5000]	860 [5900]
			0.250 [6.35]	28.06 [41.75]	...	20	840 [5800]	980 [6800]
			0.279 [7.09]	31.23 [46.49]	...	...	930 [6400]	1090 [7500]
			0.307 [7.80]	34.27 [51.01]	...	30	1030 [7100]	1200 [8300]
			0.344 [8.74]	38.27 [56.96]	...	...	1150 [7900]	1340 [9200]
			0.365 [9.27]	40.52 [60.29]	STD	40	1220 [8400]	1430 [9900]
			0.438 [11.13]	48.28 [71.87]	...	...	1470 [10 100]	1710 [11 800]
			0.500 [12.70]	54.79 [81.52]	XS	60	1670 [11 500]	1950 [13 400]
			0.594 [15.09]	64.49 [95.97]	...	80	1990 [13 700]	2320 [16 000]
			0.719 [18.26]	77.10 [114.70]	...	100	2410 [16 600]	2800 [19 300]
			0.844 [21.44]	89.38 [133.00]	...	120	2800 [19 300]	2800 [19 300]
			1.000 [25.40]	104.23 [155.09]	XXS	140	2800 [19 300]	2800 [19 300]
			1.125 [28.57]	115.75 [172.21]	...	160	2800 [19 300]	2800 [19 300]
12	300	12.750 [323.8]	0.203 [5.16]	27.23 [40.55]	...	...	570 [3900]	670 [4600]
			0.219 [5.56]	29.34 [43.63]	...	...	620 [4300]	720 [5000]
			0.250 [6.35]	33.41 [49.71]	...	20	710 [4900]	820 [5700]
			0.281 [7.14]	37.46 [55.75]	...	...	790 [5400]	930 [6400]
			0.312 [7.92]	41.48 [61.69]	...	...	880 [6100]	1030 [7100]
			0.330 [8.38]	43.81 [65.18]	...	30	930 [6400]	1090 [7500]
			0.344 [8.74]	45.62 [67.90]	...	...	970 [6700]	1130 [7800]
			0.375 [9.52]	49.61 [73.78]	STD	...	1060 [7300]	1240 [8500]
			0.406 [10.31]	53.57 [79.70]	...	40	1150 [7900]	1340 [9200]
			0.438 [11.13]	57.65 [85.82]	...	...	1240 [8500]	1440 [9900]
			0.500 [12.70]	65.48 [97.43]	XS	...	1410 [9700]	1650 [11 400]
			0.562 [14.27]	73.22 [108.92]	...	60	1590 [11 000]	1850 [12 800]
			0.688 [17.48]	88.71 [132.04]	...	80	1940 [13 400]	2270 [15 700]
			0.844 [21.44]	107.42 [159.86]	...	100	2390 [16 500]	2780 [19 200]
			1.000 [25.40]	125.61 [186.91]	XXS	120	2800 [19 300]	2800 [19 300]
			1.125 [28.57]	139.81 [208.00]	...	140	2800 [19 300]	2800 [19 300]
			1.312 [33.32]	160.42 [238.68]	...	160	2800 [19 300]	2800 [19 300]
14	350	14.000 [355.6]	0.210 [5.33]	30.96 [46.04]	...	...	540 [3700]	630 [4300]
			0.219 [5.56]	32.26 [47.99]	...	...	560 [3900]	660 [4500]
			0.250 [6.35]	36.75 [54.69]	...	10	640 [4400]	750 [5200]
			0.281 [7.14]	41.21 [61.35]	...	...	720 [5000]	840 [5800]
			0.312 [7.92]	45.65 [67.90]	...	20	800 [5500]	940 [6500]
			0.344 [8.74]	50.22 [74.76]	...	...	880 [6100]	1030 [7100]
			0.375 [9.52]	54.62 [81.25]	STD	30	960 [6600]	1120 [7700]
			0.438 [11.13]	63.50 [94.55]	...	40	1130 [7800]	1310 [9000]
			0.469 [11.91]	67.84 [100.94]	...	...	1210 [8300]	1410 [9700]
			0.500 [12.70]	72.16 [107.39]	XS	...	1290 [8900]	1500 [10 300]
			0.594 [15.09]	85.13 [126.71]	...	60	1530 [10 500]	1790 [12 300]
			0.750 [19.05]	106.23 [158.10]	...	80	1930 [13 300]	2250 [15 500]
			0.938 [23.83]	130.98 [194.96]	...	100	2410 [16 600]	2800 [19 300]
			1.094 [27.79]	150.93 [224.65]	...	120	2800 [19 300]	2800 [19 300]
			1.250 [31.75]	170.37 [253.56]	...	140	2800 [19 300]	2800 [19 300]
			1.406 [35.71]	189.29 [281.70]	...	160	2800 [19 300]	2800 [19 300]
			2.000 [50.80]	256.56 [381.83]	...	...	2800 [19 300]	2800 [19 300]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ^A psi [kPa]	
							Grade A	Grade B
16	400	16.000 [406.4]	2.125 [53.97]	269.76 [401.44]	...	...	2800 [19 300]	2800 [19 300]
			2.200 [55.88]	277.51 [413.01]	...	...	2800 [19 300]	2800 [19 300]
			2.500 [63.50]	307.34 [457.40]	...	...	2800 [19 300]	2800 [19 300]
			0.219 [5.56]	36.95 [54.96]	...	...	490 [3400]	570 [3900]
			0.250 [6.35]	42.09 [62.64]	...	10	560 [3900]	660 [4500]
			0.281 [7.14]	47.22 [70.30]	...	...	630 [4300]	740 [5100]
			0.312 [7.92]	52.32 [77.83]	...	20	700 [4800]	820 [5700]
			0.344 [8.74]	57.57 [85.71]	...	...	770 [5300]	900 [6200]
			0.375 [9.52]	62.64 [93.17]	STD	30	840 [5800]	980 [6800]
0.438 [11.13]	72.86 [108.49]	...	...	990 [6800]	1150 [7900]			
0.469 [11.91]	77.87 [115.86]	...	...	1060 [7300]	1230 [8500]			
0.500 [12.70]	82.85 [123.30]	XS	40	1120 [7700]	1310 [9000]			
0.656 [16.66]	107.60 [160.12]	...	60	1480 [10 200]	1720 [11 900]			
0.844 [21.44]	136.74 [203.53]	...	80	1900 [13 100]	2220 [15 300]			
1.031 [26.19]	164.98 [245.56]	...	100	2320 [16 000]	2710 [18 700]			
1.219 [30.96]	192.61 [286.64]	...	120	2740 [18 900]	2800 [19 300]			
1.438 [36.53]	223.85 [333.19]	...	140	2800 [19 300]	2800 [19 300]			
1.594 [40.49]	245.48 [365.35]	...	160	2800 [19 300]	2800 [19 300]			
18	450	18.000 [457]	0.250 [6.35]	47.44 [70.60]	...	10	500 [3400]	580 [4000]
			0.281 [7.14]	53.23 [79.24]	...	...	560 [3900]	660 [4500]
			0.312 [7.92]	58.99 [87.75]	...	20	620 [4300]	730 [5000]
			0.344 [8.74]	64.93 [96.66]	...	...	690 [4800]	800 [5500]
			0.375 [9.52]	70.65 [105.10]	STD	...	750 [5200]	880 [6100]
			0.406 [10.31]	76.36 [113.62]	...	...	810 [5600]	950 [6500]
			0.438 [11.13]	82.23 [122.43]	...	30	880 [6100]	1020 [7000]
			0.469 [11.91]	87.89 [130.78]	...	...	940 [6500]	1090 [7500]
			0.500 [12.70]	93.54 [139.20]	XS	...	1000 [6900]	1170 [8100]
			0.562 [14.27]	104.76 [155.87]	...	40	1120 [7700]	1310 [9000]
			0.750 [19.05]	138.30 [205.83]	...	60	1500 [10 300]	1750 [12 100]
			0.938 [23.83]	171.08 [254.67]	...	80	1880 [13 000]	2190 [15 100]
			1.156 [29.36]	208.15 [309.76]	...	100	2310 [15 900]	2700 [18 600]
			1.375 [34.92]	244.37 [363.64]	...	120	2750 [19 000]	2800 [19 300]
			1.562 [39.67]	274.48 [408.45]	...	140	2800 [19 300]	2800 [19 300]
1.781 [45.24]	308.79 [459.59]	...	160	2800 [19 300]	2800 [19 300]			
20	500	20.000 [508]	0.250 [6.35]	52.78 [78.55]	...	10	450 [3100]	520 [3600]
			0.281 [7.14]	59.23 [88.19]	...	...	510 [3500]	590 [4100]
			0.312 [7.92]	65.66 [97.67]	...	...	560 [3900]	660 [4500]
			0.344 [8.74]	72.28 [107.60]	...	...	620 [4300]	720 [5000]
			0.375 [9.52]	78.67 [117.02]	STD	20	680 [4700]	790 [5400]
			0.406 [10.31]	84.04 [126.53]	...	...	730 [5000]	850 [5900]
			0.438 [11.13]	91.59 [136.37]	...	...	790 [5400]	920 [6300]
			0.469 [11.91]	97.92 [145.70]	...	...	850 [5900]	950 [6500]
			0.500 [12.70]	104.23 [155.12]	XS	30	900 [6200]	1050 [7200]
			0.594 [15.09]	123.23 [183.42]	...	40	1170 [8100]	1250 [8600]
			0.812 [20.62]	166.56 [247.83]	...	60	1460 [10 100]	1710 [11 800]
			1.031 [26.19]	209.06 [311.17]	...	80	1860 [12 800]	2170 [15 000]
			1.281 [32.54]	256.34 [381.53]	...	100	2310 [15 900]	2690 [18 500]
			1.500 [38.10]	296.65 [441.49]	...	120	2700 [18 600]	2800 [19 300]
			1.750 [44.45]	341.41 [508.11]	...	140	2800 [19 300]	2800 [19 300]
1.969 [50.01]	379.53 [564.81]	...	160	2800 [19 300]	2800 [19 300]			
24	600	24.000 [610]	0.250 [6.35]	63.47 [94.46]	...	10	380 [2600]	440 [3000]
			0.281 [7.14]	71.25 [106.08]	...	...	420 [2900]	490 [3400]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ⁴ psi [kPa]	
							Grade A	Grade B
			0.312 [7.92]	79.01 [117.51]	...	...	470 [3200]	550 [3800]
			0.344 [8.74]	86.99 [129.50]	...	...	520 [3600]	600 [4100]
			0.375 [9.52]	94.71 [140.88]	STD	20	560 [3900]	660 [4500]
			0.406 [10.31]	102.40 [152.37]	...	...	610 [4200]	710 [4900]
			0.438 [11.13]	110.32 [164.26]	...	...	660 [4500]	770 [5300]
			0.469 [11.91]	117.98 [175.54]	...	...	700 [4800]	820 [5700]
			0.500 [12.70]	125.61 [186.94]	XS	...	750 [5200]	880 [6100]
			0.562 [14.27]	140.81 [209.50]	...	30	840 [5800]	980 [6800]
			0.688 [17.48]	171.45 [255.24]	...	40	1030 [7100]	1200 [8300]
			0.938 [23.83]	231.25 [344.23]	...	...	1410 [9700]	1640 [11 300]
			0.969 [24.61]	238.57 [355.02]	...	60	1450 [10 000]	1700 [11 700]
			1.219 [30.96]	296.86 [441.78]	...	80	1830 [12 600]	2130 [14 700]
			1.531 [38.89]	367.74 [547.33]	...	100	2300 [15 900]	2680 [18 500]
			1.812 [46.02]	429.79 [639.58]	...	120	2720 [18 800]	2800 [19 300]
			2.062 [52.37]	483.57 [719.63]	...	140	2800 [19 300]	2800 [19 300]
			2.344 [59.54]	542.64 [807.63]	...	160	2800 [19 300]	2800 [19 300]
26	650	26.000 [660]	0.250 [6.35]	68.82 [102.42]	...	...	350 [2400]	400 [2800]
			0.281 [7.14]	77.26 [115.02]	...	...	390 [2700]	450 [3100]
			0.312 [7.92]	85.68 [127.43]	...	10	430 [3000]	500 [3400]
			0.344 [8.74]	94.35 [140.45]	...	...	480 [3300]	560 [3900]
			0.375 [9.52]	102.72 [152.80]	STD	...	520 [3600]	610 [4200]
			0.406 [10.31]	111.08 [165.28]	...	...	560 [3900]	660 [4500]
			0.438 [11.13]	119.69 [178.20]	...	...	610 [4200]	710 [4900]
			0.469 [11.91]	128.00 [190.46]	...	...	650 [4500]	760 [5200]
			0.500 [12.70]	136.30 [202.85]	XS	20	690 [4800]	810 [5600]
			0.562 [14.27]	152.83 [227.37]	...	...	780 [5400]	910 [6300]

⁴ The minimum test pressure for outside diameters and wall thicknesses not listed shall be computed by the formula given below. The computed test pressure shall be used in all cases with the following exceptions:

(1) When the wall thickness is greater than the heaviest wall thickness shown for a given diameter, the test pressure for the heaviest wall listed shall be the required test pressure.

(2) For Grades A and B in sizes under NPS 2 [DN 50], when the wall thickness is lighter than the lightest shown for a given diameter, use the test pressure given for the lightest wall thickness of the table for the diameter involved.

(3) For all sizes of Grades A and B pipe smaller than NPS 2 [DN 50], the test pressure has been arbitrarily assigned. Test pressures for intermediate outside diameters need not exceed those for the next larger listed size.

$$P = 2St/D$$

where:

P = minimum hydrostatic test pressure, psi [kPa],

S = 0.60 times the specified minimum yield strength, psi [kPa],

t = nominal wall thickness, in. [mm], and

D = specified outside diameter, in. [mm].

TABLE X2.3
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR THREADED AND COUPLED PIPE

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Threaded and Coupled, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, psi [kPa]	
							Grade A	Grade B
1/8	6	0.405 [10.3]	0.068 [1.73]	0.25 [0.37]	STD	40	700 [4800]	700 [4800]
			0.095 [2.41]	0.32 [0.46]	XS	80	850 [5900]	850 [5900]
1/4	8	0.540 [13.7]	0.088 [2.24]	0.43 [0.63]	STD	40	700 [4800]	700 [4800]
			0.119 [3.02]	0.54 [0.80]	XS	80	850 [5900]	850 [5900]
3/8	10	0.675 [17.1]	0.091 [2.31]	0.57 [0.84]	STD	40	700 [4800]	700 [4800]
			0.126 [3.20]	0.74 [1.10]	XS	80	850 [5900]	850 [5900]
1/2	15	0.840 [21.3]	0.109 [2.77]	0.86 [1.27]	STD	40	700 [4800]	700 [4800]
			0.147 [3.73]	1.09 [1.62]	XS	80	850 [5900]	850 [5900]
			0.294 [7.47]	1.72 [2.54]	XXS	...	1000 [6900]	1000 [6900]
3/4	20	1.050 [26.7]	0.113 [2.87]	1.14 [1.69]	STD	40	700 [4800]	700 [4800]
			0.154 [3.91]	1.48 [2.21]	XS	80	850 [5900]	850 [5900]
			0.308 [7.82]	2.45 [3.64]	XXS	...	1000 [6900]	1000 [6900]
1	25	1.315 [33.4]	0.133 [3.38]	1.69 [2.50]	STD	40	700 [4800]	700 [4800]
			0.179 [4.55]	2.19 [3.25]	XS	80	850 [5900]	850 [5900]
			0.358 [9.09]	3.66 [5.45]	XXS	...	1000 [6900]	1000 [6900]
1 1/4	32	1.660 [42.2]	0.140 [3.56]	2.28 [3.40]	STD	40	1000 [6900]	1100 [7600]
			0.191 [4.85]	3.03 [4.49]	XS	80	1500 [10 300]	1600 [11 000]
			0.382 [9.70]	5.23 [7.76]	XXS	...	1800 [12 400]	1900 [13 100]
1 1/2	40	1.900 [48.3]	0.145 [3.68]	2.74 [4.04]	STD	40	1000 [6900]	1100 [7600]
			0.200 [5.08]	3.65 [5.39]	XS	80	1500 [10 300]	1600 [11 000]
			0.400 [10.16]	6.41 [9.56]	XXS	...	1800 [12 400]	1900 [13 100]
2	50	2.375 [60.3]	0.154 [3.91]	3.68 [5.46]	STD	40	2300 [15 900]	2500 [17 200]
			0.218 [5.54]	5.08 [7.55]	XS	80	2500 [17 200]	2500 [17 200]
			0.436 [11.07]	9.06 [13.44]	XXS	...	2500 [17 200]	2500 [17 200]
2 1/2	65	2.875 [73.0]	0.203 [5.16]	5.85 [8.67]	STD	40	2500 [17 200]	2500 [17 200]
			0.276 [7.01]	7.75 [11.52]	XS	80	2500 [17 200]	2500 [17 200]
			0.552 [14.02]	13.72 [20.39]	XXS	...	2500 [17 200]	2500 [17 200]
3	80	3.500 [88.9]	0.216 [5.49]	7.68 [11.35]	STD	40	2200 [15 200]	2500 [17 200]
			0.300 [7.62]	10.35 [15.39]	XS	80	2500 [17 200]	2500 [17 200]
			0.600 [15.24]	18.60 [27.66]	XXS	...	2500 [17 200]	2500 [17 200]
3 1/2	90	4.000 [101.6]	0.226 [5.74]	9.27 [13.71]	STD	40	2000 [13 800]	2400 [16 500]
			0.318 [8.08]	12.67 [18.82]	XS	80	2800 [19 300]	2800 [19 300]
4	100	4.500 [114.3]	0.237 [6.02]	10.92 [16.23]	STD	40	1900 [13 100]	2200 [15 200]
			0.337 [8.56]	15.20 [22.60]	XS	80	2700 [18 600]	2800 [19 300]
			0.674 [17.12]	27.62 [41.09]	XXS	...	2800 [19 300]	2800 [19 300]
5	125	5.563 [141.3]	0.258 [6.55]	14.90 [22.07]	STD	40	1700 [11 700]	1900 [13 100]
			0.375 [9.52]	21.04 [31.42]	XS	80	2400 [16 500]	2800 [19 300]
			0.750 [19.05]	38.63 [57.53]	XXS	...	2800 [19 300]	2800 [19 300]
6	150	6.625 [168.3]	0.280 [7.11]	19.34 [28.58]	STD	40	1500 [10 300]	1800 [12 400]
			0.432 [10.97]	28.88 [43.05]	XS	80	2300 [15 900]	2700 [18 600]
			0.864 [21.95]	53.19 [79.18]	XXS	...	2800 [19 300]	2800 [19 300]
8	200	8.625 [219.1]	0.277 [7.04]	25.53 [38.07]	...	30	1200 [8300]	1300 [9000]
			0.322 [8.18]	29.35 [43.73]	STD	40	1300 [9000]	1600 [11 000]
			0.500 [12.70]	44.00 [65.41]	XS	80	2100 [14 500]	2400 [16 500]
			0.875 [22.22]	72.69 [107.94]	XXS	...	2800 [19 300]	2800 [19 300]
10	250	10.750 [273.0]	0.279 [7.09]	32.33 [48.80]	...	...	950 [6500]	1100 [7600]
			0.307 [7.80]	35.33 [53.27]	...	30	1000 [6900]	1200 [8300]
			0.365 [9.27]	41.49 [63.36]	STD	40	1200 [8300]	1400 [9700]
			0.500 [12.70]	55.55 [83.17]	XS	60	1700 [11 700]	2000 [13 800]
12	300	12.750 [323.8]	0.330 [8.38]	45.47 [67.72]	...	30	950 [6500]	1100 [7600]
			0.375 [9.52]	51.28 [76.21]	STD	...	1100 [7600]	1200 [8300]
			0.500 [12.70]	66.91 [99.4]	XS	...	1400 [9700]	1600 [11 000]

TABLE X2.4
TABLE OF MINIMUM WALL THICKNESSES ON INSPECTION FOR NOMINAL PIPE WALL THICKNESSES

Nominal Wall Thickness (t_n), in. [mm]	Minimum Wall Thickness on Inspection (t_m), in. [mm]	Nominal Wall Thickness (t_n), in. [mm]	Minimum Wall Thickness on Inspection (t_m), in. [mm]	Nominal Wall Thickness (t_n), in. [mm]	Minimum Wall Thickness on Inspection (t_m), in. [mm]
0.068 [1.73]	0.060 [1.52]	0.294 [7.47]	0.257 [6.53]	0.750 [19.05]	0.656 [16.66]
0.088 [2.24]	0.077 [1.96]	0.300 [7.62]	0.262 [6.65]	0.812 [20.62]	0.710 [18.03]
0.091 [2.31]	0.080 [2.03]	0.307 [7.80]	0.269 [6.83]	0.844 [21.44]	0.739 [18.77]
0.095 [2.41]	0.083 [2.11]	0.308 [7.82]	0.270 [6.86]	0.864 [21.94]	0.756 [19.20]
0.109 [2.77]	0.095 [2.41]	0.312 [7.92]	0.273 [6.93]	0.875 [22.22]	0.766 [19.46]
0.113 [2.87]	0.099 [2.51]	0.318 [8.08]	0.278 [7.06]	0.906 [23.01]	0.793 [20.14]
0.119 [3.02]	0.104 [2.64]	0.322 [8.18]	0.282 [7.16]	0.938 [23.82]	0.821 [20.85]
0.125 [3.18]	0.109 [2.77]	0.330 [8.38]	0.289 [7.34]	0.968 [24.59]	0.847 [21.51]
0.126 [3.20]	0.110 [2.79]	0.337 [8.56]	0.295 [7.49]	1.000 [25.40]	0.875 [22.22]
0.133 [3.38]	0.116 [2.95]	0.343 [8.71]	0.300 [7.62]	1.031 [26.19]	0.902 [22.91]
0.140 [3.56]	0.122 [3.10]	0.344 [8.74]	0.301 [7.65]	1.062 [26.97]	0.929 [23.30]
0.145 [3.68]	0.127 [3.23]	0.358 [9.09]	0.313 [7.95]	1.094 [27.79]	0.957 [24.31]
0.147 [3.73]	0.129 [3.28]	0.365 [9.27]	0.319 [8.10]	1.125 [28.58]	0.984 [24.99]
0.154 [3.91]	0.135 [3.43]	0.375 [9.52]	0.328 [8.33]	1.156 [29.36]	1.012 [25.70]
0.156 [3.96]	0.136 [3.45]	0.382 [9.70]	0.334 [8.48]	1.219 [30.96]	1.067 [27.08]
0.179 [4.55]	0.157 [3.99]	0.400 [10.16]	0.350 [8.89]	1.250 [31.75]	1.094 [27.79]
0.187 [4.75]	0.164 [4.17]	0.406 [10.31]	0.355 [9.02]	1.281 [32.54]	1.121 [28.47]
0.188 [4.78]	0.164 [4.17]	0.432 [10.97]	0.378 [9.60]	1.312 [33.32]	1.148 [29.16]
0.191 [4.85]	0.167 [4.24]	0.436 [11.07]	0.382 [9.70]	1.343 [34.11]	1.175 [29.85]
0.200 [5.08]	0.175 [4.44]	0.437 [11.10]	0.382 [9.70]	1.375 [34.92]	1.203 [30.56]
0.203 [5.16]	0.178 [4.52]	0.438 [11.13]	0.383 [9.73]	1.406 [35.71]	1.230 [31.24]
0.216 [5.49]	0.189 [4.80]	0.500 [12.70]	0.438 [11.13]	1.438 [36.53]	1.258 [31.95]
0.218 [5.54]	0.191 [4.85]	0.531 [13.49]	0.465 [11.81]	1.500 [38.10]	1.312 [33.32]
0.219 [5.56]	0.192 [4.88]	0.552 [14.02]	0.483 [12.27]	1.531 [38.89]	1.340 [34.04]
0.226 [5.74]	0.198 [5.03]	0.562 [14.27]	0.492 [12.50]	1.562 [39.67]	1.367 [34.72]
0.237 [6.02]	0.207 [5.26]	0.594 [15.09]	0.520 [13.21]	1.594 [40.49]	1.395 [35.43]
0.250 [6.35]	0.219 [5.56]	0.600 [15.24]	0.525 [13.34]	1.750 [44.45]	1.531 [38.89]
0.258 [6.55]	0.226 [5.74]	0.625 [15.88]	0.547 [13.89]	1.781 [45.24]	1.558 [39.57]
0.276 [7.01]	0.242 [6.15]	0.656 [16.66]	0.574 [14.58]	1.812 [46.02]	1.586 [40.28]
0.277 [7.04]	0.242 [6.15]	0.674 [17.12]	0.590 [14.99]	1.968 [49.99]	1.722 [43.74]
0.279 [7.09]	0.244 [6.20]	0.688 [17.48]	0.602 [15.29]	2.062 [52.37]	1.804 [45.82]
0.280 [7.11]	0.245 [6.22]	0.719 [18.26]	0.629 [15.98]	2.344 [59.54]	2.051 [52.10]
0.281 [7.14]	0.246 [6.25]				

Note 1 — The following equation, upon which this table is based, shall be applied to calculate minimum wall thickness from nominal wall thickness:

$$t_n \times 0.875 = t_m$$

where:

t_n = nominal wall thickness, in. [mm], and
 t_m = minimum wall thickness, in. [mm].

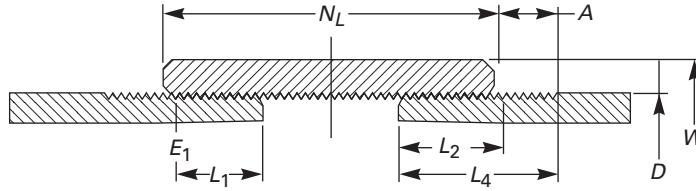
The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped in accordance with Practice E 29.

Note 2 — This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

X3. BASIC THREADING DATA

X3.1 Figure X3.1 is to be used with Table X3.1. Figure X3.2 is to be used with Table X3.2.

FIG. X3.1 DIMENSIONS OF HAND TIGHT ASSEMBLY FOR USE WITH TABLE X3.1



**TABLE X3.1
BASIC THREADING DATA FOR STANDARD-WEIGHT NPS 6 [DN 50] AND UNDER**

Pipe		Threads						Coupling		
NPS Designator	DN Designator	Outside Diameter, in. [mm] <i>D</i>	Number per inch	End of Pipe to Hand Tight Plane, in. [mm] <i>L₁</i>	Effective Length, in. [mm] <i>L₂</i>	Total Length, in. [mm] <i>L₄</i>	Pitch Diameter at Hand Tight Plane, in. [mm] <i>E₁</i>	Outside Diameter, in. [mm] <i>W</i>	Length, min., in. [mm] <i>N_L</i>	Hand Tight Stand-Off (Number of Threads) <i>A</i>
1/8	6	0.405 [10.3]	27	0.1615 [4.1021]	0.2638 [6.7005]	0.3924 [9.9670]	0.37360 [9.48944]	0.563 [14.3]	3/4 [19]	4
1/4	8	0.540 [13.7]	18	0.2278 [5.7861]	0.4018 [10.2057]	0.5946 [15.1028]	0.49163 [12.48740]	0.719 [18.3]	1 1/8 [29]	5 1/2
3/8	10	0.675 [17.1]	18	0.240 [6.096]	0.4078 [10.3581]	0.6006 [15.2552]	0.62701 [15.92605]	0.875 [22.2]	1 1/8 [29]	5
1/2	15	0.840 [21.3]	14	0.320 [8.128]	0.5337 [13.5560]	0.7815 [19.8501]	0.77843 [19.77212]	1.063 [27.0]	1 1/2 [38]	5
3/4	20	1.050 [26.7]	14	0.339 [8.611]	0.5457 [13.8608]	0.7935 [20.1549]	0.98887 [25.11730]	1.313 [33.4]	1 [40]	5
1	25	1.315 [33.4]	11 1/2	0.400 [10.160]	0.6828 [17.3431]	0.9845 [25.0063]	1.23863 [31.46120]	1.576 [40.0]	1 15/16 [49]	5
1 1/4	32	1.660 [42.2]	11 1/2	0.420 [10.668]	0.7068 [17.9527]	1.0085 [25.6159]	1.58338 [40.21785]	1.900 [48.3]	2 [50]	5
1 1/2	40	1.900 [48.3]	11 1/2	0.420 [10.668]	0.7235 [18.3769]	1.0252 [26.0401]	1.82234 [46.28744]	2.200 [55.9]	2 [50]	5 1/2
2	50	2.375 [60.3]	11 1/2	0.436 [11.074]	0.7565 [19.2151]	1.0582 [26.8783]	2.29627 [58.32526]	2.750 [69.8]	2 1/16 [52]	5 1/2
2 1/2	65	2.875 [73.0]	8	0.682 [17.323]	1.1376 [28.8950]	1.5712 [39.9085]	2.76216 [70.15886]	3.250 [82.5]	3 1/16 [78]	5 1/2
3	80	3.500 [88.9]	8	0.766 [19.456]	1.2000 [30.4800]	1.6337 [41.4960]	3.38850 [86.06790]	4.000 [101.6]	3 3/16 [81]	5 1/2
3 1/2	90	4.000 [101.6]	8	0.821 [20.853]	1.2500 [31.7500]	1.6837 [42.7660]	3.88881 [98.77577]	4.625 [117.5]	3 5/16 [84]	5 1/2
4	100	4.500 [114.3]	8	0.844 [21.438]	1.3000 [33.0200]	1.7337 [44.0360]	4.38713 [111.43310]	5.000 [127.0]	3 7/16 [87]	5
5	125	5.563 [141.3]	8	0.937 [23.800]	1.4063 [35.7200]	1.8400 [46.7360]	5.44929 [138.41200]	6.296 [159.9]	3 11/16 [94]	5
6	150	6.625 [168.3]	8	0.958 [24.333]	1.5125 [38.4175]	1.9462 [49.4335]	6.50597 [165.25164]	7.390 [187.7]	4 15/16 [125]	6

Note 1 — All dimensions in this table are nominal and subject to mill tolerances.

Note 2 — The taper of threads is 3/4 in./ft [62.5 mm/m] on the diameter.

FIG. X3.2 DIMENSIONS OF HAND TIGHT ASSEMBLY FOR USE WITH TABLE X3.2

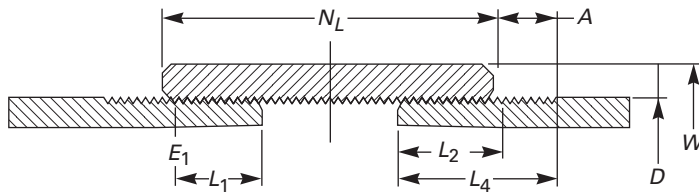


TABLE X3.2
BASIC THREADING DATA FOR STANDARD-WEIGHT PIPE IN NPS 8 [DN 200] AND LARGER, AND ALL SIZES OF EXTRA-STRONG AND DOUBLE-EXTRA-STRONG WEIGHT

Pipe		Threads						Coupling		
NPS Designator	DN Designator	Outside Diameter, in. [mm] <i>D</i>	Number per inch	End of Pipe to Hand Tight Plane, in. [mm] <i>L₁</i>	Effective Length, in. [mm] <i>L₂</i>	Total Length, in. [mm] <i>L₄</i>	Pitch Diameter at Hand Tight Plane, in. [mm] <i>E₁</i>	Outside Diameter, in. [mm] <i>W</i>	Length, min., in. [mm] <i>N_L</i>	Hand Tight Stand-Off (Number of Threads) <i>A</i>
1/8	6	0.405 [10.3]	27	0.1615 [4.1021]	0.2638 [6.7005]	0.3924 [9.9670]	0.37360 [9.48944]	0.563 [14.3]	1 1/16 [27]	3
1/4	8	0.540 [13.7]	18	0.2278 [5.7861]	0.4018 [10.2057]	0.5946 [15.1028]	0.49163 [12.48740]	0.719 [18.3]	1 5/8 [41]	3
3/8	10	0.675 [17.1]	18	0.240 [6.096]	0.4078 [10.3581]	0.6006 [15.2552]	0.62701 [15.92605]	0.875 [22.2]	1 5/8 [41]	3
1/2	15	0.840 [21.3]	14	0.320 [8.128]	0.5337 [13.5560]	0.7815 [19.8501]	0.77843 [19.77212]	1.063 [27.0]	2 1/8 [54]	3
3/4	20	1.050 [26.7]	14 1/2	0.339 [8.611]	0.5457 [13.8608]	0.7935 [20.1549]	0.98887 [25.11730]	1.313 [33.4]	2 1/8 [54]	3
1	25	1.315 [33.4]	11	0.400 [10.160]	0.6828 [17.3431]	0.9845 [25.0063]	1.23863 [31.46120]	1.576 [40.0]	2 5/8 [67]	3
1 1/4	32	1.660 [42.2]	11 1/2	0.420 [10.668]	0.7068 [17.9527]	1.0085 [25.6159]	1.58338 [40.21785]	2.054 [52.2]	2 3/4 [70]	3
1 1/2	40	1.900 [48.3]	11 1/2	0.420 [10.668]	0.7235 [18.3769]	1.0252 [26.0401]	1.82234 [46.28744]	2.200 [55.9]	2 3/4 [70]	3
2	50	2.375 [60.3]	11 1/2	0.436 [11.074]	0.7565 [19.2151]	1.0582 [26.8783]	2.29627 [58.32526]	2.875 [73.0]	2 7/8 [73]	3
2 1/2	65	2.875 [73.0]	8	0.682 [17.323]	1.1375 [28.8950]	1.5712 [39.9085]	2.76216 [70.15886]	3.375 [85.7]	4 1/8 [105]	2
3	80	3.500 [88.9]	8	0.766 [19.456]	1.2000 [30.4800]	1.6337 [41.4960]	3.38850 [86.06790]	4.000 [101.6]	4 1/4 [108]	2
3 1/2	90	4.000 [101.6]	8	0.821 [20.853]	1.2500 [31.7500]	1.6837 [42.7660]	3.88881 [98.77577]	4.625 [117.5]	4 3/8 [111]	2
4	100	4.500 [114.3]	8	0.844 [21.438]	1.3000 [33.0200]	1.7337 [44.0360]	4.38713 [111.43310]	5.200 [132.1]	4 1/2 [114]	2
5	125	5.563 [141.3]	8	0.937 [23.800]	1.4063 [35.7200]	1.8400 [46.7360]	5.44929 [138.41200]	6.296 [159.9]	4 5/8 [117]	2
6	150	6.625 [168.3]	8	0.958 [24.333]	1.5125 [38.4175]	1.9462 [49.4335]	6.50597 [165.25164]	7.390 [187.7]	4 7/8 [124]	2
8	200	8.625 [219.1]	8	1.063 [27.000]	1.7125 [43.4975]	2.1462 [54.5135]	8.50003 [215.90076]	9.625 [244.5]	5 1/4 [133]	2

TABLE X3.2
 BASIC THREADING DATA FOR STANDARD-WEIGHT PIPE IN NPS 8 [DN 200] AND LARGER, AND ALL SIZES OF
 EXTRA-STRONG AND DOUBLE-EXTRA-STRONG WEIGHT (CONT'D)

Pipe		Threads						Coupling		
NPS Designator	DN Designator	Outside Diameter, in. [mm] <i>D</i>	Number per inch	End of Pipe to Hand Tight Plane, in. [mm] <i>L₁</i>	Effective Length, in. [mm] <i>L₂</i>	Total Length, in. [mm] <i>L₄</i>	Pitch Diameter at Hand Tight Plane, in. [mm] <i>E₁</i>	Outside Diameter, in. [mm] <i>W</i>	Length, min., in. [mm] <i>N_L</i>	Hand Tight Stand-Off (Number of Threads) <i>A</i>
10	250	10.750 [273.0]	8	1.210 [30.734]	1.9250 [48.8950]	2.3587 [59.9110]	10.62094 [269.77188]	11.750 [298.4]	5 ³ / ₄ [146]	2
12	300	12.750 [323.8]	8	1.360 [34.544]	2.1250 [53.9750]	2.5587 [64.9910]	12.61781 [320.49237]	14.000 [355.6]	6 ³ / ₈ [156]	2
14	350	14.000 [355.6]	8	1.562 [39.675]	2.2500 [57.1500]	2.6837 [68.1660]	13.87263 [352.36480]	15.000 [381.0]	6 ³ / ₈ [162]	2
16	400	16.000 [406.4]	8	1.812 [46.025]	2.4500 [62.2300]	2.8837 [73.2460]	15.87575 [403.24405]	17.000 [432]	6 ³ / ₄ [171]	2
18	450	18.000 [457]	8	2.000 [50.800]	2.6500 [67.3100]	3.0837 [78.3260]	17.87500 [454.02500]	19.000 [483]	7 ¹ / ₈ [181]	2
20	500	20.000 [508]	8	2.125 [53.975]	2.8500 [72.3900]	3.2837 [83.4060]	19.87031 [504.70587]	21.000 [533]	7 ⁵ / ₈ [194]	2

Note 1 — The taper of threads is $\frac{3}{4}$ in./ft [62.5 mm/m] on the diameter.

X4. ELONGATION VALUES

X4.1 Tabulated in Table X4.1 are the minimum elongation values calculated by the equation given in Table 2.

**TABLE X4.1
ELONGATION VALUES**

Area, A , in. ²	Tension Test Specimen			Elongation in 2 in., min, %	
	Nominal Wall Thickness, in.			Specified Tensile Strength, psi	
	$\frac{3}{4}$ in. Specimen	1 in. Specimen	$1\frac{1}{2}$ in. Specimen	48 000	60 000
0.75 and greater	0.994 and greater	0.746 and greater	0.497 and greater	36	30
0.74	0.980–0.993	0.735–0.745	0.490–0.496	36	29
0.73	0.967–0.979	0.726–0.734	0.484–0.489	36	29
0.72	0.954–0.966	0.715–0.725	0.477–0.483	36	29
0.71	0.941–0.953	0.706–0.714	0.471–0.476	36	29
0.70	0.927–0.940	0.695–0.705	0.464–0.470	36	29
0.69	0.914–0.926	0.686–0.694	0.457–0.463	36	29
0.68	0.900–0.913	0.675–0.685	0.450–0.456	35	29
0.67	0.887–0.899	0.666–0.674	0.444–0.449	35	29
0.66	0.874–0.886	0.655–0.665	0.437–0.443	35	29
0.65	0.861–0.873	0.646–0.654	0.431–0.436	35	29
0.64	0.847–0.860	0.635–0.645	0.424–0.430	35	29
0.63	0.834–0.846	0.626–0.634	0.417–0.423	35	29
0.62	0.820–0.833	0.615–0.625	0.410–0.416	35	28
0.61	0.807–0.819	0.606–0.614	0.404–0.409	35	28
0.60	0.794–0.806	0.595–0.605	0.397–0.403	35	28
0.59	0.781–0.793	0.586–0.594	0.391–0.396	34	28
0.58	0.767–0.780	0.575–0.585	0.384–0.390	34	28
0.57	0.754–0.766	0.566–0.574	0.377–0.383	34	28
0.56	0.740–0.753	0.555–0.565	0.370–0.376	34	28
0.55	0.727–0.739	0.546–0.554	0.364–0.369	34	28
0.54	0.714–0.726	0.535–0.545	0.357–0.363	34	28
0.53	0.701–0.713	0.526–0.534	0.351–0.356	34	28
0.52	0.687–0.700	0.515–0.525	0.344–0.350	34	27
0.51	0.674–0.686	0.506–0.514	0.337–0.343	33	27
0.50	0.660–0.673	0.495–0.505	0.330–0.336	33	27
0.49	0.647–0.659	0.486–0.494	0.324–0.329	33	27
0.48	0.634–0.646	0.475–0.485	0.317–0.323	33	27
0.47	0.621–0.633	0.466–0.474	0.311–0.316	33	27
0.46	0.607–0.620	0.455–0.465	0.304–0.310	33	27
0.45	0.594–0.606	0.446–0.454	0.297–0.303	33	27
0.44	0.580–0.593	0.435–0.445	0.290–0.296	32	27
0.43	0.567–0.579	0.426–0.434	0.284–0.289	32	26
0.42	0.554–0.566	0.415–0.425	0.277–0.283	32	26
0.41	0.541–0.553	0.406–0.414	0.271–0.276	32	26
0.40	0.527–0.540	0.395–0.405	0.264–0.270	32	26
0.39	0.514–0.526	0.386–0.394	0.257–0.263	32	26
0.38	0.500–0.513	0.375–0.385	0.250–0.256	32	26
0.37	0.487–0.499	0.366–0.374	0.244–0.249	31	26

TABLE X4.1
ELONGATION VALUES (CONT'D)

Area, A , in. ²	Tension Test Specimen			Elongation in 2 in., min, %	
	Nominal Wall Thickness, in.			Specified Tensile Strength, psi	
	$\frac{3}{4}$ in. Specimen	1 in. Specimen	1½ in. Specimen	48 000	60 000
0.36	0.474–0.486	0.355–0.365	0.237–0.243	31	26
0.35	0.461–0.473	0.346–0.354	0.231–0.236	31	25
0.34	0.447–0.460	0.335–0.345	0.224–0.230	31	25
0.33	0.434–0.446	0.326–0.334	0.217–0.223	31	25
0.32	0.420–0.433	0.315–0.325	0.210–0.216	30	25
0.31	0.407–0.419	0.306–0.314	0.204–0.209	30	25
0.30	0.394–0.406	0.295–0.305	0.197–0.203	30	25
0.29	0.381–0.393	0.286–0.294	0.191–0.196	30	24
0.28	0.367–0.380	0.275–0.285	0.184–0.190	30	24
0.27	0.354–0.366	0.266–0.274	0.177–0.183	29	24
0.26	0.340–0.353	0.255–0.265	0.170–0.176	29	24
0.25	0.327–0.339	0.246–0.254	0.164–0.169	29	24
0.24	0.314–0.326	0.235–0.245	0.157–0.163	29	24
0.23	0.301–0.313	0.226–0.234	0.151–0.156	29	23
0.22	0.287–0.300	0.215–0.225	0.144–0.150	28	23
0.21	0.274–0.286	0.206–0.214	0.137–0.143	28	23
0.20	0.260–0.273	0.195–0.205	0.130–0.136	28	23
0.19	0.247–0.259	0.186–0.194	0.124–0.129	27	22
0.18	0.234–0.246	0.175–0.185	0.117–0.123	27	22
0.17	0.221–0.233	0.166–0.174	0.111–0.116	27	22
0.16	0.207–0.220	0.155–0.165	0.104–0.110	27	22
0.15	0.194–0.206	0.146–0.154	0.097–0.103	26	21
0.14	0.180–0.193	0.135–0.145	0.091–0.096	26	21
0.13	0.167–0.179	0.126–0.134	0.084–0.090	25	21
0.12	0.154–0.166	0.115–0.125	0.077–0.083	25	20
0.11	0.141–0.153	0.106–0.114	0.071–0.076	25	20
0.10	0.127–0.140	0.095–0.105	0.064–0.070	24	20
0.09	0.114–0.126	0.086–0.094	0.057–0.063	24	19
0.08	0.100–0.113	0.075–0.085	0.050–0.056	23	19
0.07	0.087–0.099	0.066–0.074	0.044–0.049	22	18
0.06	0.074–0.086	0.055–0.065	0.037–0.043	22	18
0.05	0.061–0.073	0.046–0.054	0.031–0.036	21	17
0.04	0.047–0.060	0.035–0.045	0.024–0.030	20	16
0.03	0.034–0.046	0.026–0.034	0.017–0.023	19	16
0.02	0.020–0.033	0.015–0.025	0.010–0.016	17	14
0.01 and less	0.019 and less	0.014 and less	0.009 and less	15	12

X4.2 Tabulated in Table X4.2 are the minimum elongation values calculated by the equation given in Table 2.

**TABLE X4.2
ELONGATION VALUES**

Area, A , mm^2	Tension Test Specimen			Elongation in 50 mm, min, %	
	Nominal Wall Thickness, mm			Specified Tensile Strength, MPa	
	19 mm Specimen	25 mm Specimen	38 mm Specimen	330	415
500 and greater	26.3 and greater	20.0 and greater	13.2 and greater	36	30
480–499	25.3–26.2	19.2–19.9	12.7–13.1	36	30
460–479	24.2–25.2	18.4–19.1	12.1–12.6	36	29
440–459	23.2–24.1	17.6–18.3	11.6–12.0	36	29
420–439	22.1–23.1	16.8–17.5	11.1–11.5	35	29
400–419	21.1–22.0	16.0–16.7	10.6–11.0	35	29
380–399	20.0–21.0	15.2–15.9	10.0–10.5	35	28
360–379	19.0–19.9	14.4–15.0	9.5–9.9	34	28
340–359	17.9–18.9	13.6–14.3	9.0–9.4	34	28
320–339	16.9–17.8	12.8–13.5	8.5–8.9	34	27
300–319	15.8–16.8	12.0–12.7	7.9–8.4	33	27
280–299	14.8–15.7	11.2–11.9	7.4–7.8	33	27
260–279	13.7–14.7	10.4–11.1	6.9–7.3	32	26
240–259	12.7–13.6	9.6–10.3	6.4–6.8	32	26
220–239	11.6–12.6	8.8–9.5	5.8–6.3	31	26
200–219	10.5–11.5	8.0–8.7	5.3–5.7	31	25
190–199	10.0–10.4	7.6–7.9	5.0–5.2	30	25
180–189	9.5–9.9	7.2–7.5	4.8–4.9	30	24
170–179	9.0–9.4	6.8–7.1	4.5–4.7	30	24
160–169	8.4–8.9	6.4–6.7	4.2–4.4	29	24
150–159	7.9–8.3	6.0–6.3	4.0–4.1	29	24
140–149	7.4–7.8	5.6–5.9	3.7–3.9	29	23
130–139	6.9–7.3	5.2–5.5	3.5–3.6	28	23
120–129	6.3–6.8	4.8–5.1	3.2–3.4	28	23
110–119	5.8–6.2	4.4–4.7	2.9–3.1	27	22
100–109	5.3–5.7	4.0–4.3	2.7–2.8	27	22
90–99	4.8–5.2	3.6–3.9	2.4–2.6	26	21
80–89	4.2–4.7	3.2–3.5	2.1–2.3	26	21
70–79	3.7–4.1	2.8–3.1	1.9–2.0	25	21
60–69	3.2–3.6	2.4–2.7	1.6–1.8	24	20
50–59	2.7–3.1	2.0–2.3	...	24	19
40–49	2.1–2.6	1.6–1.9	...	23	19
30–39	1.6–2.0	...	...	22	18

SPECIFICATION FOR CARBON STEEL FORGINGS, FOR PIPING APPLICATIONS



SA-105/SA-105M



(21)

(Identical with ASTM Specification A105/A105M-05.)

SPECIFICATION FOR CARBON STEEL FORGINGS FOR PIPING APPLICATIONS



SA-105/SA-105M



(Identical with ASTM Specification A 105/A 105M-05.)

1. Scope

1.1 This specification covers forged carbon steel piping components for ambient- and higher-temperature service in pressure systems. Included are flanges, fittings, valves, and similar parts ordered either to dimensions specified by the purchaser or to dimensional standards such as the MSS, ASME, and API specifications referenced in Section 2. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266/A 266M. Tubesheets and hollow cylindrical forgings for pressure vessel shells are not included within the scope of this specification. Although this specification covers some piping components machined from rolled bar and seamless tubular products (see 4.2), it does not cover raw material produced in these product forms.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 Specification A 266/A 266M covers other steel forgings and Specifications A 675/A 675M and A 696 cover other steel bars.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 961, the following list of standards apply to this specification:

2.2 ASTM Standards:

- A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties
- A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components
- A 788 Specification for Steel Forgings, General Requirements
- A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.3 MSS Standards:

- SP 44 Standard for Steel Pipe Line Flanges

2.4 ASME Standards:

- B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings
- B16.9 Wrought Steel Buttwelding Fittings
- B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
- B16.11 Forged Steel Fittings, Socket Weld, and Threaded
- B16.34 Valves-Flanged, Threaded and Welding End
- B16.47 Large Diameter Steel Flanges

2.5 ASME Boiler and Pressure Vessel Code:
Section IX Welding Qualifications

2.6 API Standards:
API-600 Flanged and Butt-Welding-End Steel Gate Valves
API-602 Compact Design Carbon Steel Gate Valves for Refinery Use

3. Ordering Information

3.1 See Specification A 961.

3.1.1 Additional requirements (see 12.2).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification. In case of a conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

4.2 Except as permitted by Section 6 in Specification A 961, the finished product shall be a forging as defined in the Terminology Section of Specification A 961.

5. Heat Treatment

5.1 Heat treatment is not a mandatory requirement of this specification except for the following piping components:

5.1.1 Flanges above Class 300,¹

5.1.2 Flanges of special design where the design pressure at the design temperature exceeds the pressure-temperature ratings of Class 300, Group 1.1,

5.1.3 Flanges of special design where the design pressure or design temperature are not known,

5.1.4 Piping components other than flanges which meet both of the following criteria: (1) over NPS 4 and (2) above Class 300, and

5.1.5 Piping components of Special Class² other than flanges which meet both of the following criteria: (1) over NPS 4 and (2) when the working pressure at the operating temperature exceeds the tabulated values for Special Class 300, Group 1.1.

5.2 Heat treatment, when required by 5.1 shall be annealing, normalizing, or normalizing and tempering or

quenching and tempering in accordance with Specification A 961.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements specified in Table 1.

6.2 Steels to which lead has been added shall not be used.

7. Mechanical Properties

7.1 The material shall conform to the mechanical property requirements prescribed in Table 2 and Table 3.

7.2 For normalized, normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the $\frac{1}{4} T$ plane or deeper position, where T is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat-treated surface. When section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location.

7.3 Tension Tests:

7.3.1 One tension test shall be made for each heat of as-forged components.

7.3.2 One tension test shall be made from each heat-treating charge. If more than one heat is included in such a charge, each heat shall be tested.

7.3.2.1 When the heat-treating temperatures are the same and the furnaces (either batch or continuous type), are controlled within $\pm 25^\circ\text{F}$ [$\pm 14^\circ\text{C}$] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat-treatment charge. The test specimen material shall be included with a furnace charge.

7.3.3 Testing shall be performed in accordance with Test Methods and Definitions A 370. The largest feasible round specimen as described in Test Methods and Definitions A 370 shall be used except when hollow cylindrically shaped parts are machined from seamless tubulars. The gage length for measuring elongation shall be four times the diameter of the test section. When hollow cylindrically shaped parts are machined from seamless tubular materials, strip tests may be used.

7.3.4 Forgings too small to permit obtaining a sub-size specimen of 0.250 in. [6.35 mm] diameter or larger (see Test Methods and Definitions A 370) parallel to the dimension of maximum working, and produced in equipment unsuitable for the production of a separately forged

¹ For definition of Class 300, see ASME B16.5.

² For definition of special class, see ASME B16.34.

test bar such as an automatic or semi-automatic press, may be accepted on the basis of hardness only. One percent of the forgings per lot (see Note 2), or ten forgings, whichever is the lesser number, shall be selected at random, prepared, and tested using the standard Brinell test in Test Methods and Definitions A 370. The locations of the indentations shall be at the option of the manufacturer but shall be selected to be representative of the forging as a whole. One indentation per forging shall be required but additional indentations may be made to establish the representative hardness. The hardness of all forgings so tested shall be 137 to 187 HB inclusive.

NOTE 2 — A lot is defined as the product from a mill heat or if heat treated, the product of a mill heat per furnace charge.

7.4 Hardness Tests — Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 7.3.2.1 to ensure that forgings are within the hardness limits given in Table 2. When only one forging is produced, it shall be hardness tested as defined in 7.3.2.1 to ensure it is within the hardness limits given in Table 2. Testing shall be in accordance with Test Methods and Definitions A 370. The purchaser may verify that the requirement has been met by testing at any location on the forging, provided such testing does not render the forging useless.

8. Hydrostatic Tests

8.1 Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S8 in Specification A 961 is specified.

9. Retreatment

9.1 If the results of the mechanical tests do not conform to the requirement specified, the manufacturer may heat treat or reheat treat the forgings as applicable and repeat the test specified in Section 7.

10. Repair by Welding

10.1 Repair of defects by the manufacturer is permissible for forgings made to dimensional standards such as those of ASME or for other parts made for stock by the manufacturer. Prior approval of the purchaser is required to repair-weld special forgings made to the purchaser's requirements.

10.2 Weld repairs shall be made by a process that does not produce undesirably high levels of hydrogen in the welded areas.

10.3 All forgings repaired by welding shall be post-weld heat treated between 1100°F [593°C] and the lower

transformation temperature for a minimum of $\frac{1}{2}$ h/in. [$\frac{1}{2}$ h/25.4 mm] of maximum section thickness, or alternatively annealed, normalized and tempered, or quenched and tempered. If the forging was not previously heat treated, the original tempering temperature was exceeded, or the forging was fully heat treated in the post weld cycle, then the forging shall be tested in accordance with Section 7 on completion of the cycle.

10.4 The mechanical properties of the procedure-qualification weldment shall, when tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, conform with the requirements listed in Table 2 for the thermal condition of repair-welded forgings.

11. Rejection and Rehearing

11.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

12. Certification

12.1 Identification Marking — For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Specification A 961 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification. The specification designation included on test reports shall include year date and revision letter, if any.

12.2 Test Reports — When test reports are required, the manufacturer shall also provide the following, where applicable:

12.2.1 Type heat treatment, Section 5,

12.2.2 Tensile property results, Section 7 (Table 2), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent; and, if longitudinal strip tension specimens are used, report the width of the gage length,

12.2.3 Chemical analysis results, Section 6 (Table 1). When the amount of an unspecified element is less than 0.02%, then the analysis for that element may be reported as "< 0.02%,"

12.2.4 Hardness results, Section 7 (Table 2), and

12.2.5 Any supplementary testing required by the purchase order.

13. Product Marking

13.1 If the forgings have been quenched and tempered, the letters "QT" shall be stamped on the forgings following this specification number.

13.2 Forgings repaired by welding shall be marked with the letter “W” following this specification number.

13.3 When test reports are required for larger products, the markings shall consist of the manufacturer’s symbol or name, this specification number, and such other markings as necessary to identify the part with the test report (13.1 and 13.2 shall apply). The specification number marked on the forgings need not include specification year date and revision letter.

13.4 Bar Coding — In addition to the requirements in Specification A 961 and 13.3, bar coding is acceptable as a supplemental identification method. The purchaser may

specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

14. Keywords

14.1 pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, carbon; steel valves; temperature service applications, elevated; temperature service applications, high

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon	0.35 max.
Manganese	0.60–1.05
Phosphorus	0.035 max.
Sulfur	0.040 max.
Silicon	0.10–0.35
Copper	0.40 max. [Note (1)]
Nickel	0.40 max. [Note (1)]
Chromium	0.30 max. [Notes (1), (2)]
Molybdenum	0.12 max. [Notes (1), (2)]
Vanadium	0.08 max. [Note (1)]

GENERAL NOTE: For each reduction of 0.01% below the specified carbon maximum (0.35%), an increase of 0.06% manganese above the specified maximum (1.05%) will be permitted up to a maximum of 1.35%.

NOTES:

- (1) The sum of copper, nickel, chromium, molybdenum and vanadium shall not exceed 1.00%.
- (2) The sum of chromium and molybdenum shall not exceed 0.32%.

TABLE 2
MECHANICAL REQUIREMENTS [NOTE (1)]

Tensile strength, min., psi [MPa]	70 000 [485]
Yield strength, min., psi [MPa] [Note (2)]	36 000 [250]
Elongation in 2 in. or 50 mm, min., %: Basic minimum elongation for walls $\frac{5}{16}$ in. [7.9 mm] and over in thickness, strip tests.	30
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimens with the gage length equal to 4D is used	22
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.9 mm] from the basic minimum elongation of the percentage points of Table 3	1.50 [Note (3)]
Reduction of area, min., % [Note (4)]	30
Hardness, HB, max.	187

NOTES:

- (1) For small forgings, see 7.3.4.
- (2) Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
- (3) See Table 3 for computed minimum values.
- (4) For round specimens only.

TABLE 3
COMPUTED MINIMUM VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min., %
in.	mm	
$\frac{5}{16}$ (0.312)	7.9	30.00
$\frac{9}{32}$ (0.281)	7.1	28.50
$\frac{1}{4}$ (0.250)	6.4	27.00
$\frac{7}{32}$ (0.219)	5.6	25.50
$\frac{3}{16}$ (0.188)	4.8	24.00
$\frac{5}{32}$ (0.156)	4.0	22.50
$\frac{1}{8}$ (0.125)	3.2	21.00
$\frac{3}{32}$ (0.094)	2.4	19.50
$\frac{1}{16}$ (0.062)	1.6	18.00

GENERAL NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

$$E = 48T + 15.00$$

where:

E = elongation in 2 in. or 50 mm, %, and
 T = actual thickness of specimen, in. [mm]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Hardness

S1.1 The purchaser may check the hardness of any or all forgings supplied at any location on the forging and the hardness shall be 137 to 187 HB. All forgings not within the specified hardness range shall be rejected.

S2. Heat Treatment

S2.1 All forgings shall be heat treated as specified by the purchaser.

S2.2 When forgings not requiring heat treatment by 5.1 are supplied heat treated by purchaser request, the basis for determining conformance with Table 2 and Table 3 shall be hardness testing per 7.4 and either (1) tensile testing of heat treated forgings per 7.2, or (2) tensile tests from as-forged forgings or separately forged test blanks, as agreed upon between the supplier and purchaser.

S2.3 When test reports are required, and tensile test results were obtained from as-forged forgings or as-forged test blanks, it shall be so indicated on the test report.

S2.4 In addition to the marking required by Section 13, this specification shall be followed by the letter: A for annealed, N for normalized, NT for normalized and tempered, or QT for quenched and tempered, as appropriate.

S3. Marking Small Forgings

S3.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with the test reports.

S3.2 When the configuration or size does not permit marking directly on the forging, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S4. Carbon Equivalent

S4.1 The maximum carbon equivalent, based on heat analysis, shall be 0.47 for forgings with a maximum section thickness of 2 in. or less, and 0.48 for forgings with a maximum section thickness of greater than 2 in.

S4.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S4.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

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SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE



SA-106/SA-106M



(Identical with ASTM Specification A106/A106M-08.)

SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE



SA-106/SA-106M



(Identical with ASTM Specification A 106/A 106M-08)

1. Scope

1.1 This specification covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS $\frac{1}{8}$ to NPS 48 [DN 6 to DN 1200] (Note 2) inclusive, with nominal (average) wall thickness as given in ASME B36.10M. It shall be permissible to furnish pipe having other dimensions provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized.

NOTE 1 — It is suggested, consideration be given to possible graphitization.

NOTE 2 — The dimensionless designator NPS (nominal pipe size) [DN (diameter nominal)] has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.2 Supplementary requirements of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The following precautionary caveat pertains only to the test method portion, Sections 11, 12, and 13 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
- E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
- E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 ASME Standard:

ASME B36.10M Welded and Seamless Wrought Steel Pipe

2.3 Military Standards:

- MIL-STD-129 Marking for Shipment and Storage
- MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 Federal Standard:

- Fed. Std. No. 123 Marking for Shipments (Civil Agencies)
- Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 Other Standards:

SSPC-SP 6 Surface Preparation Specification No. 6

3. Ordering Information

3.1 The inclusion of the following, as required will describe the desired material adequately, when ordered under this specification:

- 3.1.1** Quantity (feet, metres, or number of lengths),
- 3.1.2** Name of material (seamless carbon steel pipe),
- 3.1.3** Grade (Table 1),
- 3.1.4** Manufacture (hot-finished or cold-drawn),

3.1.5 Size (NPS [DN] and weight class or schedule number, or both; outside diameter and nominal wall thickness; or inside diameter and nominal wall thickness),

3.1.6 Special outside diameter tolerance pipe (16.2.2),

3.1.7 Inside diameter tolerance pipe, over 10 in. [250 mm] ID (16.2.3),

3.1.8 Length (specific or random, Section 17),

3.1.9 Optional requirements (Section 9 and S1 to S8),

3.1.10 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.11 Specification designation (A 106 or A 106M, including year-date),

3.1.12 End use of material,

3.1.13 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.

3.1.14 Special requirements.

4. Process

4.1 The steel shall be killed steel, with the primary melting process being open-hearth, basic-oxygen, or electric-furnace, possibly combined with separate degassing or refining. If secondary melting, using electroslag remelting or vacuum-arc remelting is subsequently employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 Steel cast in ingots or strand cast is permissible. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 For pipe NPS 1½ [DN 40] and under, it shall be permissible to furnish hot finished or cold drawn.

4.4 Unless otherwise specified, pipe NPS 2 [DN 50] and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, it is permissible to furnish cold-drawn pipe.

5. Heat Treatment

5.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200°F (650°C) or higher.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition

of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 5.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (see 20.1) shall be made by the manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties given in Table 2.

11. Bending Requirements

11.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter (as shown in ASME B36.10M) of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter (as shown in ASME B36.10M) of the pipe, without failure.

11.2 For pipe whose diameter exceeds 25 in. [635 mm] and whose diameter to wall thickness ratio, where the

diameter to wall thickness ratio is the specified outside diameter divided by the nominal wall thickness, is 7.0 or less, the bend test shall be conducted. The bend test specimens shall be bent at room temperature through 180° with the inside diameter of the bend being 1 in. [25 mm] without cracking on the outside portion of the bent portion.

Example: For 28 in. [711 mm] diameter 5.000 in. [127 mm] thick pipe the diameter to wall thickness ratio = $28/5 = 5.6$ [$711/127 = 5.6$].

12. Flattening Tests

12.1 Although testing is not required, pipe shall be capable of meeting the flattening test requirements of Supplementary Requirement S3, if tested.

13. Hydrostatic Test

13.1 Except as allowed by 13.2, 13.3, and 13.4, each length of pipe shall be subjected to the hydrostatic test without leakage through the pipe wall.

13.2 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order, it shall be permissible for the full body of each pipe to be tested with a nondestructive electric test described in Section 14.

13.3 Where specified in the purchase order, it shall be permissible for pipe to be furnished without the hydrostatic test and without the nondestructive electric test in Section 14; in this case, each length so furnished shall include the mandatory marking of the letters “NH.” It shall be permissible for pipe meeting the requirements of 13.1 or 13.2 to be furnished where pipe without either the hydrostatic or nondestructive electric test has been specified in the purchase order; in this case, such pipe need not be marked with the letters “NH.” Pipe that has failed either the hydrostatic test of 13.1 or the nondestructive electric test of 13.2 shall not be furnished as “NH” pipe.

13.4 Where the hydrostatic test and the nondestructive electric test are omitted and the lengths marked with the letters “NH,” the certification, where required, shall clearly state “Not Hydrostatically Tested,” and the letters “NH” shall be appended to the product specification number and material grade shown on the certification.

14. Nondestructive Electric Test

14.1 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order as an alternative or addition to the hydrostatic test, the full body of each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, E 309, or E 570. In such cases, the marking of each

length of pipe so furnished shall include the letters “NDE.” It is the intent of this nondestructive electric test to reject pipe with imperfections that produce test signals equal to or greater than that produced by the applicable calibration standard.

14.2 Where the nondestructive electric test is performed, the lengths shall be marked with the letters “NDE.” The certification, where required, shall state “Nondestructive Electric Tested” and shall indicate which of the tests was applied. Also, the letters “NDE” shall be appended to the product specification number and material grade shown on the certification.

14.3 The following information is for the benefit of the user of this specification:

14.3.1 The reference standards defined in 14.4 through 14.6 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

14.3.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

14.3.3 The eddy current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short abrupt type.

14.3.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections.

14.3.5 The hydrostatic test referred to in Section 13 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

14.3.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific applications of these examinations is directed to discuss this with the manufacturer of the tubular product.

14.4 For ultrasonic testing, the calibration reference notches shall be, at the option of the producer, any one of the three common notch shapes shown in Practice E 213.

The depth of notch shall not exceed $12\frac{1}{2}\%$ of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection:

14.5.1 Drilled Hole — The calibration pipe shall contain depending upon the pipe diameter three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

NPS	DN	Diameter of Drilled Hole
$\leq \frac{1}{2}$	≤ 15	0.039 in. (1 mm)
$> \frac{1}{2} \leq 1\frac{1}{4}$	$> 15 \leq 32$	0.055 in. (1.4 mm)
$> 1\frac{1}{4} \leq 2$	$> 32 \leq 50$	0.071 in. (1.8 mm)
$> 2 \leq 5$	$> 50 \leq 125$	0.087 in. (2.2 mm)
> 5	> 125	0.106 in. (2.7 mm)

14.5.2 Transverse Tangential Notch — Using a round tool or file with a $\frac{1}{4}$ in. [6 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding $12\frac{1}{2}\%$ of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5.3 Longitudinal Notch — A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding $12\frac{1}{2}\%$ of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

14.5.4 Compatibility — The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

14.6 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thicknesses under $\frac{1}{2}$ in. [12.7 mm], outside and inside notches shall be used; for wall thicknesses equal to and above $\frac{1}{2}$ in. [12.7 mm], only an outside notch shall be used. Notch depth shall not exceed $12\frac{1}{2}\%$ of the specified wall thickness, or 0.004 in. [0.1 mm], whichever is greater. notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

14.7 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be reexamined.

14.7.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like imperfections shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by this specification. The OD at the point of grinding may be reduced by the amount so reduced.

14.7.2 Test signals produced by visual imperfections such as those listed below may be evaluated in accordance with the provisions of Section 18:

14.7.2.1 Dinges,

14.7.2.2 Straightener marks,

14.7.2.3 Cutting chips,

14.7.2.4 Scratches,

14.7.2.5 Steel die stamps,

14.7.2.6 Stop marks, or

14.7.2.7 Pipe reducer ripple.

14.8 The test methods described in this section are not necessarily capable of inspecting the end portion of pipes, a condition referred to as “end effect.” The length of such end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

15. Nipples

15.1 Nipples shall be cut from pipe of the same dimensions and quality described in this specification.

16. Dimensions, Mass, and Permissible Variations

16.1 Mass — The mass of any length of pipe shall not vary more than 10% over and 3.5% under that specified. Unless otherwise agreed upon between the manufacturer and the purchaser, pipe in NPS 4 [DN 100] and smaller may be weighed in convenient lots; pipe larger than NPS 4 [DN 100] shall be weighed separately.

16.2 Diameter — Except as provided for thin-wall pipe in paragraph 11.2 of Specification A 530/A 530M, the tolerances for diameter shall be in accordance with the following:

16.2.1 Except for pipe ordered as special outside diameter tolerance pipe or as inside diameter tolerance pipe, variations in outside diameter shall not exceed those given in Table 3.

16.2.2 For pipe over 10 in. [250 mm] OD ordered as special outside diameter tolerance pipe, the outside diameter shall not vary more than 1% over or 1% under the specified outside diameter.

16.2.3 For pipe over 10 in. [250 mm] ID ordered as inside diameter tolerance pipe, the inside diameter shall not vary more than 1% over or 1% under the specified inside diameter.

16.3 Thickness — The minimum wall thickness at any point shall not be more than 12.5% under the specified wall thickness.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

17.1.2 No jointers are permitted unless otherwise specified.

17.1.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft [4.8 to 6.7 m] with 5% 12 to 16 ft [3.7 to 4.8 m], or in double random lengths with a minimum average of 35 ft [10.7 m] and a minimum length of 22 ft [6.7 m] with 5% 16 to 22 ft [4.8 to 6.7 m].

18. Workmanship, Finish and Appearance

18.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but consideration should be given to the necessity of exploring all surface imperfections to assure compliance with 18.2.

18.2 Surface imperfections that penetrate more than 12½% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

18.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within the limits specified in 16.3.

18.2.2 Repaired in accordance with the repair welding provisions of 18.6.

18.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

18.2.4 Rejected.

18.3 To provide a workmanlike finish and basis for evaluating conformance with 18.2 the pipe manufacturer

shall remove by grinding the following noninjurious imperfections:

18.3.1 Mechanical marks and abrasions — such as cable marks, dinges, guide marks, roll marks, ball scratches, scores, and die marks—and pits, any of which imperfections are deeper than ¼ in. [1.6 mm].

18.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 18.1 to be deeper than 5% of the nominal wall thickness.

18.4 At the purchaser's discretion, pipe shall be subjected to rejection if surface imperfections acceptable under 18.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding is permitted to be reduced by the amount so removed.

18.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

18.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

18.7 The finished pipe shall be reasonably straight.

19. End Finish

19.1 The Pipe shall be furnished to the following practice, unless otherwise specified.

19.1.1 NPS 1½ [DN 40] and Smaller — All walls shall be either plain-end square cut, or plain-end beveled at the option of the manufacturer.

19.1.2 NPS 2 [DN 50] and Larger — Walls through extra strong weights, shall be plain-end-beveled.

19.1.3 NPS 2 [DN 50] and Larger — Walls over extra strong weights, shall be plain-end square cut.

19.2 Plain-end beveled pipe shall be plain-end pipe having a bevel angle of 30°, + 5° or ± 0°, as measured from a line drawn perpendicular to the axis of the pipe with a root face of ¼ in. ± ⅓₂ in. [1.6 ± 0.8 mm]. Other bevel angles may be specified by agreement between the purchaser and the manufacturer.

20. Sampling

20.1 For product analysis (see 9.1) and tensile tests (see 21.1), a lot is the number of lengths of the same size and wall thickness from any one heat of steel; of 400 lengths or fraction thereof, of each size up to, but not including, NPS 6 [DN 150]; and of 200 lengths or fraction thereof of each size NPS 6 [DN 150] and over.

20.2 For bend tests (see 21.2), a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof, of each size.

20.3 For flattening tests, a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

21. Number of Tests

21.1 The tensile requirements specified in Section 10 shall be determined on one length of pipe from each lot (see 20.1).

21.2 For pipe NPS 2 [DN 50] and under, the bend test specified in 11.1 shall be made on one pipe from each lot (see 20.2). The bend test, where used as required by 11.2, shall be made on one end of 5% of the pipe from each lot. For small lots, at least one pipe shall be tested.

21.3 If any test specimen shows flaws or defective machining, it shall be permissible to discard it and substitute another test specimen.

22. Retests

22.1 If the percentage of elongation of any tension test specimen is less than that given in Table 1 and any part of the fracture is more than $\frac{3}{4}$ in. [19 mm] from the center of the gage length of a 2 in. [50 mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

23. Test Specimens and Test Methods

23.1 On NPS 8 [DN 200] and larger, specimens cut either longitudinally or transversely shall be acceptable for the tension test. On sizes smaller than NPS 8 [DN 200], the longitudinal test only shall be used.

23.2 When round tension test specimens are used for pipe wall thicknesses over 1.0 in. [25.4 mm], the mid—length of the longitudinal axis of such test specimens shall be from a location midway between the inside and outside surfaces of the pipe.

23.3 Test specimens for the bend test specified in Section 11 and for the flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

23.4 Test specimens for the bend test specified in 11.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either $\frac{1}{2}$ by $\frac{1}{2}$ in. [12.5 by 12.5 mm] in section or 1 by $\frac{1}{2}$ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over $\frac{1}{16}$ in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

23.5 All routine check tests shall be made at room temperature.

24. Certification

24.1 When test reports are requested, in addition to the requirements of Specification A 530/A 530M, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

25. Product Marking

25.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include heat number, the information as per Table 4, an additional symbol “S” if one or more of the supplementary requirements apply; the length, OD 1%, if ordered as special outside diameter tolerance pipe; ID 1%, if ordered as special inside diameter tolerance pipe; the schedule number, weight class, or nominal wall thickness; and, for sizes larger than NPS 4 [DN 100], the weight. Length shall be marked in feet and tenths of a foot [metres to two decimal places], depending on the units to which the material was ordered, or other marking subject to agreement. For sizes NPS $1\frac{1}{2}$, $1\frac{1}{4}$, 1, and $\frac{3}{4}$ [DN 40, 32, 25, and 20], each length shall be marked as prescribed in Specification A 530/A 530M. These sizes shall be bundled in accordance with standard mill practice and the total bundle footage marked on the bundle tag; individual lengths of pipe need not be marked with footage. For sizes less than NPS $\frac{3}{4}$ [DN 20], all the required markings shall be on the bundle tag or on each length of pipe and shall include the total footage; individual lengths of pipe need not be marked with footage. If not marked on the bundle tag, all required marking shall be on each length.

25.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor

shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

25.3 Bar Coding — In addition to the requirements in 25.1 and 25.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

26. Government Procurement

26.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for the shipment

of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

26.2 Inspection — Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer shall use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

27. Keywords

27.1 carbon steel pipe; seamless steel pipe; steel pipe

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max ^A	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max ^B	0.40	0.40	0.40
Copper, max ^B	0.40	0.40	0.40
Molybdenum, max ^B	0.15	0.15	0.15
Nickel, max ^B	0.40	0.40	0.40
Vanadium, max ^B	0.08	0.08	0.08

^A For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

^B These five elements combined shall not exceed 1%.

TABLE 2
TENSILE REQUIREMENTS

	Grade A		Grade B		Grade C	
Tensile strength, min, psi (MPa)	48 000 [330]		60 000 [415]		70 000 [485]	
Yield strength, min, psi (MPa)	30 000 [205]		35 000 [240]		40 000 [275]	
	Longitu- dinal	Transverse	Longitu- dinal	Transverse	Longitu- dinal	Transverse
Elongation in 2 in. [50 mm], min, %:						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2 in. [50 mm] gage length test specimen is used	28	20	22	12	20	12
For longitudinal strip tests	A		A		A	
For transverse strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.9 mm] from the basic minimum elongation of the following percentage shall be made		1.25		1.00		1.00

^A The minimum elongation in 2 in. [50 mm] shall be determined by the following equation:

$$e = 625\,000A^{0.2}/U^{0.9}$$

for inch-pound units, and

$$e = 1\,940A^{0.2}/U^{0.9}$$

for SI units,

where:

e = minimum elongation in 2 in. [50 mm], %, rounded to the nearest 0.5%.

A = cross-sectional area of the tension test specimen, in.² [mm²], based upon specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.² [1 mm²]. If the area thus calculated is greater than 0.75 in.² [500 mm²], then the value 0.75 in.² [500 mm²] shall be used, and

U = specified tensile strength, psi [MPa].

TABLE 3
VARIATIONS IN OUTSIDE DIAMETER

NPS [DN Designator]	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
$\frac{1}{8}$ to $1\frac{1}{2}$ [6 to 40], incl	$\frac{1}{64}$ (0.015)	0.4	$\frac{1}{64}$ (0.015)	0.4
Over $1\frac{1}{2}$ to 4 [40 to 100], incl	$\frac{1}{32}$ (0.031)	0.8	$\frac{1}{32}$ (0.031)	0.8
Over 4 to 8 [100 to 200], incl	$\frac{1}{16}$ (0.062)	1.6	$\frac{1}{32}$ (0.031)	0.8
Over 8 to 18 [200 to 450], incl	$\frac{3}{32}$ (0.093)	2.4	$\frac{1}{32}$ (0.031)	0.8
Over 18 to 26 [450 to 650], incl	$\frac{1}{8}$ (0.125)	3.2	$\frac{1}{32}$ (0.031)	0.8
Over 26 to 34 [650 to 850], incl	$\frac{5}{32}$ (0.156)	4.0	$\frac{1}{32}$ (0.031)	0.8
Over 34 to 48 [850 to 1200], incl	$\frac{3}{16}$ (0.187)	4.8	$\frac{1}{32}$ (0.031)	0.8

TABLE 4
MARKING

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 [DN 200] and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test, Standard

S3.1 For pipe over NPS 2 [DN 50], a section of pipe not less than 2½ in. [63.5 mm] in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the “H” value, the following “e” constants shall be used:

- 0.08 for Grade A
- 0.07 for Grades B and C

S3.2 When low *D-to-t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the *D-to-t* ratio is less than ten.

S3.3 The flattening test shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and from each lot of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

S3.4 Should a crop end of a finished pipe fail in the flattening test, one retest is permitted to be made from the failed end. Pipe shall be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

S4. Flattening Test, Enhanced

S4.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S5. Metal Structure and Etching Test

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Carbon Equivalent

S6.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S6.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S6.3 The CE shall be reported on the test report.

S7. Heat Treated Test Specimens

S7.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen

from each heat of steel furnished which has been either stress relieved at 1250°F or normalized at 1650°F, as specified by the purchaser. Other stress relief or annealing temperatures, as appropriate to the analysis, may be specified by agreement between the purchaser and the manufacturer. The results of this test shall meet the requirements of Table 1.

S8. Internal Cleanliness—Government Orders

S8.1 The internal surface of hot finished ferritic steel pipe and tube shall be manufactured to a free of scale condition equivalent to the visual standard listed in SSPC-SP 6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

S9. Requirements for Carbon Steel Pipe for Hydrofluoric Acid Alkylation Service

S9.1 Pipe shall be provided in the normalized heat-treated condition.

S9.2 The carbon equivalent (CE), based upon heat analysis, shall not exceed 0.43% if the specified wall thickness is equal to or less than 1 in. [25.4 mm] or 0.45% if the

specified wall thickness is greater than 1 in. [25.4 mm].

S9.3 The carbon equivalent (CE) shall be determined using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S9.4 Based upon heat analysis in mass percent, the vanadium content shall not exceed 0.02%, the niobium content shall not exceed 0.02%, and the sum of the vanadium and niobium contents shall not exceed 0.03%.

S9.5 Based upon heat analysis in mass percent, the sum of the nickel and copper contents shall not exceed 0.15%.

S9.6 Based upon heat analysis in mass percent, the carbon content shall not be less than 0.18%.

S9.7 Welding consumables of repair welds shall be of low hydrogen type. E60XX electrodes shall not be used and the resultant weld chemical composition shall meet the chemical composition requirements specified for the pipe.

S9.8 The designation “HF-N” shall be stamped or marked on each pipe to signify that the pipe complies with this supplementary requirement.

SPECIFICATION FOR PIPE, STEEL, ELECTRIC-FUSION (ARC)-WELDED (SIZES NPS 16 AND OVER)



SA-134/SA-134M



(21)

(Identical with ASTM Specification A134/A134M-19. For products ordered to Section III, Division 1, Supplementary Requirement S1 is mandatory..)

Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)

1. Scope

1.1 This specification covers electric-fusion (arc)-welded straight seam or spiral seam steel pipe NPS 16 and over in diameter (inside or outside as specified by purchaser), with wall thicknesses up to $\frac{3}{4}$ in. [19 mm], inclusive. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification. The pipe is available in various grades based on the ASTM specification ordered (Section 4).

NOTE 1—Acceptability for many services may be controlled by codes or standards such as those published by the American National Standards Institute and American Society of Mechanical Engineers.

NOTE 2—For testing methods not specifically covered in this specification, reference can be made to Test Methods and Definitions A370, with particular reference to Annex A2 on Steel Tubular Products.

NOTE 3—A comprehensive listing of standardized pipe dimensions is contained in ANSI B 36.10.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order. In this specification hard or rationalized conversions apply to diameter, lengths, and tensile properties. Soft conversion applies to other SI measurements.

NOTE 4—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.3 The following caveat pertains specifically to Section 5 of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish*

appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A36/A36M Specification for Carbon Structural Steel
 A283/A283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
 A285/A285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
 A370 Test Methods and Definitions for Mechanical Testing of Steel Products
 A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
 A1011/A1011M Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
 A1018/A1018M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Commercial, Drawing, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
 A1058 Test Methods for Mechanical Testing of Steel Products—Metric

2.2 ASME Boiler and Pressure Vessel Code:

Section III
 Section IX

2.3 *American National Standards Institute Standard:*

B 16.25 Buttwelding Ends

B 36.10 Welded and Seamless Wrought Steel Pipe

3. Ordering Information

3.1 Orders for electric-fusion arc-welded pipe under this specification shall contain information concerning as many of the following items as are required, to describe the desired pipe adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (electric-fusion (arc)-welded pipe),

3.1.3 ASTM Specification A134 or A134M and year date,

3.1.4 Grade (if applicable) of steel from which the pipe shall be made (Section 4),

3.1.5 Size (inside or outside diameter and nominal wall thickness), and

3.1.6 Length (specified or random).

3.2 The purchaser shall have the option to order additional requirements, including, but not limited to the following:

3.2.1 Specific straightness requirements (see 12.3),

3.2.2 End finish (Section 14),

3.2.3 Hydrostatic Test Pressure (Section 11),

3.2.4 Protective coating (Section 20),

3.2.5 End use of pipe, and

3.2.6 Other special or supplementary requirements, if any.

4. Material

4.1 The steel from which the pipe is made shall conform to Specifications A36/A36M, A283/A283M, A285/A285M, A1011/A1011M, A1018/A1018M, or to other ASTM specifications for equally suitable weldable material, as specified. For purposes of marking and certification, when required, the pipe grade of material shall be established by the A xxx plate specification designation and plate grade, when applicable.

5. Manufacture

5.1 The longitudinal edges of the steel shall be shaped to give the most satisfactory results by the particular welding process employed. The steel shall then be properly formed and may be tacked preparatory to welding. The weld shall be made by automatic means (except tack welds) and shall be of reasonably uniform width and height for the entire length of the pipe. By agreement between the purchaser and the manufacturer, manual welding by qualified procedure and welders may be used as an equal alternate under this specification.

5.2 All longitudinal seams, spiral seams, and shop girth seams shall be butt-welded.

6. Number of Production Weld Tests

6.1 One weld test specimen specified in Section 8 shall be made from each lot of 3000 ft [900 m] of pipe or fraction thereof of each size and wall thickness.

6.2 If any test specimen shows defective machining or develops flaws not associated with the welding, it may be discarded and another specimen substituted.

6.3 Each length of pipe shall be subjected to the hydrostatic test specified in Section 11, unless otherwise specified in 11.3.

7. Retests

7.1 If any specimen tested in accordance with Section 10 fails to meet the requirements, retests of two additional specimens from the same lot of pipe shall be made, each of which shall meet the requirements specified. If any of the retests fail to conform to the requirements, test specimens may be taken from each untested pipe length at the manufacturer's option. Each specimen shall meet the requirements specified, or that pipe shall be rejected.

8. Test Specimens of Production Welds

8.1 The weld-test specimens for the reduced-section tension test shall be taken perpendicularly across the weld and from the end of the pipe or, alternatively, from flat test pieces of material conforming to the requirements in the specifications used in the manufacture of the pipe. The alternative weld-test specimens shall be welded with the same procedure and by the same operator and equipment, and in sequence with the welding of the longitudinal joints in the pipe. The test pieces shall have the weld approximately in the middle of the specimen. The specimens shall be straightened cold, and shall be tested at room temperature.

8.2 Reduced-section tension-test specimens shall be prepared in accordance with Fig. A2.3 of Test Methods and Definitions A370, Annex A2 Steel Tubular Products.

9. Qualification of Welding Procedure

9.1 The welding procedure shall be qualified in accordance with the American Welding Society Standard Qualification Procedure⁵ or ASME Section IX of the Boiler and Pressure Vessel Code as agreed to between the manufacturer and the purchaser using the tests and test values specified in 9.2 and 9.3. Thicknesses less than $\frac{3}{8}$ in. [10 mm] shall be qualified for each wall thickness of pipe manufactured. Thicknesses $\frac{3}{8}$ to $\frac{3}{4}$ in. [10 mm to 19 mm], inclusive, shall be qualified in $\frac{3}{8}$ -in. [10-mm] thickness.

9.2 Two reduced-section tension specimens (transverse weld) made in accordance with Fig. A2.3 of Test Methods and Definitions A370, with the weld reinforcement removed, shall show a tensile strength not less than 100 % of the minimum specified tensile strength of the base material used.

9.3 Two face-bend test specimens shall be prepared in accordance with Section A2.5.1.7 of Test Methods and Definitions A370 and shall withstand being bent 180° in a jig substantially in accordance with Fig. A2.15.3 of Test Methods and Definitions A370. The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. [3 mm] in any direction be present in the weld metal or between the weld and the pipe

metal after bending. Cracks that originate along the edges of the specimens during testing and that are less than ¼ in. [6 mm] in any direction, shall not be considered.

10. Tensile Properties of Production Welds

10.1 Reduced-section tension test specimens required in Section 8, taken perpendicularly across the weld with the weld reinforcement removed, shall show a tensile strength not less than 95 % of the specified minimum strength of the steel. At the manufacturer's option, the test may be made without removing the weld reinforcement, in which case the tensile strength shall be not less than the specified minimum tensile strength for the grade of steel used.

11. Hydrostatic Test (Note 5)

11.1 Each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress of 60 % of the specified minimum yield point of the steel used at room temperature. The pressure shall be determined by the following equation:

$$P = 2St/D$$

where:

- P = minimum hydrostatic test pressure, psi (Note 6) (not to exceed 2800 psi [19 MPa]),
- S = 0.60 times the minimum specified yield point of the steel used, psi [MPa],
- t = specified wall thickness, in. [mm], and
- D = specified outside diameter, in. [mm].

NOTE 5—A hydrostatic sizing operation is not to be considered a hydrostatic test or a substitute for it.

NOTE 6—When the diameter and wall thickness of pipe are such that the capacity limits of testing equipment are exceeded by these requirements, the test pressures may be reduced by agreement between the purchaser and the manufacturer.

11.2 Test pressure shall be held for not less than 5 s, or for a longer time as agreed upon between the purchaser and the manufacturer.

NOTE 7—When agreed upon between the purchaser and the manufacturer and so stated on the order, pipe may be tested to one and one half times the specified working pressure, except that the maximum test pressure shall not exceed 2800 psi [19 MPa] nor shall the maximum fiber stress exceed 85 % of specified minimum yield point of steel or to a fiber stress that does not exceed 85 % of the specified minimum yield point of the steel or 2800-psi [19-MPa] test pressure.

11.3 When specified in the order, pipe may be furnished without hydrostatic testing and each length so furnished shall include the mandatory marking of the letters "NH." Additionally, the certification, when required, shall state "Not Hydrostatically Tested" and the specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

12. Permissible Variations in Weights and Dimensions

12.1 *Thickness and Weight*—The wall thickness and weight for welded pipe under this specification shall be governed by the requirements of the specifications to which the steel was ordered.

12.2 *Circumference*—The outside circumference of the pipe shall not vary more than ± 0.5 % from the nominal outside circumference based upon the diameter specified, except that the circumference at ends shall be sized, if necessary, to meet the requirements of Section 14.

12.3 *Straightness*—Finished pipe shall be commercially straight. When specific straightness requirements are desired, the order should so state, and the tolerances shall be a matter of agreement between the purchaser and the manufacturer.

12.4 *Ovality—Out-of-roundness*—The difference between major and minor outside diameter shall not exceed 1 %. Closer tolerances may be established by agreement between the manufacturer and the purchaser. Where the D/T (outside diameter/wall thickness) is over 120, internal bracing should be utilized to achieve sizing of ends and ovality shall be by agreement between the manufacturer and purchaser.

13. Lengths

13.1 Pipe lengths shall be supplied in accordance with the following regular practice:

13.1.1 The lengths shall be as specified on the order with a tolerance of $\pm 1/2$ in. [13 mm], except that the shorter lengths from which test coupons have been cut may also be shipped.

13.1.2 When random lengths are specified, pipe shall be furnished in lengths having a minimum average of 29 ft [9 m] with a minimum length of 20 ft [6 m], but not more than 5 % may be under 25 ft [8 m].

13.2 Pipe lengths containing circumferentially welded joints (Note 8) shall be permitted by agreement between the manufacturer and the purchaser. Tests of these welded joints shall be made in accordance with the procedure tests specified in Section 9 and the production weld tests specified in Section 10. The number of production weld tests shall be one per each lot of 100 joints or fraction thereof, but not less than one for each welder or welding operator.

NOTE 8—Joints are defined for the purpose of this specification as a circumferential welded seam lying in one plane, used to join lengths of straight pipe.

14. Ends

14.1 Pipe shall be furnished with a plain right-angle cut or with bevel ends as specified. All burrs at the ends of pipe shall be removed.

14.1.1 Unless otherwise specified, pipe with beveled ends shall meet the requirements of ANSI B 16.25.

14.2 Unless otherwise specified, the outside circumference of pipe ends for a distance of not less than 4 in. [100 mm] shall not vary more than ± 60 % of the nominal wall thickness of the pipe from the nominal outside circumference based on the diameter specified, except that the tolerance shall not be less than $\pm 3/16$ in. [5 mm].

14.3 By agreement between the manufacturer and the purchaser the ends of the pipe may be sized within agreed-upon tolerances if necessary to meet the requirements of special installations.

15. Finish

15.1 *Repair by Welding*—The welding of injurious defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, will be permitted. Defects in the welds, such as sweats or leaks, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then welding.

15.2 All repaired pipe shall be tested hydrostatically in accordance with Section 11, unless otherwise specified in 11.3.

16. Inspection

16.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment and unless otherwise specified, shall be so conducted as not to interfere unnecessarily with the operation of the works. If agreed upon, the manufacturer shall notify the purchaser in time so that he may have his inspector present to witness any part of the manufacture or tests that may be desired. The certification shall include reference to this specification and the pipe grade (ASTM plate specification designation and plate grade, when applicable).

16.2 *Certification*—Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished. When hydrostatic test is omitted, the certificate shall include the letters "NH."

17. Rejection

17.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the

requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected, and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter of agreement between the purchaser and the manufacturer.

18. Certification

18.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, including year date, together with a report of the chemical and tensile tests shall be furnished. The pipe grade shall be identified by the plate specification designation (year date not required) and the plate grade (where applicable).

19. Product Marking

19.1 Each section of pipe shall be marked with the manufacturer's distinguishing marking, this specification number, and the pipe grade. The marking need not include the year date of the pipe or plate specification.

19.2 *Bar Coding*—In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

20. Protective Coating

20.1 If agreed upon between the purchaser and the manufacturer, the pipe shall be given a protective coating of the kind and in the manner specified by the purchaser.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. ASME Section III Construction

S1.1 Products furnished under this specification that are intended for application under the rules of the ASME Boiler and Pressure Vessel Code Section III, Class 3 Piping, shall be manufactured by holders of the appropriate ASME Certificate of Authorization and Certification Mark. The product is subject to all applicable requirements of Section III, Class 3 Piping,

including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

S1.2 The applicable ASME Partial Data Report Form, signed by an Authorized Nuclear Inspector, and a material test report shall be furnished for each lot of pipe.

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SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED STEEL PIPE



SA-135/SA-135M

(21)

(Identical with ASTM Specification A135/A135M-19 except certification has been made mandatory.)

Specification for Electric-Resistance-Welded Steel Pipe

1. Scope

1.1 This specification covers two grades of electric-resistance-welded steel pipe in NPS 2 to NPS 30 [DN 50 to DN 750] inclusive, with nominal (average) wall thickness up to 0.500 in. [12.70 mm], inclusive, and in nominal sizes NPS $\frac{3}{4}$ to NPS 5 [DN 20 to DN 125] inclusive with nominal (average) wall thickness 0.083 in. [2.11 mm] to 0.134 in. [3.40 mm], depending on size. Pipe having other dimensions (Note 1) may be furnished provided such pipe complies with all other requirements of this specification. The pipe is intended for conveying gas, vapor, water or other liquid; only Grade A is adapted for flanging and bending (Note 2). The suitability of pipe for various purposes is somewhat dependent upon its dimensions, properties, and conditions of service, so that the purpose for which the pipe is intended should be stated in the order. The pipe may be furnished either nonexpanded or cold expanded at the option of the manufacturer. When pipe is cold expanded, the amount of expansion shall not exceed 1.5 % of the outside diameter pipe size.

NOTE 1—A comprehensive listing of standardized pipe dimensions is contained in ASME B36.10M.

NOTE 2—This provision is not intended to prohibit the cold bending of Grade B pipe.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A865/A865M Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints
- A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
- E6 Terminology Relating to Methods of Mechanical Testing
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing
- E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing
- E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation
- E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products
- E1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 ASME Standard:

- B1.20.1 Pipe Threads, General Purpose
- B36.10M Welded and Seamless Wrought Steel Pipe

2.3 Federal Standards:

- Fed. STD No. 123 Marking for Shipments (Civil Agencies)
- Fed. STD No. 183 Continuous Identification Marking of Iron and Steel Products

2.4 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage

3. Terminology

3.1 For definitions of terms relating to steel manufacturing and properties, refer to Terminology A941.

3.2 For definitions of terms relating to mechanical testing, refer to Terminology E6.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *burr, n*—a rough or sharp edge left on pipe ends by cutting or sawing.

3.3.2 *lot, n*—all pipe of the same size, wall thickness and rolled length that is produced from the same heat of steel and subject to the same heat treatment.

3.3.3 *black thread, n*—a thread crease exhibiting the original pipe surface after machining.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 4.1.1 Quantity (feet, metres, or number of lengths),
- 4.1.2 Name of product (electric-resistance-welded pipe),
- 4.1.3 Specification designation and year of issue,
- 4.1.4 Grade (see Table 1),
- 4.1.5 Size (nominal size, NPS [DN], or outside diameter; and nominal wall thickness),
- 4.1.6 Length (specific or random, see 12.4),
- 4.1.7 End finish (plain or threaded, see 13.2),
 - 4.1.7.1 Threaded and coupled, if specified,

- 4.1.7.2 Threads only, if specified,
- 4.1.7.3 Plain end, if specified,
- 4.1.8 Alternative electric test (see Section 11),
- 4.1.9 Tension test specimen (see Section 15),
- 4.1.10 Heat analysis, if required (see 6.1),
- 4.1.11 DELETED
- 4.1.12 Special requirements.

5. Manufacture

5.1 The steel shall be made by either or both of the following processes: basic-oxygen or electric-furnace.

5.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The pipe shall be manufactured from flat rolled steel in individual lengths or in continuous length by electric-resistance or electric-induction welding without the addition of extraneous material.

5.4 The weld seam of electric-resistance welded pipe to Grade B pipe shall be heat treated after welding to a minimum temperature of 1000 °F [540 °C] or processed in such a manner that no untempered martensite remains.

6. Chemical Composition

6.1 The steel shall conform to the requirements prescribed in Table 2, based on the heat analysis. When specified in the order, the heat analyses shall be reported to the purchaser or a representative of the purchaser.

TABLE 1 Tensile Requirements

	Grade A	Grade B
Tensile strength, min, ksi [MPa]	48 [330]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	35 [240]
Elongation in 2 in. or [50 mm], min, %:		
For pipe having a specified wall thickness of $\frac{5}{16}$ in. [7.9 mm] or more, if tested using a longitudinal strip test specimen.	35	30
For pipe having a specified wall thickness of less than $\frac{5}{16}$ in. [7.9 mm], if tested using a longitudinal strip test specimen.	^A	^B
For pipe of any size, if tested using a full-size longitudinal test specimen.	35	30

^A The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 56t + 16.5$$

$$[E = 2.2t + 16.5]$$

where:

E = elongation in 2 in. or [50 mm], minimum, %, and
 t = specified wall thickness, in. [mm].

^B The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 48t + 14$$

$$[E = 1.9t + 14]$$

where:

E = elongation in 2 in. or [50 mm], minimum, %, and
 t = specified wall thickness, in. [mm].

TABLE 2 Chemical Requirements

Element	Composition, max, %	
	Grade A	Grade B
Carbon	0.25	0.30
Manganese	0.95	1.20
Phosphorus	0.035	0.035
Sulfur	0.035	0.035

7. Product Analysis

7.1 An analysis may be made by the purchaser on samples of pipe selected at random and shall conform to the requirements specified in Table 2. Methods and Practices relating to chemical analysis shall be in accordance with Test Method, Practices, and Terminology A751.

8. Mechanical Properties Requirements

8.1 Tensile Properties:

8.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1.

8.1.2 The yield strength shall be determined by the offset method utilizing 0.2 % of the gauge length or by the total extension under load method using 0.5 % of the gauge length.

8.1.3 Longitudinal test specimens shall be full-size longitudinal test specimens (see Figure A2.1 of Test Methods and Definitions A370) or longitudinal strip test specimens (see Specimen No. 4 in Fig. A2.3 of Test Methods and Definitions A370).

8.2 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8 [DN 200].

9. Flattening Test

9.1 A specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps with the weld located either 0° or 90° from the line of direction of force as required in 9.2. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur before the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur before the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.2 For pipe produced in single lengths, the flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of

direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.3 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 13.

9.4 Superficial cracks as a result of surface imperfections shall not be cause for rejection.

10. Hydrostatic Test

10.1 Except as provided for in 10.3, each length of pipe shall be hydrostatically tested at the mill, without leakage through the wall, to a pressure calculated from the following equation:

$$P = 2St/D$$

where:

- P = minimum hydrostatic test pressure, psi, [kPa]. The test pressure need not exceed 2500 psi [17 200 kPa],
 S = allowable fiber stress 18 000 psi [124 000 kPa] for Grade A and 21 000 psi [145 000 kPa] for Grade B. This does not prohibit testing at higher pressure at the manufacturer's option,
 t = specified wall thickness, in. [mm], and
 D = specified outside diameter, in. [mm].

Plain end pipe may be tested at the discretion of the manufacturer in single lengths or in multiple lengths.

10.2 The hydrostatic pressure shall be maintained for not less than 5 s.

10.3 When specified in the order, pipe may be furnished without hydrostatic testing, and each length so furnished shall include with the mandatory marking the letters "NH."

NOTE 3—This provision is not intended to apply to light wall (Schedule 10) pipe listed in Table X1.1.

10.4 When the hydrostatic test has been omitted, the certification shall clearly state "Not Hydrostatically Tested." The specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

11. Nondestructive Examination Requirements

11.1 As an alternate to the hydrostatic test, and when accepted by the purchaser, each pipe shall be tested with a nondestructive electric test. Except for pipe produced on a hot-stretch reducing mill, the weld seam of each length of pipe shall be tested with a nondestructive test in accordance with Practices E213, E273, E309, or E570. Each length of pipe produced on a hot-stretch-reducing mill shall be tested with a nondestructive electric test that inspects the full volume of the pipe in accordance with Practices E213, E309, or E570.

11.2 Recognized methods for meeting this test are electromagnetic (eddy current) or ultrasonic.

11.3 The following information is for the benefit of the user of this specification:

11.3.1 The ultrasonic examination referred to in this specification is intended to detect longitudinal imperfections having

a reflective area similar to or larger than the reference notch. The examination may not detect circumferentially oriented imperfections of short, deep imperfections.

11.3.2 The eddy-current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short, abrupt type.

11.3.3 The hydrostatic test referred to in Section 10 is a test method provided for in many product specifications. This test has the capability of finding imperfections of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

11.3.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.4 In order to accommodate the various types of nondestructive electric testing equipment and techniques in use, the calibration pipe shall contain, at the option of the producer, any one or more of the following discontinuities to establish a minimum sensitivity level for rejection:

11.4.1 *Drilled Hole*—A hole not larger than 0.031-in. [0.8-mm] diameter shall be drilled radially and completely through pipe wall, preferably in the weld area, care being taken to avoid distortion of the pipe while drilling.

11.4.2 *Transverse Tangential Notch*—A notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe preferably in the weld area. Said notch shall have a depth not exceeding 12.5 % of the nominal wall thickness of the pipe or 0.004 in. [0.10 mm], whichever is greater.

11.4.3 *Longitudinal Notch*—A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe preferably in the weld area, to have a depth not exceeding 12.5 % of the nominal wall thickness of the pipe or 0.004 in. [0.10 mm], whichever is greater.

11.5 Pipe producing a signal equal to or greater than the calibration imperfection shall be rejected.

12. Dimensions, Weight (Mass), and Permissible Variations

12.1 *Weight (Mass)*—The weight (mass) of any length of pipe other than Schedule 10 shall not vary more than 3.5 % under or 10 % over that specified, but the carload weight (mass) shall be not more than 1.75 % under the nominal weight (mass). The weight (mass) of pipe furnished to Schedule 10 shall not vary more than ± 10 % from that calculated using the weight (mass) per unit length prescribed in Appendix Table X1.1. The weight (mass) of the pipe shall be calculated from the relevant equation in ASME B36.10M.

NOTE 4—A system of standard pipe sizes has been approved by the American National Standards Institute as American National Standard for Welded and Seamless Wrought Steel Pipe (ASME B36.10M).

12.2 *Diameter*—The outside diameter shall not vary more than ± 1 % from the nominal size specified.

12.3 *Minimum Wall Thickness*—The minimum wall thickness at any point shall be not more than 12.5 % under the specified wall thickness.

NOTE 5—The minimum wall thickness on inspection is shown in Table X1.2 of the Appendix.

12.4 Lengths:

12.4.1 Except as allowed in 12.4.2, pipe shall be furnished in lengths averaging 38 ft [11.6 m] or over, with a minimum length of 20 ft [6.1 m], but no more than 5 % may be under 32 ft [9.8 m]. Jointers made by welding are permissible. When threaded pipe is ordered, jointers shall be made by threaded connections and shall not exceed 5 % of the order.

12.4.2 Unless otherwise specified, Schedule 10 pipe shall be between 16 and 22 ft [4.9 and 6.7 m] for a minimum of 90 % of the footage furnished, with any balance being shorter lengths at least 8 ft [2.4 m] long.

13. Workmanship, Finish, and Appearance

13.1 The finished pipe shall be reasonably straight and free of defects. Surface imperfections in excess of 12.5 % of the nominal wall thickness shall be considered defects.

13.2 End Finish:

13.2.1 *Schedule 10 Pipe*—Pipe furnished to Schedule 10 shall be plain end only. All inside and outside cutting burrs shall be removed. This generally involves breaking the corners.

13.2.2 *Ends, Plain End Pipe*—Unless otherwise specified, plain end pipe for use with the Dresser or Dayton type coupling shall be reamed both outside and inside sufficiently to remove all burrs. Plain end pipe for welding shall be beveled on the outside to an angle of 30° with a tolerance of + 5° and – 0° and with a width of flat at the end of the pipe of $\frac{1}{16} \pm \frac{1}{32}$ in. [1.6 \pm 0.8 mm]. When material is ordered beveled to any other than a 30° angle, it should be understood that the angle is to be measured from a line drawn perpendicular to the axis of the pipe. This means that a greater amount of material is removed with a 60° angle than with a 30° angle. Pipe shall be sufficiently free from indentations, projections, or roll marks for a distance of 8 in. [200 mm] from the end of the pipe to make a tight joint with the rubber gasket type of coupling. All plain end pipe intended for Dresser or Dayton type joints or for welding, sizes NPS 10 [DN 250] and smaller in outside diameter specified, shall be not more than $\frac{1}{32}$ in. [0.8 mm] smaller than the outside diameter specified for a distance of 8 in. [200 mm] from the ends of the pipe and shall permit the passing for a distance of 8 in. [200 mm] of a ring gauge that has a bore $\frac{1}{16}$ in. [1.6 mm] larger than the outside diameter specified of the pipe. Sizes larger than NPS 10 [DN 250] shall be not more than $\frac{1}{32}$ in. [0.8 mm] smaller than the nominal outside diameter for a distance of 8 in. [200 mm] from the end of the pipe and shall permit the passing for a distance of 8 in. [200 mm] of a ring gauge which has a bore $\frac{3}{32}$ in. [2.4 mm] larger than the nominal outside diameter of the pipe.

13.2.3 *Ends, Threaded Pipe*—Each end of threaded pipe shall be reamed to remove all burrs. All threads shall be in accordance with the American National Standard Pipe Threads

(Note 6) and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gauge, shall not exceed one and one-half turns either way. Pipe shall not be rounded by hammering in order to get a full thread. There shall be not more than two black threads for $\frac{3}{4}$ -in. [19.0-mm] taper among the perfect threads. Black threads should not be confused with imperfect threads, such as those torn, shaven, or broken.

NOTE 6—A complete description of the American National Standard Pipe Threads applicable to pipe, valves, and fittings is contained in ASME B1.20.1; also “Screw-Thread Standards for Federal Services, 1942,” National Bureau of Standards *Handbook H 28*, January, 1942, the pertinent data in both sources being identical.

13.3 *Couplings*—Each length of threaded pipe shall be provided with one coupling manufactured in accordance with Specification A865/A865M except that the coupling may be wrought iron (Note 7). Threads shall be cut so as to make a tight joint. Taper-tapped couplings shall be furnished on all weights (masses) of threaded pipe NPS 2½ [DN 65] and larger.

NOTE 7—For sizes NPS 2 [DN 50] and smaller, it is commercial practice to furnish straight-tapped couplings for standard-weight (mass) (Schedule 40) pipe and taper-tapped couplings for extra-strong (Schedule 80) and double-extra-strong pipe. If taper-tapped couplings are required for sizes NPS 2 [DN 50] and smaller on standard weight (mass) (Schedule 40) pipe, line pipe in accordance with Specification 5L of the American Petroleum Institute should be ordered, thread lengths to be in accordance with ASME B1.20.1. Taper-tapped couplings for sizes NPS 2 [DN 50] and smaller in standard weight (mass) may be used on mill-threaded standard weight (mass) type of the same size.

13.4 *Protective Coating:*

13.4.1 After the pipe has been subjected to the hydrostatic test, and if required by the purchaser, it shall be thoroughly cleaned of all dirt, oil, grease, loose scale, and rust; then dried, and given a protective coating of the kind and in the manner specified by the purchaser. Pipe furnished to Schedule 10 shall be normally shipped with a light coating of processing oil. If so specified, the pipe can be given a mill coating or a special coating.

14. Weld Repair

14.1 *Welding Repair:*

14.2 Defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, shall be repaired by electric welding. Defects in the welds such as sweats or leaks, unless otherwise specified, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then electric welding.

14.3 All repaired pipe shall be retested hydrostatically in accordance with Section 10.

15. Sampling

15.1 *Chemical Analysis:*

15.1.1 Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E1806. The number of samples shall be determined as follows:

NPS	Numbers of Samples Selected
Under 6 [DN 150]	2 from each lot of 400 pipes or fraction thereof
6 [DN 150] to 20 [DN 500], incl	2 from each lot of 200 pipes or fraction thereof
Over 20 [DN 500] to 30 [DN 750], incl	2 from each lot of 100 pipes or fraction thereof

15.2 *Tension Test:*

15.2.1 One longitudinal tension test shall be made on one length (Note 8) from each lot of 400 lengths or fraction thereof of each size under NPS 8 [DN 200] and one transverse body and one transverse weld tension test on one length from each lot of 200 lengths or fraction thereof of each size NPS 8 to NPS 20 [DN 200 to DN 500] and on one length from each lot of 100 lengths or fraction thereof of each size over NPS 20 to NPS 30 [DN 500 to DN 750]. When taken from the skelp, the number of tests shall be determined in the same manner as when taken from the finished pipe.

NOTE 8—Length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than double random, which is defined as the length as rolled, prior to cutting to the required short lengths.

15.3 *Flattening Test:*

15.3.1 When pipe is produced in single length, the flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, flattening tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.

15.4 *Hydrostatic Test:*

15.4.1 Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

16. Test, Retest, and Resampling

16.1 *Chemical Analysis:*

16.1.1 If the results of the analysis of either length of pipe does not conform to the requirements specified in Section 7, analyses of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2 *Tension Test:*

16.2.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A370, except that all specimens shall be tested at room temperature.

16.2.2 The longitudinal tension test specimen shall be taken from the end of the pipe, or by agreement between the manufacturer and the purchaser may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gauge marks. The sides of each specimen shall be parallel between gauge marks. At the manufacturer option, the tension test may be made on full section of pipe.

16.2.3 Transverse weld test specimens shall be taken with the weld at the center of the specimen. Transverse body test specimens shall be taken opposite to the weld. All transverse test specimens shall be approximately 1½ in. [38 mm] wide in the gauge length and shall represent the full wall thickness of the pipe from which the specimen was cut.

16.2.4 If any test specimen shows defective machining or develops flaws not associated with the quality of the steel or the welding, it may be discarded and another specimen substituted.

16.2.5 If the results of the tension tests of any lot do not conform to the requirements specified in 9.1, retests of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2.6 If the percentage of elongation of any tension test specimen is less than that specified in 8.1, and any part of the fracture is more than $\frac{3}{4}$ -in. [19.0-mm] from the center of the gauge length as indicated by scribe scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

16.3 *Flattening Test:*

16.3.1 Specimens for flattening tests shall be smooth at the ends and free from burrs.

16.3.2 If any section of the pipe fails to comply with the requirements of 9.1, for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80 % of its length after the initial cropping; otherwise, the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple; such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

16.4 All specimens shall be tested at room temperature.

17. Inspection

17.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the manufacturer's operation.

18. Rejection

18.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and

test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

19. Certification

19.1 A manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. A report of the test results shall be furnished.

20. Identification of Material

20.1 Each length of pipe shall be legibly marked with appropriate symbols by stenciling, stamping, or rolling to show the manufacturer's name, the size, the specification designation, the grade, and the hydrostatic test pressure when tested, or the letters "NH" when not tested.

20.2 In addition to the requirements in 20.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

21. Packaging, Marking, and Loading for Shipment

21.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with Practices A700.

21.2 The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

22. Keywords

22.1 eddy current testing; electric resistance welded pipe; hydrostatic testing; plain end pipe; Schedule 10 pipe; threaded pipe

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL DATA

X1.1 Additional data on dimensions nominal weights (masses) and test pressures is provided in Table X1.1.

X1.2 Additional data on wall thicknesses are provided in Table X1.2.

TABLE X1.1 Dimensions, Nominal Weights (Masses), and Test Pressures for Light Wall Steel Pipe

NPS	DN	Outside Diameter, in. [mm]	Schedule 10		Test Pressure, psi [MPa] ^A	
			Specified Wall Thickness ^A in. [mm]	Weight (Mass) Per Unit Length lb/ft [kg/m]	Grade A	Grade B
¼	20	1.050 [26.7]	0.083 [2.11]	0.86 [1.28]	2500 [17 200]	2500 [17 200]
1	25	1.315 [33.4]	0.109 [2.77]	1.41 [2.09]	2500 [17 200]	2500 [17 200]
1¼	32	1.660 [42.2]	0.109 [2.77]	1.81 [2.69]	2400 [16 500]	2500 [17 200]
1½	40	1.900 [48.3]	0.109 [2.77]	2.09 [3.11]	2100 [14 500]	2400 [16 500]
2	50	2.375 [60.3]	0.109 [2.77]	2.64 [3.93]	1700 [11 700]	1900 [13 100]
2½	65	2.875 [73.0]	0.120 [3.05]	3.53 [5.26]	1500 [10 300]	1700 [11 700]
3	80	3.500 [88.9]	0.120 [3.05]	4.34 [6.46]	1200 [8 200]	1400 [9 600]
3½	90	4.000 [101.6]	0.120 [3.05]	4.98 [7.41]	1000 [6 900]	1200 [8 200]
4	100	4.500 [114.3]	0.120 [3.05]	5.62 [8.37]	900 [6 200]	1100 [7 600]
5	125	5.563 [141.3]	0.134 [3.40]	7.78 [11.58]	850 [5 900]	1000 [6 900]

^A The test pressures are calculated by the following equation (but need not exceed 2500 psi or [17 200 KPa]):

$$P = 2St/D$$

where:

- P = pressure, psi [kPa],
 S = fiber stress 60 % of the specified minimum yield strength, psi [kPa],
 t = specified wall thickness, in. [mm], and
 D = specified outside diameter, in. [mm].

TABLE X1.2 Minimum Permissible Wall Thickness on Inspection

NOTE 1—The following equation, upon which this table is based, is used to derive the minimum permissible wall thickness values from the specified wall thickness values, with the calculated values rounded to three decimal places in accordance with the rounding method of Practice E29:

$$t_m \times 0.875 = t$$

where:

t_m = minimum permissible wall thickness, in. [mm], and

t = specified wall thickness, in. [mm].

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Specified Wall Thickness (t), in. [mm]	Minimum Permissible Wall Thickness (t_m), in. [mm]	Specified Wall Thickness (t), in. [mm]	Minimum Permissible Wall Thickness (t_m), in. [mm]	Specified Wall Thickness (t), in. [mm]	Minimum Permissible Wall Thickness (t_m), in. [mm]
0.068 [1.73]	0.060 [1.52]	0.294 [7.47]	0.257 [6.53]	0.750 [19.05]	0.656 [16.66]
0.088 [2.24]	0.077 [1.96]	0.300 [7.62]	0.262 [6.65]	0.812 [20.62]	0.710 [18.03]
0.091 [2.31]	0.080 [2.03]	0.307 [7.80]	0.269 [6.83]	0.844 [21.44]	0.738 [18.75]
0.095 [2.41]	0.083 [2.11]	0.308 [7.82]	0.270 [6.86]	0.864 [21.94]	0.756 [19.20]
0.113 [2.87]	0.099 [2.51]	0.312 [7.92]	0.273 [6.93]	0.875 [22.22]	0.766 [19.46]
0.119 [3.02]	0.104 [2.64]	0.318 [8.08]	0.278 [7.06]	0.906 [23.01]	0.793 [20.14]
0.125 [3.18]	0.109 [2.77]	0.322 [8.18]	0.282 [7.16]	0.937 [23.82]	0.820 [20.85]
0.126 [3.20]	0.110 [2.79]	0.330 [8.38]	0.289 [7.34]	0.968 [24.59]	0.847 [21.51]
0.133 [3.38]	0.116 [2.95]	0.337 [8.56]	0.295 [7.49]	1.000 [25.40]	0.875 [22.22]
0.140 [3.56]	0.122 [3.10]	0.343 [8.71]	0.300 [7.62]	1.031 [26.19]	0.902 [22.91]
0.145 [3.68]	0.127 [3.23]	0.344 [8.74]	0.301 [7.65]	1.062 [26.97]	0.929 [23.60]
0.147 [3.73]	0.129 [3.28]	0.358 [9.09]	0.313 [7.95]	1.094 [27.79]	0.957 [24.31]
0.154 [3.91]	0.135 [3.43]	0.365 [9.27]	0.319 [8.10]	1.125 [28.58]	0.984 [24.99]
0.156 [3.96]	0.136 [3.45]	0.375 [9.52]	0.328 [8.33]	1.156 [29.36]	1.012 [25.70]
0.179 [4.55]	0.157 [3.99]	0.382 [9.70]	0.334 [8.48]	1.219 [30.96]	1.066 [27.08]
0.187 [4.75]	0.164 [4.17]	0.400 [10.16]	0.350 [8.89]	1.250 [31.75]	1.094 [27.79]
0.188 [4.78]	0.164 [4.17]	0.406 [10.31]	0.355 [9.02]	1.281 [32.54]	1.121 [28.47]
0.191 [4.85]	0.167 [4.24]	0.432 [10.97]	0.378 [9.60]	1.312 [33.32]	1.148 [29.16]
0.200 [5.08]	0.175 [4.44]	0.436 [11.07]	...	1.343 [34.11]	1.175 [29.85]
0.203 [5.16]	0.178 [4.52]	0.437 [11.10]	0.382 [9.70]	1.375 [34.92]	1.203 [30.56]
0.216 [5.49]	0.189 [4.80]	0.438 [11.13]	0.383 [9.73]	1.406 [35.71]	1.230 [31.24]
0.218 [5.54]	0.191 [4.85]	0.500 [12.70]	0.438 [11.13]	1.437 [36.53]	1.258 [31.95]
0.219 [5.56]	0.192 [4.88]	0.531 [13.49]	0.465 [11.81]	1.500 [38.10]	1.312 [33.32]
0.226 [5.74]	0.198 [5.03]	0.552 [14.02]	0.483 [12.27]	1.531 [38.89]	1.340 [34.04]
0.237 [6.02]	0.207 [5.26]	0.562 [14.27]	0.492 [12.50]	1.562 [39.67]	1.367 [34.72]
0.250 [6.35]	0.219 [5.56]	0.593 [15.06]	0.520 [13.21]	1.594 [40.69]	1.394 [35.43]
0.258 [6.55]	0.226 [5.74]	0.600 [15.24]	0.525 [13.34]	1.750 [44.45]	1.531 [38.89]
0.276 [7.01]	0.242 [6.15]	0.625 [15.88]	0.547 [13.89]	1.781 [45.24]	1.558 [39.57]
0.277 [7.04]	0.242 [6.15]	0.656 [16.66]	0.574 [14.58]	1.812 [46.02]	1.586 [40.28]
0.279 [7.09]	0.244 [6.20]	...	...	...	...
0.280 [7.11]	0.245 [6.22]	0.687 [17.48]	0.602 [15.29]	2.062 [52.37]	1.804 [45.82]
0.281 [7.14]	0.246 [6.25]	0.719 [18.26]	0.629 [15.96]	2.343 [59.54]	2.050 [52.10]

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL AND CARBON-MANGANESE STEEL BOILER AND SUPERHEATER TUBES



SA-178/SA-178M



(Identical with ASTM Specification A178/A178M-95.)

SPECIFICATION FOR ELECTRIC-RESISTANCE- WELDED CARBON STEEL AND CARBON-MANGANESE STEEL BOILER AND SUPERHEATER TUBES



SA-178/SA-178M



(Identical with ASTM Specification A 178/A 178M-95.)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded tubes made of carbon steel and carbon-manganese steel intended for use as boiler tubes, boiler flues, superheater flues, and safe ends.

NOTE 1 — Type C and D tubes are not suitable for safe-ending for forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.320 in. [0.9 to 9.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 226/A 226M Specification for Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service
- A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
- A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction.
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 3.1.1** Quantity (feet, metres, or number of lengths),
- 3.1.2** Name of material (electric-resistance-welded tubes),
- 3.1.3** Grade (A, C, or D, Table 1),
- 3.1.4** Size (outside diameter and minimum wall thickness),
- 3.1.5** Length (specific or random),
- 3.1.6** Optional requirements (product analysis, Section 7; crush test, Section 10; hydrostatic or nondestructive electric test, 11.6),
- 3.1.7** Test report required (Certification Section of Specification A 450/A 450M),
- 3.1.8** Specification, and designation,

3.1.9 Individual supplementary requirements, if required, and

3.1.10 Special requirements.

4. Manufacture

4.1 The steel for Grade D shall be killed.

4.2 Tubes shall be made by electric-resistance welding.

5. Heat Treatment

5.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled-atmosphere furnace. Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200° [650°C] or higher.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed in Table 1 is not permitted.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specifications shall be rejected.

NOTE 2 — A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

8. General Requirements

8.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M unless otherwise provided herein.

9. Tensile Requirements

9.1 Grade C and D tubes shall conform to the requirements as to tensile properties prescribed in Table 2.

NOTE 3: *Explanatory Note* — For purposes of design the following tensile properties may be assumed for Grade A tubes:

Tensile strength, min, ksi [MPa]	47 [325]
Yield Strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

10. Crush Test

10.1 When required by the purchaser, crushing tests shall be made on sections of tube 2½ in. [63 mm] in length which shall stand crushing longitudinally without cracking, splitting, or opening at the weld, as follows:

Wall Thickness of Tubes, in. [mm]	Height of Crushed Section, in. [mm]	
	Grade A Tubes	Grade C and D Tubes
0.135 [3.43] and under	¾ [19] or until outside folds are in contact	Crush tests not required
Over 0.135 [3.43]	1¼ [32]	...

10.2 Table 3 gives the computed minimum elongation values for each 1/32 in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm, %, and,
 t = actual thickness of specimen, in. [mm].

10.3 For tubing less than 1 in. [25.4 mm] in outside diameter, the length of the specimen shall be 2½ times the outside diameter of the tube. Slight surface checks shall not be cause for rejection.

11. Mechanical Tests Required

11.1 Flattening Test:

11.1.1 For Grade A, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2)

or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.1.2 For Grades C and D, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 Flange Test:

11.2.1 For Grade A, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.2.2 For Grades C and D, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof. The width of the flange shall not be less than 75% of that specified in Specification A 450/A 450M.

11.3 Crush Test — For Grade A, when required by the purchaser, one crush test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.4 Tension Test — For Grades C and D, one tension test shall be made on specimens from each of two tubes from each lot. The term *lot* for tension test requirements applies to all tubes prior to cutting, of the same nominal diameter and wall thickness, which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace, at the same temperature, time at heat, and furnace speed.

11.5 Reverse Flattening Test — One reverse flattening test shall be made on each 1500 ft [450 m] of finished tubing.

11.6 Hydrostatic or Nondestructive Electric Test — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

12. Forming Operations

12.1 When inserted in the boiler, tubes shall withstand expanding and beading without showing cracks or flaws, or opening at the weld. When properly manipulated, superheater tubes shall withstand all forging, welding, and bending operations necessary for application without developing defects.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

13.2 The manufacturer’s name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

14. Keywords

14.1 boiler tube; resistance welded steel tube; steel tube, carbon; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A, Low-Carbon Steel	Grade C, Medium- Carbon Steel	Grade D, Carbon-Manganese Steel
Carbon	0.06–0.18	0.35 max	0.27 max
Manganese	0.27–0.63	0.80 max	1.00–1.50
Phosphorus, max	0.035	0.035	0.030
Sulfur, max	0.035	0.035	0.015
Silicon	...	...	0.10 min

TABLE 2
TENSILE REQUIREMENTS

	Grade C	Grade D
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal strip tests a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made.	1.50 ^A	1.50 ^A

^A See Table 3 for the computed minimum values:

TABLE 3
MINIMUM ELONGATION VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, % ^A
in.	mm	
$\frac{5}{16}$ (0.312)	8	30
$\frac{9}{32}$ (0.281)	7.2	29
$\frac{1}{4}$ (0.250)	6.4	27
$\frac{7}{32}$ (0.219)	5.6	26
$\frac{3}{16}$ (0.188)	4.8	24
$\frac{5}{32}$ (0.156)	4	22
$\frac{1}{8}$ (0.125)	3.2	21
$\frac{3}{32}$ (0.094)	2.4	20
$\frac{1}{16}$ (0.062)	1.6	18

^A Calculated elongation requirements shall be rounded to the nearest whole number.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and production order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for ASME Requirements

S1.1 The weld seam of each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S1.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests

permitted by Specification A 450/A 450M.

S1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.4 In addition to the marking prescribed in Specification A 450/A 450M, "S1" shall be added after the grade designation.

SPECIFICATION FOR SEAMLESS COLD-DRAWN LOW-CARBON STEEL HEAT-EXCHANGER AND CONDENSER TUBES



SA-179/SA-179M



(21)

(Identical with ASTM Specification A179/A179M-90a(2012).)

Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless cold-drawn low-carbon steel tubes for tubular heat exchangers, condensers, and similar heat transfer apparatus.

1.2 This specification covers tubes $\frac{1}{8}$ to 3 in. [3.2 to 76.2 mm], inclusive, in outside diameter.

NOTE 1—Tubing smaller in outside diameter and having a thinner wall than indicated in this specification is available. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or with a wall thickness under 0.015 in. [0.4 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A450/A450M Specification for General Requirements for Carbon and Low Alloy Steel Tubes

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 3.1.1 Quantity (feet, metres, or number of lengths),
- 3.1.2 Name of material (seamless tubes),
- 3.1.3 Manufacture (cold-drawn),

- 3.1.4 Size (outside diameter and minimum wall thickness),
- 3.1.5 Length (specific or random),
- 3.1.6 Optional requirements (product analysis, Section 9, flange test, 11.3),
- 3.1.7 Test report required (Certification Section of Specification A450/A450M),
- 3.1.8 Specification number, and
- 3.1.9 Special requirements.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A450/A450M, unless otherwise provided herein.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be cold drawn.

6. Heat Treatment

6.1 Tubes shall be heat treated after the final cold draw pass at a temperature of 1200°F [650°C] or higher.

7. Surface Condition

7.1 Finished tubes shall be free of scale. A slight amount of oxidation will not be considered as scale.

8. Chemical Composition

8.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035

8.2 Supplying an alloy grade that specifically requires the addition of any element other than those listed in 8.1 is not permitted.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from 1 tube per 250 pieces or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2—A lot consists of 250 tubes.

10. Hardness Requirements

10.1 The tubes shall have a hardness number not exceeding 72 HRB.

11. Mechanical Tests Required

11.1 *Flattening Test*—One flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 *Flaring Test*—One flaring test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.3 *Flange Test*—When specified as a substitute for the flaring test, for tubes having a wall thickness (actual mean wall) less than 10 % of the outside diameter, one test shall be made on specimens from each of two tubes from each lot (Note

2) or fraction thereof. For tubes other than specified above, the flange test shall not be required.

11.4 *Hardness Test*—Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes, prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

11.5 *Hydrostatic Test*—Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A450/A450M, the marking shall include the name and order number of the purchaser.

13. Keywords

13.1 cold drawn tube; condenser tubes; heat exchanger tubes; low carbon steel; seamless tube

EXPLANATORY NOTES

NOTE 1—For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

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SPECIFICATION FOR CARBON STEEL FORGINGS, FOR GENERAL-PURPOSE PIPING



SA-181/SA-181M



(Identical with ASTM Specification A181/A181M-06.)

SPECIFICATION FOR CARBON STEEL FORGINGS, FOR GENERAL-PURPOSE PIPING



SA-181/SA-181M



(Identical with ASTM Specification A 181/A 181M-06)

1. Scope

1.1 This specification covers nonstandard as-forged fittings, valve components, and parts for general service. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266/A 266M.

1.2 Two classes of material are covered, designated as Classes 60 and 70, respectively, and are classified in accordance with their mechanical properties as specified in 6.1.

1.3 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components
- A 788/A 788M Specification for Steel Forgings, General Requirements
- A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M,

including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961/A 961M constitutes non-conformance with this specification.

3.2 It is the purchaser’s responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the ordering information in Specification A 961/A 961M and the following:

3.2.1 Supplementary requirements, and

3.2.2 Additional requirements (See 4.3, 9.1, 10.2, 12.1, and 12.2).

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 961/A 961M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 Except for flanges of all types, hollow, cylindrically shaped parts may be machined from hot-rolled or forged bar, provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, up to and including NPS 4 may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.2 Except as permitted in 4.1, the finished product shall be a forging as defined in the Terminology section (exclusively) of Specification A 788/A 788M.

4.3 When specified in the order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining.

4.4 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.5 Heat treatment is neither required nor prohibited, but when applied, heat treatment shall consist of tempering, annealing, normalizing, or normalizing and tempering.

5. Chemical Composition

5.1 An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The chemical composition thus determined shall conform to the requirements in Table 1.

6. Mechanical Properties

6.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

7. Number of Tests

7.1 One tension test shall be made from each heat.

7.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

8. Retests

8.1 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, heat-treated or reheat-treated in accordance with 4.5, and tested in accordance with Sections 6 and 7.

9. Reports of Testing

9.1 Upon request of the purchaser in the contract or order, a report of the test results and chemical analyses shall be furnished. The specification designation included on reports of testing shall include year of issue and revision letter, if any.

10. Repair by Welding

10.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ANSI or equivalent standards.

10.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's requirements.

10.3 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

11. Marking of Forgings

11.1 Identification marks consisting of the manufacturer's symbol or name, designation of service rating, Specification number, class, and size shall be legibly forged or stamped on each forging, and in such a position as not to injure the usefulness of the forgings.

11.2 Bar Coding — In addition to the requirements in 11.1, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts the bar code may be applied to the box or a substantially applied tag.

12. Certificate of Compliance

12.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The specification designation included on certificates of compliance shall include year of issue and revision letter, if any.

12.2 When specified in the purchase order or contract, a report of the test results shall be furnished.

13. Keywords

13.1 pipe fittings, steel; piping applications; pressure containing parts; steel forgings, carbon; steel valves

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, % Classes 60 and 70
Carbon, max.	0.35
Manganese, max.	1.10 ^A
Phosphorus, max.	0.05
Silicon	0.10–0.35
Sulfur, max.	0.05

^A Manganese may be increased to 1.35% max. provided the carbon is reduced 0.01% for each 0.06% increase in manganese over the limit shown in the table.

TABLE 2
TENSILE REQUIREMENTS

	Class 60	Class 70
Tensile strength, min., ksi [MPa]	60 [415]	70 [485]
Yield strength, ^A min., ksi [MPa]	30 [205]	36 [250]
Elongation in 2 in. [50 mm], min., %	22	18
Reduction of area, min., %	35	24

^A Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent based on heat analysis shall be as follows:

Class	Maximum Carbon Equivalent Value	
	Maximum Section Thickness Less Than or Equal to 2 in.	Maximum Section Thickness Greater Than 2 in.
60	0.45	0.46
70	0.47	0.48

S1.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

S1.4 When this Supplementary Requirement is invoked, all elements in the carbon equivalent formula shall be analyzed and the amounts reported.

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**SPECIFICATION FOR FORGED OR ROLLED ALLOY AND
STAINLESS STEEL PIPE FLANGES, FORGED FITTINGS,
AND VALVES AND PARTS FOR HIGH-TEMPERATURE
SERVICE**



SA-182/SA-182M

(21)

(Identical with ASTM Specification A182/A182M-18 except for the inclusion of Grade F316Ti in para. 7.3.1, and the removal of reduced strength levels for thicker sections of Grade F53 in Table 3 and Note (G) in Table 3, and the increase of minimum yield strength for Grade F60 in Table 3.)

Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service

1. Scope

1.1 This specification covers forged low alloy and stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts to specified dimensions or to dimensional standards, such as the ASME specifications that are referenced in Section 2.

1.2 For bars and products machined directly from bar (other than those directly addressed by this specification; see 6.4), refer to Specifications A479/A479M and A739 for the similar grades available in those specifications. Products made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. For larger products and products for other applications, refer to Specifications A336/A336M and A965/A965M for the similar ferritic and austenitic grades, respectively, available in those specifications.

1.3 Several grades of low alloy steels and ferritic, martensitic, austenitic, and ferritic-austenitic stainless steels are included in this specification. Selection will depend upon design and service requirements. Several of the ferritic/austenitic (duplex) grades are also found in Specification A1049/A1049M.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 In addition to the referenced documents listed in Specification A961/A961M, the following list of standards apply to this specification.

2.2 ASTM Standards:

- A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- A275/A275M Practice for Magnetic Particle Examination of Steel Forgings
- A336/A336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
- A388/A388M Practice for Ultrasonic Examination of Steel Forgings
- A479/A479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
- A484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
- A739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both

A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A788/A788M Specification for Steel Forgings, General Requirements

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

A961/A961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

A965/A965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts

A1049/A1049M Specification for Stainless Steel Forgings, Ferritic/Austenitic (Duplex), for Pressure Vessels and Related Components

A1084 Test Method for Detecting Detrimental Phases in Lean Duplex Austenitic/Ferritic Stainless Steels

E92 Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials

E112 Test Methods for Determining Average Grain Size

E165/E165M Practice for Liquid Penetrant Examination for General Industry

E340 Practice for Macroetching Metals and Alloys

2.3 ASME Standards:

B16.11 Forged Steel Fittings, Socket Welding, and Threaded

2.4 ASME Boiler and Pressure Vessel Code:

Section IX

2.5 AWS Specifications

A5.4/A5.4M Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.9/A5.9M Specification for Bare Stainless Steel Welding Electrodes and Rods

A5.11/A5.11M Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding

A5.14/A5.14M Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods

A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Specification A961/A961M.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hardened condition, n*—for F23, the metallurgical condition achieved after normalizing and cooling to room temperature but prior to tempering.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification A961/A961M, orders should include the following information:

4.1.1 Additional requirements (see 7.2.1, Table 2 footnotes, 9.3, and 19.2), and

4.1.2 Requirement, if any, that manufacturer shall submit drawings for approval showing the shape of the rough forging before machining and the exact location of test specimen material (see 9.3.1).

5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A961/A961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A961/A961M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A961/A961M, this specification shall prevail.

6. Manufacture

6.1 The low-alloy ferritic steels shall be made by the open-hearth, electric-furnace, or basic-oxygen process with the option of separate degassing and refining processes in each case.

6.2 The stainless steels shall be melted by one of the following processes: (a) electric-furnace (with the option of separate degassing and refining processes); (b) vacuum-furnace; or (c) one of the former followed by vacuum or electroslog-consumable remelting. Grade F XM-27Cb may be produced by electron-beam melting.

6.3 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

6.4 The material shall be forged as close as practicable to the specified shape and size.

6.4.1 Flanges of any type, elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

6.4.2 Cylindrically-shaped parts may be machined from forged or rolled solution-annealed austenitic stainless steel bar without additional hot working.

6.4.3 Cylindrically-shaped low alloy, martensitic stainless, ferritic stainless, and ferritic-austenitic stainless steel parts, NPS-4 [DN 100] and under, may be machined from forged or rolled bar, without additional hot working.

6.5 Except as provided for in 6.4, the finished product shall be a forging as defined in the Terminology section of Specification A788/A788M.

7. Heat Treatment

7.1 After hot working, forgings shall be cooled to a temperature below 1000 °F [538 °C] prior to heat treating in accordance with the requirements of Table 1.

7.2 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—The low alloy steels and ferritic and martensitic stainless steels shall be heat treated in accordance with the requirements of 7.1 and Table 1. When more than one heat treatment option is listed for a Grade in Table 1, any one of the heat treatments listed shall be performed. The selection of the heat treatment shall be at the manufacturer's option, unless otherwise stated in the purchase order.

7.2.1 *Liquid Quenching*—Except as permitted in 7.2.2, for F 1, F 2, and F 3, and when agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 1 for each grade are used.

7.2.1.1 *Marking*—Parts that are liquid quenched and tempered shall be marked "QT."

7.2.2 Alternatively, Grade F 1, F 2, and F 12, Classes 1 and 2 may be given a heat treatment of 1200 °F [650 °C] minimum after final hot or cold forming.

7.3 *Austenitic and Ferritic-Austenitic Stainless Steels*—Except as permitted by 7.5, the austenitic and ferritic-austenitic stainless steels shall be heat treated and liquid-quenched in accordance with the requirements of 7.1 and Table 1.

7.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solution annealing temperature specified in Table 1, forgings made from austenitic grades (except grades F 304H, F 309H, F 310, F 310H, F 316H, F316Ti, F 321, F 321H, F 347, F 347H, F 348, F 348H, F 45, and F 56) may be individually rapidly quenched in accordance with the requirements of Table 1. Ferritic-austenitic grades may be solution annealed without cooling below 1000 °F by being re-heated to the solution annealing temperature required in Table 1, held for a time sufficient to dissolve phases and precipitates which may cause a reduction in corrosion or mechanical properties, and quenched in accordance with Table 1.

7.3.2 See Supplementary Requirement S8 if a particular heat treatment method is to be employed.

7.4 *Time of Heat Treatment*—Heat treatment of forgings may be performed before machining.

7.5 *Forged or Rolled Bar*—Forged or rolled austenitic stainless bar from which cylindrically shaped parts are to be machined, as permitted by 6.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing and quenching or rapid-cooling requirements of Specification A484/A484M or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S3 if annealing must be the final operation).

8. Chemical Composition

8.1 A chemical heat analysis in accordance with Specification A961/A961M shall be made and conform to the chemical composition prescribed in Table 2.

8.2 Grades to which lead, selenium, or other elements are added for the purpose of rendering the material free-machining shall not be used.

8.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 2 for the applicable grade of material is not permitted.

8.4 Steel grades covered in this specification shall not contain an unspecified element, other than nitrogen in stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation or Grade designation and identification symbol in Table 2.

8.5 *Product Analysis*—The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A961/A961M.

9. Mechanical Properties

9.1 The material shall conform to the requirements as to mechanical properties for the grade ordered as listed in Table 3.

9.2 Mechanical test specimens shall be obtained from production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is required, test specimens shall not be removed until after post-weld heat treatment is complete, except for ferritic grades when the post-weld heat treatment is conducted at least 50 °F [30 °C] below the actual tempering temperature. When test blanks are used, they shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product and shall approximate the maximum cross section of the forgings they represent.

9.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall be taken at least $\frac{1}{4} T$ from the nearest surface as-heat-treated, where T is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the mid-length of the test specimen shall be at least T from all other surfaces as-heat-treated, exclusive of the T dimension surfaces. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

9.3.1 With prior purchase approval, the test specimen for ferritic steel forgings may be taken at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance ($2 t$) from any second surface. However, the test depth shall not be nearer to one treated surface than $\frac{3}{4}$ in. [19 mm] and to the second

TABLE 1 Heat Treating Requirements

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C] ^A	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
Low Alloy Steels					
F 1	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 2	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 5, F 5a	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 9	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 91 Types 1 and 2	normalize and temper or quench and temper	1900–1975 [1040–1080]	air cool accelerated air cool or liquid	<i>B</i>	1350–1470 [730–800]
F 92	normalize and temper	1900–1975 [1040–1080]	air cool	<i>B</i>	1350–1470 [730–800]
F 93	normalize and temper	1960–2140 [1070–1170]	air cool	385 [200]	1380–1455 [750–790]
F 122	normalize and temper	1900–1975 [1040–1080]	air cool	<i>B</i>	1350–1470 [730–800]
F 911	normalize and temper	1900–1975 [1040–1080]	air cool or liquid	<i>B</i>	1365–1435 [740–780]
F 11, Class 1, 2, 3	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 12, Class 1, 2	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 21, F 3V, and F 3VCb	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 22, Class 1, 3	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1250 [675]
F 22V	normalize and temper or quench and temper	1650 [900]	air cool or liquid	<i>B</i>	1250 [675]
F 23	normalize and temper	1900–1975 [1040–1080]	air cool accelerated cool	<i>B</i>	1350–1470 [730–800]
F 24	normalize and temper	1800–1975 [980–1080]	air cool or liquid	<i>B</i>	1350–1470 [730–800]
FR	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize	1750 [955]	air cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 36, Class 1	normalize and temper	1650 [900]	air cool	<i>B</i>	1100 [595]
F 36, Class 2	normalize and temper or quench and temper	1650 [900]	air cool accelerated air cool or liquid	<i>B</i>	1100 [595]
Martensitic Stainless Steels					
F 6a Class 1	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	<i>B</i>	<i>B</i>	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	<i>B</i>	<i>B</i>	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
F 6NM	normalize and temper	1850 [1010]	air cool	200 [95]	1040–1120 [560–600]
Ferritic Stainless Steels					
F XM-27 Cb	anneal	1850 [1010]	furnace cool	<i>B</i>	<i>B</i>
F 429	anneal	1850 [1010]	furnace cool	<i>B</i>	<i>B</i>
F 430	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
Austenitic Stainless Steels					
F 304	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 304H	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 304L	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 304N	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 304LN	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 309H	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 310	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 310H	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 310MoLN	solution treat and quench	1900–2010 [1050–1100]	liquid ^E	500 [260]	<i>B</i>
F 316	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 316H	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 316L	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 316N	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 316LN	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 316Ti	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 317	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>

TABLE 1 Continued

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C] ^A	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
F 317L	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 72	solution treat and quench	1975–2155 [1080–1180]	liquid ^E	500 [260]	<i>B</i>
F 73	solution treat and quench	1975–2155 [1080–1180]	liquid ^E	500 [260]	<i>B</i>
F 347	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 347H	solution treat and quench	2000 [1095]	liquid ^E	500 [260]	<i>B</i>
F 347LN	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 348	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 348H	solution treat and quench	2000 [1095]	liquid ^E	500 [260]	<i>B</i>
F 321	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 321H	solution treat and quench	2000 [1095]	liquid ^E	500 [260]	<i>B</i>
F XM-11	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F XM-19	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 20	solution treat and quench	1700–1850 [925–1010]	liquid ^E	500 [260]	<i>B</i>
F 44	solution treat and quench	2100 [1150]	liquid ^E	500 [260]	<i>B</i>
F 45	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 46	solution treat and quench	2010–2140 [1100–1140]	liquid ^E	500 [260]	<i>B</i>
F 47	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 48	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 49	solution treat and quench	2050 [1120]	liquid ^E	500 [260]	<i>B</i>
F 56	solution treat and quench	2050–2160 [1120–1180]	liquid ^E	500 [260]	<i>B</i>
F 58	solution treat and quench	2085 [1140]	liquid ^E	500 [260]	<i>B</i>
F 62	solution treat and quench	2025 [1105]	liquid ^E	500 [260]	<i>B</i>
F 63	solution treat and quench	1900 [1040]	liquid ^E	500 [260]	<i>B</i>
F 64	solution treat and quench	2010–2140 [1100–1170]	liquid ^E	500 [260]	<i>B</i>
F 904L	solution treat and quench	1920–2100 [1050–1150]	liquid ^E	500 [260]	<i>B</i>
F 70	solution treat and quench	1900 [1040]	liquid ^D	500 [260]	<i>B</i>
Ferritic-Austenitic Stainless Steels					
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	<i>B</i>
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	<i>B</i>
F 52 ^C			liquid	500 [260]	<i>B</i>
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	<i>B</i>
F 54	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	<i>B</i>
F 55	solution treat and quench	2010–2085 [1100–1140]	liquid	500 [260]	<i>B</i>
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	<i>B</i>
F 59	solution treat and quench	1975–2050 [1080–1120]	liquid	500 [260]	<i>B</i>
F 60	solution treat and quench	1870 [1020]	liquid	500 [260]	<i>B</i>
F 61	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	<i>B</i>
F 65	solution treat and quench	1830–2100 [1000–1150]	liquid ^D	500 [260]	<i>B</i>
F 66	solution treat and quench	1870–1975 [1020–1080]	liquid	500 [260]	<i>B</i>
F 67	solution treat and quench	1870–2050 [1020–1120]	liquid	500 [260]	<i>B</i>
F 68	solution treat and quench	1700–1920 [925–1050]	liquid	500 [260]	<i>B</i>
F 69	solution treat and quench	1870 [1020]	liquid	500 [260]	<i>B</i>
F 71	solution treat and quench	1925–2100 [1050–1150]	liquid	500 [260]	<i>B</i>

^A Minimum unless temperature range is listed.

^B Not applicable.

^C Grade F 52 shall be solution treated at 1825 to 1875 °F [995 to 1025 °C] 30 min/in. of thickness and water quenched.

^D The cooling media for Grades F 65 and F 70 shall be quenching in water or rapidly cooling by other means.

^E Forged or rolled bar meeting the requirements of 7.5 shall be liquid quenched or rapid-cooled by other means in accordance with Specification A484/A484M.

treated surface than 1½ in. [38 mm]. This method of test specimen location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where ¼ $T \times T$ testing (see 9.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

9.3.2 *Metal Buffers*—The required distances from heat-treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½-in. [13-mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

9.4 For annealed low alloy steels, ferritic stainless steels, and martensitic stainless steels, and also for austenitic and ferritic-austenitic stainless steels, the test specimen may be taken from any convenient location.

9.5 Tension Tests:

9.5.1 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—One tension test shall be made for each heat in each heat treatment charge.

9.5.1.1 When the heat-treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each heat of each forging type (see Note 1) and section size is required, instead of one test from each heat in each heat-treatment charge.

TABLE 2 Chemical Requirements^A

Grade/Identification Symbol	UNS Designation	Composition, %										
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
Low Alloy Steels												
F 1	K12822	0.28	0.60–0.90	0.045	0.045	0.15–0.35	...	...	0.44–0.65	...	...	...
F 2 ^B	K12122	0.05–0.21	0.30–0.80	0.040	0.040	0.10–0.60	...	0.50–0.81	0.44–0.65	...	...	...
F 5 ^C	K41545	0.15	0.30–0.60	0.030	0.030	0.50	0.50	4.0–6.0	0.44–0.65	...	...	...
F 5a ^C	K42544	0.25	0.60	0.040	0.030	0.50	0.50	4.0–6.0	0.44–0.65	...	...	...
F 9	K90941	0.15	0.30–0.60	0.030	0.030	0.50–1.00	...	8.0–10.0	0.90–1.10	...	...	...
F 10	S33100	0.10–0.20	0.50–0.80	0.040	0.030	1.00–1.40	19.0–22.0	7.0–9.0	...	...	...	...
F 91 Type 1	K90901	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40	8.0–9.5	0.85–1.05	0.06–0.10	...	N 0.03–0.07 Al 0.02 ^D V 0.18–0.25 Ti 0.01 ^D Zr 0.01 ^D
F 91 Type 2 Heat Product	K90901	0.08–0.12 0.07–0.13	0.30–0.50 ^D	0.020 ^D	0.005 ^D	0.20–0.40 ^D	0.20 ^D	8.0–9.5 ^D	0.85–1.05 0.80–1.05	0.06–0.10 0.05–0.11	0.01 ^D	N 0.035–0.070 ^D Al 0.020 ^D N/Al ratio, min 4.0 V Heat 0.18–0.25 V Prod 0.16–0.27 ^D Zr 0.01 ^D B 0.001 ^D Cu 0.10 ^D W 0.05 ^D Sn 0.010 ^D As 0.010 ^D Sb 0.003 ^D
F 92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50	0.40	8.50–9.50	0.30–0.60	0.04–0.09	...	V 0.15–0.25 N 0.030–0.070 Al 0.02 ^D W 1.50–2.00 B 0.001–0.006 Ti 0.01 ^D Zr 0.01 ^D
F 93	K91350	0.05–0.10	0.20–0.70	0.020	0.008	0.05–0.50	0.20	8.50–9.50	...	...	...	V 0.15–0.30 B 0.007–0.015 Al 0.030 W 2.5–3.5 Co 2.5–3.5 N 0.005–0.015 Cb + Ta 0.05–0.12 Nd 0.010–0.06 O 0.0050
F 122	K91271	0.07–0.14	0.70	0.020	0.010	0.50	0.50	10.00–11.50	0.25–0.60	0.04–0.10	...	V 0.15–0.30 B 0.005 N 0.040–0.100 Al 0.02 ^D Cu 0.30–1.70 W 1.50–2.50 Ti 0.01 ^D Zr 0.01 ^D
F 911	K91061	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40	8.5–9.5	0.90–1.10	0.060–0.10	...	W 0.90–1.10 Al 0.02 ^D N 0.04–0.09 V 0.18–0.25 B 0.0003–0.006 Ti 0.01 ^D Zr 0.01 ^D
F 11 Class 1	K11597	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...
F 11 Class 2	K11572	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...
F 11 Class 3	K11572	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...
F 12 Class 1	K11562	0.05–0.15	0.30–0.60	0.045	0.045	0.50 max	...	0.80–1.25	0.44–0.65	...	...	...
F 12 Class 2	K11564	0.10–0.20	0.30–0.80	0.040	0.040	0.10–0.60	...	0.80–1.25	0.44–0.65	...	...	...
F 21	K31545	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.7–3.3	0.80–1.06	...	...	...
F 3V	K31830	0.05–0.18	0.30–0.60	0.020	0.020	0.10	...	2.8–3.2	0.90–1.10	...	0.015–0.035	V 0.20–0.30 B 0.001–0.003

TABLE 2 Continued

Grade/Identification Symbol	UNS Designation	Composition, %										
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 3VCb	K31390	0.10–0.15	0.30–0.60	0.020	0.010	0.10	0.25	2.7–3.3	0.90–1.10	0.015–0.070	0.015	V 0.20–0.30 Cu 0.25 Ca 0.0005–0.0150
F 22 Class 1	K21590	0.05–0.15	0.30–0.60	0.040	0.040	0.50	...	2.00–2.50	0.87–1.13	...	...	...
F 22 Class 3	K21590	0.05–0.15	0.30–0.60	0.040	0.040	0.50	...	2.00–2.50	0.87–1.13	...	...	...
F 22V	K31835	0.11–0.15	0.30–0.60	0.015	0.010	0.10	0.25	2.00–2.50	0.90–1.10	0.07	0.030	Cu 0.20 V 0.25–0.35 B 0.002 Ca 0.015 ^E V 0.20–0.30 B 0.0010–0.006 N 0.015 ^F Al 0.030 W 1.45–1.75 V 0.20–0.30
F 23	K41650	0.04–0.10	0.10–0.60	0.030	0.010	0.50	0.40	1.90–2.60	0.05–0.30	0.02–0.08	0.005–0.060 ^F	V 0.20–0.30 B 0.0010–0.006 N 0.015 ^F Al 0.030 W 1.45–1.75 V 0.20–0.30
F 24	K30736	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	...	2.20–2.60	0.90–1.10	...	0.06–0.10	N 0.12 Al 0.020 B 0.0015–0.0070 Cu 0.75–1.25 N 0.020 Al 0.050 Cu 0.50–0.80 V 0.02
FR	K22035	0.20	0.40–1.06	0.045	0.050	...	1.60–2.24	...	...	...	...	Cu 0.75–1.25
F 36	K21001	0.10–0.17	0.80–1.20	0.030	0.025	0.25–0.50	1.00–1.30	0.30	0.25–0.50	0.015–0.045	...	N 0.020 Al 0.050 Cu 0.50–0.80 V 0.02
Martensitic Stainless Steels												
F 6a	S41000	0.15	1.00	0.040	0.030	1.00	0.50	11.5–13.5	...	...	...	...
F 6b	S41026	0.15	1.00	0.020	0.020	1.00	1.00–2.00	11.5–13.5	0.40–0.60	...	...	Cu 0.50
F 6NM	S41500	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00	...	...	...
Ferritic Stainless Steels												
F XM-27Cb	S44627	0.010 ^G	0.40	0.020	0.020	0.40	0.50 ^G	25.0–27.5	0.75–1.50	0.05–0.20	...	N 0.015 ^G Cu 0.20 ^G
F 429	S42900	0.12	1.00	0.040	0.030	0.75	0.50	14.0–16.0	...	...	...	...
F 430	S43000	0.12	1.00	0.040	0.030	0.75	0.50	16.0–18.0	...	...	...	...
Austenitic Stainless Steels												
F 304	S30400	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	N 0.10
F 304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
F 304L	S30403	0.030	2.00	0.045	0.030	1.00	8.0–13.0	18.0–20.0	...	...	...	N 0.10
F 304N	S30451	0.08	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0	...	...	...	N 0.10–0.16
F 304LN	S30453	0.030	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0	...	...	...	N 0.10–0.16
F 309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...
F 310	S31000	0.25	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
F 310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
F 310MoLN	S31050	0.030	2.00	0.030	0.015	0.40	21.0–23.0	24.0–26.0	2.00–3.00	...	...	N 0.10–0.16
F 316	S31600	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	N 0.10
F 316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316L	S31603	0.030	2.00	0.045	0.030	1.00	10.0–15.0	16.0–18.0	2.00–3.00	...	...	N 0.10
F 316N	S31651	0.08	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00	...	...	N 0.10–0.16
F 316LN	S31653	0.030	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00	...	...	N 0.10–0.16
F 316Ti	S31635	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	^H	N 0.10 max
F 317	S31700	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 317L	S31703	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 72	S31727	0.030	1.00	0.030	0.030	1.00	14.5–16.5	17.5–19.0	3.8–4.5	...	...	Cu 2.8–4.0 N 0.15–0.21 Cu 4.0–5.0 N 0.045
F 70	S31730	0.030	2.00	0.040	0.010	1.00	15–16.5	17.0–19.0	3.0–4.0	...	...	N 0.17–0.22
F 73	S32053	0.030	1.00	0.030	0.010	1.00	24.0–28.0	22.0–24.0	5.0–6.0	...	...	N 0.17–0.22
F 321	S32100	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	^I	...
F 321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	^J	...
F 347	S34700	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	...	^K	...
F 347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	...	^L	...
F347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	9.0–13.0	17.0–19.0	...	0.20–0.50 ^M	...	N 0.06–0.10
F 348	S34800	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	...	^K	Co 0.20 Ta 0.10
F 348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	...	^L	Co 0.20 Ta 0.10
F XM-11	S21904	0.040	8.0–10.0	0.060	0.030	1.00	5.5–7.5	19.0–21.5	...	...	...	N 0.15–0.40
F XM-19	S20910	0.06	4.0–6.0	0.040	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	0.10–0.30	...	N 0.20–0.40 V 0.10–0.30

TABLE 2 Continued

Grade/Identifi- cation Symbol	UNS Design- ation	Composition, %										
		Carbon	Manga- nese	Phos- phorus	Sulfur	Silicon	Nickel	Chromium	Molybde- num	Colum- bium	Titan- ium	Other Elements
F 20	N08020	.07	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	8xCmin –1.00	...	Cu 3.0–4.0
F 44	S31254	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	...	...	Cu 0.50–1.00 N 0.18–0.25 N 0.14–0.20 Ce 0.03–0.08
F 45	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	Cu 0.50 N 0.10
F 46	S30600	0.018	2.00	0.020	0.020	3.7–4.3	14.0–15.5	17.0–18.5	0.20	...	...	Cu 0.50
F 47	S31725	0.030	2.00	0.045	0.030	0.75	13.0–17.5	18.0–20.0	4.0–5.0	...	...	N 0.10
F 48	S31726	0.030	2.00	0.045	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0	...	...	N 0.10–0.20
F 49	S34565	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	0.10	...	N 0.40–0.60
F 56	S33228	0.04–0.08	1.00	0.020	0.015	0.30	31.0–33.0	26.0–28.0	...	0.6–1.0	...	Ce 0.05–0.10 Al 0.025 N 0.35–0.60 Cu 1.00–2.50 W 1.50–2.50
F 58	S31266	0.030	2.0–4.0	0.035	0.020	1.00	21.0–24.0	23.0–25.0	5.2–6.2	...	...	N 0.18–0.25 Cu 0.75
F 62	N08367	0.030	2.00	0.040	0.030	1.00	23.5–25.5	20.0–22.0	6.0–7.0	...	...	Cu 1.50–2.50 N 0.18–0.25 Cu 0.75
F 63	S32615	0.07	2.00	0.045	0.030	4.8–6.0	19.0–22.0	16.5–19.5	0.30–1.50	...	...	Cu 1.50–2.50
F 64	S30601	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	0.20	...	...	Cu 0.35, N 0.05
F 904L	N08904	0.020	2.0	0.040	0.030	1.00	23.0–28.0	19.0–23.0	4.0–5.0	...	...	Cu 1.00–2.00 N 0.10
Ferritic-Austenitic Stainless Steels												
F 50	S31200	0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00	...	...	N 0.14–0.20
F 51	S31803	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	...	...	N 0.08–0.20
F 69	S32101	0.040	4.00–6.00	0.040	0.030	1.00	1.35–1.70	21.0–22.0	0.10–0.80	...	...	N 0.20–0.25 Cu 0.10–0.80
F 52	S32950	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	...	...	N 0.15–0.35
F 53	S32750	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0	...	...	N 0.24–0.32 Cu 0.50
F 54	S39274	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	...	...	N 0.24–0.32 Cu 0.20–0.80 W 1.50–2.50
F 55	S32760	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	...	...	N 0.20–0.30 Cu 0.50–1.00 W 0.50–1.00 ^N
F 57	S39277	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0	...	...	Cu 1.20–2.00 W 0.80–1.20 N 0.23–0.33 N 0.20–0.35 Cu 0.50–3.00
F 59	S32520	0.030	1.50	0.035	0.020	0.80	5.5–8.0	24.0–26.0	3.0–5.0	...	...	N 0.14–0.20 Cu 1.50–2.50 N 0.10–0.25 Cu 0.80
F 60	S32205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	...	...	N 0.18–0.26 N 0.08–0.20 W 0.05–0.30
F 61	S32550	0.040	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	...	...	N 0.05–0.20 Cu 0.05–0.60
F 65	S32906	0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0–30.0	1.5–2.6	...	...	N 0.30–0.40 N 0.18–0.26 N 0.08–0.20 W 0.05–0.30
F 66	S32202	0.030	2.00	0.040	0.010	1.00	1.00–2.80	21.5–24.0	0.45	...	...	N 0.05–0.20 Cu 0.05–0.60
F 67	S32506	0.030	1.00	0.040	0.015	0.90	5.5–7.2	24.0–26.0	3.0–3.5	...	...	N 0.30–0.40 W 2.10–2.50
F 68	S32304	0.030	2.50	0.040	0.030	1.00	3.0–5.5	21.5–24.5	0.05–0.60	...	...	N 0.05–0.20 Cu 0.05–0.60
F 71	S32808	0.030	1.10	0.030	0.010	0.50	7.0–8.2	27.0–27.9	0.80–1.2	...	...	N 0.30–0.40 W 2.10–2.50

^AAll values are maximum unless otherwise stated. Where ellipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.

^BGrade F 2 was formerly assigned to the 1 % chromium, 0.5 % molybdenum grade which is now Grade F 12.

^CThe present grade F 5a (0.25 max carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 in 1955 was assigned to the 0.15 max carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding fittings, and the like.

^DApplies to both heat and product analyses.

^EFor Grade F22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

^FThe ratio of Titanium to Nitrogen shall be ≥ 3.5 . Alternatively, in lieu of this ratio limit, Grade F23 shall have a minimum hardness of 275 HV (26 HRC, 258 HBW) in the hardened condition (see 3.2.1). Hardness testing shall be performed in accordance with 9.6.3, and the hardness testing results shall be reported on the material test report (see 18.2.5).

^GGrade F XM-27Cb shall have a nickel plus copper content of 0.50 max %. Product analysis tolerance over the maximum specified limit for carbon and nitrogen shall be 0.002 %.

^HGrade F 316Ti shall have a titanium content not less than five times the carbon plus nitrogen content and not more than 0.70 %.

^IGrade F 321 shall have a titanium content of not less than five times the carbon content and not more than 0.70 %.

^JGrade F 321H shall have a titanium content of not less than four times the carbon content and not more than 0.70 %.

^KGrades F 347 and F 348 shall have a columbium content of not less than ten times the carbon content and not more than 1.10 %.

^LGrades F 347H and F 348H shall have a columbium content of not less than eight times the carbon content and not more than 1.10 %.

^MGrade F347LN shall have a columbium content of not less than 15 times the carbon content.

^N% Cr + 3.3 x % Mo + 16 x % N = 40 min.

NOTE 1—"Type" in this case is used to describe the forging shape such as a flange, ell, tee, and the like.

9.5.2 Austenitic and Ferritic-Austenitic Stainless Steel Grades—One tension test shall be made for each heat.

9.5.2.1 When heat treated in accordance with 7.1, the test blank or forging used to provide the test specimen shall be heat treated with a finished forged product.

9.5.2.2 When the alternative method in 7.3.1 is used, the test blank or forging used to provide the test specimen shall be forged and quenched under the same processing conditions as the forgings they represent.

9.5.3 Testing shall be performed as specified in Specification A961/A961M using the largest feasible of the round specimens.

9.6 Hardness Tests:

9.6.1 Except when only one forging is produced, a minimum of two pieces per batch or continuous run as defined in 9.6.2 shall be hardness tested as specified in Specification A961/A961M to ensure that the forgings are within the hardness limits given for each grade in Table 3. The purchaser may verify that the requirement has been met by testing at any location on the forging provided such testing does not render the forging useless.

9.6.2 When the reduced number of tension tests permitted by 9.5.1.1 is applied, additional hardness tests shall be made on forgings or samples, as defined in 9.2, scattered throughout the load (see Note 2). At least eight samples shall be checked from each batch load, and at least one check per hour shall be made from a continuous run. When the furnace batch is less than eight forgings, each forging shall be checked. If any check falls outside the prescribed limits, the entire lot of forgings shall be reheated and the requirements of 9.5.1 shall apply.

NOTE 2—The tension test required in 9.5.1 is used to determine material capability and conformance in addition to verifying the adequacy of the heat-treatment cycle. Additional hardness tests in accordance with 9.6.2 are required when 9.5.1.1 is applied to ensure the prescribed heat-treating cycle and uniformity throughout the load.

9.6.3 When the alternative to the Ti/N ratio limit for F23 is applied, (see Note *P* in Table 2), a minimum of two pieces per batch or continuous run as defined in 9.6.2 shall be hardness tested, in the hardened condition (see 3.2.1), to ensure that the forgings are within the hardness limit given for F23 in Note *P* of Table 2. The test samples shall be taken at the mid thickness of the thickest section of the product. Testing shall be performed in accordance with the Test Method E92 or as specified in Specification A961/A961M.

9.7 Notch Toughness Requirements—Grades F 3V, F 3VCb, and F 22V.

9.7.1 Impact test specimens shall be Charpy V-notch Type. The usage of subsize specimens due to material limitations must have prior purchaser approval.

9.7.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 9.2, 9.3, and 9.5. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

9.7.3 The longitudinal axis and mid-length of impact specimens shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat-treated surface of the forging.

9.7.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft-lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft-lbf [54 J], and it shall meet a minimum value of 35 ft-lbf [48 J].

9.7.5 The impact test temperature shall be 0 °F [−18 °C].

10. Grain Size for Austenitic Grades

10.1 All H grades and grade F 63 shall be tested for average grain size by Test Methods E112.

10.1.1 Grades F 304H, F 309H, F 310H, and F 316H shall have a grain size of ASTM No. 6 or coarser.

10.1.2 Grades F 321H, F 347H, and F 348H shall have a grain size of ASTM No. 7 or coarser.

10.1.3 Grade F 63 shall have a grain size of ASTM No. 3 or finer.

11. Corrosion Testing for Austenitic Grades and Detrimental Phase Detection in Austenitic/Ferritic Stainless Grades

11.1 Corrosion testing is not required by this specification nor is detrimental phase detection.

11.2 Austenitic grades shall be capable of meeting the intergranular corrosion test requirements described in Supplementary Requirement S4.

11.3 Austenitic/Ferritic Stainless grades shall be capable of meeting the requirements described in Supplementary Requirement S12 if the subject grade is included in the specifications listed in Supplementary Requirement S12.

12. Retreatment

12.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings and repeat the tests specified in Section 9.

13. Nondestructive Test Requirements

13.1 Hollow forgings of Grades F 91 Types 1 and 2, F 92, F 122, and F 911, NPS 4 [DIN 100] and larger, whose internal surfaces are not accessible to magnetic particle or liquid penetrant examination, shall be examined by an ultrasonic test in accordance with Practice A388/A388M.

13.2 Hollow forgings of Grades F 91 Types 1 and 2, F 92, F 122, and F 911, NPS 4 [DIN 100] and larger, whose internal surfaces are accessible to magnetic particle or liquid penetrant examination, shall be examined on their internal surfaces by either a magnetic particle test in accordance with Practice A275/A275M, or by a liquid penetrant examination in accordance with Test Method E165/E165M, as applicable.

13.3 *Time of Examination:*

TABLE 3 Tensile and Hardness Requirements^A

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] ^B	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Brinell Hardness Number, HBW, unless otherwise indicated
Low Alloy Steels					
F 1	70 [485]	40 [275]	20	30	143–192
F 2	70 [485]	40 [275]	20	30	143–192
F 5	70 [485]	40 [275]	20	35	143–217
F 5a	90 [620]	65 [450]	22	50	187–248
F 9	85 [585]	55 [380]	20	40	179–217
F 10	80 [550]	30 [205]	30	50	...
F 91 Types 1 and 2	90 [620]	60 [415]	20	40	190–248
F 92	90 [620]	64 [440]	20	45	269 max
F 93	90 [620]	64 [440]	19	40	250 max
F 122	90 [620]	58 [400]	20	40	250 max
F 911	90 [620]	64 [440]	18	40	187–248
F 11 Class 1	60 [415]	30 [205]	20	45	121–174
F 11 Class 2	70 [485]	40 [275]	20	30	143–207
F 11 Class 3	75 [515]	45 [310]	20	30	156–207
F 12 Class 1	60 [415]	32 [220]	20	45	121–174
F 12 Class 2	70 [485]	40 [275]	20	30	143–207
F 21	75 [515]	45 [310]	20	30	156–207
F 3V, and F 3VCb	85–110 [585–760]	60 [415]	18	45	174–237
F 22 Class 1	60 [415]	30 [205]	20	35	170 max
F 22 Class 3	75 [515]	45 [310]	20	30	156–207
F 22V	85–110 [585–780]	60 [415]	18	45	174–237
F 23	74 [510]	58 [400]	20	40	220 max
F 24	85 [585]	60 [415]	20	40	248 max
FR	63 [435]	46 [315]	25	38	197 max
F 36, Class 1	90 [620]	64 [440]	15	...	252 max
F 36, Class 2	95.5 [660]	66.5 [460]	15	...	252 max
Martensitic Stainless Steels					
F 6a Class 1	70 [485]	40 [275]	18	35	143–207
F 6a Class 2	85 [585]	55 [380]	18	35	167–229
F 6a Class 3	110 [760]	85 [585]	15	35	235–302
F 6a Class 4	130 [895]	110 [760]	12	35	263–321
F 6b	110–135 [760–930]	90 [620]	16	45	235–285
F 6NM	115 [790]	90 [620]	15	45	295 max
Ferritic Stainless Steels					
F XM-27Cb	60 [415]	35 [240]	20	45	190 max
F 429	60 [415]	35 [240]	20	45	190 max
F 430	60 [415]	35 [240]	20	45	190 max
Austenitic Stainless Steels					
F 304	75 [515] ^C	30 [205]	30	50	...
F 304H	75 [515] ^C	30 [205]	30	50	...
F 304L	70 [485] ^D	25 [170]	30	50	...
F 304N	80 [550]	35 [240]	30 ^E	50 ^F	...
F 304LN	75 [515] ^C	30 [205]	30	50	...
F 309H	75 [515] ^C	30 [205]	30	50	...
F 310	75 [515] ^C	30 [205]	30	50	...
F 310MoLN	78 [540]	37 [255]	25	40	...
F 310H	75 [515] ^C	30 [205]	30	50	...
F 316	75 [515] ^C	30 [205]	30	50	...
F 316H	75 [515] ^C	30 [205]	30	50	...
F 316L	70 [485] ^D	25 [170]	30	50	...
F 316N	80 [550]	35 [240]	30 ^E	50 ^F	...
F 316LN	75 [515] ^C	30 [205]	30	50	...
F 316Ti	75 [515]	30 [205]	30	40	...
F 317	75 [515] ^C	30 [205]	30	50	...
F 317L	70 [485] ^D	25 [170]	30	50	...
F 72	80 [550]	36 [245]	35	50	217
F 73	93 [640]	43 [295]	40	50	217
F 347	75 [515] ^C	30 [205]	30	50	...
F 347H	75 [515] ^C	30 [205]	30	50	...
F 347LN	75 [515]	30 [205]	30	50	...
F 348	75 [515] ^C	30 [205]	30	50	...
F 348H	75 [515] ^C	30 [205]	30	50	...
F 321	75 [515] ^C	30 [205]	30	50	...
F 321H	75 [515] ^C	30 [205]	30	50	...
F XM-11	90 [620]	50 [345]	45	60	...
F XM-19	100 [690]	55 [380]	35	55	...
F 20	80 [550]	35 [240]	30	50	...
F 44	94 [650]	44 [300]	35	50	...
F 45	87 [600]	45 [310]	40	50	...
F 46	78 [540]	35 [240]	40	50	...

TABLE 3 *Continued*

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] ^B	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Brinell Hardness Number, HBW, unless otherwise indicated
F 47	75 [525]	30 [205]	40	50	...
F 48	80 [550]	35 [240]	40	50	...
F 49	115 [795]	60 [415]	35	40	...
F 56	73 [500]	27 [185]	30	35	...
F 58	109 [750]	61 [420]	35	50	...
F 62	95 [655]	45 [310]	30	50	...
F 63	80 [550]	32 [220]	25	...	192 max
F 64	90 [620]	40 [275]	35	50	217 max
F70	70 [480]	25 [175]	35	...	HRB 90 max
F 904L	71 [490]	31 [215]	35	...	...
Ferritic-Austenitic Stainless Steels					
F 50	100–130 [690–900]	65 [450]	25	50	...
F 51	90 [620]	65 [450]	25	45	...
F 52	100 [690]	70 [485]	15	...	...
F 53	116 [800]	80 [550]	15	...	310 max
F 54	116 [800]	80 [550]	15	30	310 max
F 55	109–130 [750–895]	80 [550]	25	45	...
F 57	118 [820]	85 [585]	25	50	...
F 59	112 [770]	80 [550]	25	40	...
F 60	95 [655]	70 [485]	25	45	...
F 61	109 [750]	80 [550]	25	50	...
F 65	109 [750]	80 [550]	25	...	...
F 66	94 [650]	65 [450]	30	...	290 max
F 67	90 [620]	65 [450]	18	...	302
F 68	87 [600]	58 [400]	25	...	290 max
F 69	94 [650]	65 [450]	30	...	...
F 71	101 [700]	72 [500]	15	...	321

^AWhere ellipses appear in this table, there is no requirement and the test for the value need neither be performed nor a value reported.

^BDetermined by the 0.2 % offset method. For ferritic steels only, the 0.5 % extension-under-load method may also be used.

^CFor sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].

^DFor sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].

^ELongitudinal. The transverse elongation shall be 25 % in 2 in. or 50 mm, min.

^FLongitudinal. The transverse reduction of area shall be 45 % min.

13.3.1 Examination by one of the methods in 13.1 or 13.2, for specification acceptance, shall be performed after all mechanical processing and heat treatment. This requirement does not preclude additional testing at earlier stages in the processing.

13.4 *Evaluation of Imperfections Found by Ultrasonic Examination:*

13.4.1 Forgings producing a signal equal to or greater than the lowest signal produced by the reference discontinuities shall be identified and separated from the acceptable forgings. The area producing the signal may be reexamined.

13.4.2 Such forgings shall be rejected if the test signals were produced by imperfections that cannot be identified or were produced by cracks or crack-like imperfections. Such forgings may be repaired. To be accepted, a repaired forging shall pass the same nondestructive test by which it was rejected, and it shall meet the minimum wall thickness requirements of this specification and the purchase order.

13.4.3 If the test signals were produced by visual imperfections such as scratches, surface roughness, dings, tooling marks, cutting chips, steel die stamps, or stop marks, the forging is permitted to be accepted based upon visual exami-

nation provided that the depth of the imperfection is less than 0.004 in. [0.1 mm] or 12.5 % of the specified wall thickness, whichever is the greater.

13.5 *Treatment of Imperfections Found by Magnetic Particle or Liquid Penetrant Examination:*

13.5.1 Defects shall be completely removed prior to weld repair by chipping or grinding to sound metal. Removal of these defects shall be verified by magnetic particle inspection in accordance with Test Method A275/A275M or by liquid penetrant inspection in accordance with Test Method E165/E165M.

13.5.2 Rejected forgings may be reconditioned and retested, provided that the wall thickness is not decreased to less than that required by this specification and the purchase order. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested forgings shall meet the test requirement.

13.5.3 If the imperfection is explored to the extent that it can be identified as non-rejectable, the forging may be accepted without further test provided that the imperfection does not encroach on the minimum required wall thickness.

14. Surface Finish, Appearance, and Corrosion Protection

14.1 Forgings and finished parts shall conform to the requirements of Specification A961/A961M.

14.2 The forgings and finished parts shall be free of scale, machining burrs which might hinder fit-up, and other injurious imperfections as defined herein. The forgings and finished parts shall have a workmanlike finish, and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

15. Repair by Welding

15.1 Weld repairs shall be permitted (see Supplementary Requirement S58 of Specification A961/A961M) at the discretion of the manufacturer with the following limitations and requirements:

15.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

15.1.2 The weld metal shall be deposited using the electrodes specified in Table 4 except as otherwise provided in Supplementary Requirement S5. The electrodes shall be purchased in accordance with AWS Specifications A5.4/A5.4M, A5.5/A5.5M, A5.9/A5.9M, A5.11/A5.11M, A5.14/A5.14M, A5.23/A5.23M, A5.28/A5.28M, or A5.29/A5.29M. The submerged arc process with neutral flux, the gas metal-arc process, the gas tungsten-arc process, and gas shielded processes using flux-core consumables, may be used.

15.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic-particle inspection in accordance with Test Method A275/A275M for the low alloy steels and ferritic, martensitic, or ferritic-austenitic stainless steels, or by liquid-penetrant inspection in accordance with Test Method E165/E165M for all grades.

15.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

15.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 4 shall be met. Austenitic stainless steel forgings may be repair-welded without the post-weld heat treatment of Table 4, provided purchaser approval is obtained prior to repair.

15.1.6 Repair by welding shall not exceed 10 % of the surface area of the forging nor $33\frac{1}{3}$ % of the wall thickness of the finished forging or $\frac{3}{8}$ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

15.1.7 When approval of the purchaser is obtained, the limitations set forth in 15.1.6 may be exceeded, but all other requirements of Section 15 shall apply.

15.1.8 No weld repairs are permitted for F 6a Classes 3 and 4.

15.1.9 Post-weld heat treatment times for F 36 are: for Class 1, up to 2 in. [50 mm] in thickness, 1 h per in. [25 mm], 15 minutes minimum, and over 2 in. [50 mm], 15 minutes for each

additional in. of thickness or fraction thereof; for Class 2, 1 h per in. [25 mm], $\frac{1}{2}$ h minimum.

16. Inspection

16.1 Inspection provisions of Specification A961/A961M apply.

17. Rejection and Rehearing

17.1 The purchaser shall comply with the provisions of Specification A961/A961M.

18. Certification

18.1 In addition to the certification requirements of Specification A961/A961M, test reports shall be furnished to the purchaser or his representative.

18.2 Test reports shall provide the following where applicable:

18.2.1 Type heat treatment, Section 7,

18.2.2 Product analysis results, Section 8 of Specification A961/A961M,

18.2.3 Tensile property results, Section 9 (Table 3), report the yield strength and tensile strength, in ksi [MPa], elongation and reduction in area, in percent,

18.2.4 Chemical analysis results, Section 8 (Table 2), reported results shall be to the same number of significant figures as the limits specified in Table 2 for that element,

18.2.5 Hardness results, Section 9 (Table 3, and for F23, Tables 2 and 3),

18.2.6 Grain size results, Section 10, and

18.2.7 Any supplementary testing required by the purchase order.

19. Product Marking

19.1 In addition to the marking requirements of Specification A961/A961M, the following additional marking requirements shall apply:

19.1.1 Quenched and tempered low alloy or martensitic stainless forgings shall be stamped with the letters QT following the specification designation.

19.1.2 Forgings repaired by welding shall be marked with the letter "W" following the Specification designation. When repair-welded austenitic stainless steel forgings have not been postweld heat treated in accordance with Table 4, the letters "WNS" shall be marked following the specification designation.

19.1.3 Parts meeting all requirements for more than one class or grade may be marked with more than one class or grade designation such as F 304/F 304H, F 304/F 304L, and the like.

19.1.4 Plugs and bushings furnished to ASME B16.11 requirements are not required to be marked.

19.1.5 When agreed upon between the purchaser and manufacturer, and specified in the order, the markings shall be painted or stenciled on the fitting or stamped on a metal or plastic tag which shall be securely attached to the fitting.

19.1.6 Grade F 91 shall be additionally marked with the appropriate Type.

TABLE 4 Repair Welding Requirements

Grade Symbol	Electrodes ^A	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post Weld Heat-Treatment Temperature, Minimum or Range, °F [°C]
Low Alloy Steels			
F 1	E 7018-A 1	200–400 [95–205]	1150 [620]
F 2	E 8018-B 1	300–600 [150–315]	1150 [620]
F 5	E80XX-B6, where XX can be 15, 16, or 18	400–700 [205–370]	1250 [675]
F 5a	E80XX-B6, where XX can be 15, 16, or 18	400–700 [205–370]	1250 [675]
F 9	E80XX-B8, where XX can be 15, 16, or 18	400–700 [205–370]	1250 [675]
F 10 ^B	...	...	...
F 91 Types 1 and 2	... ^C	400–700 [205–370]	1350–1470 [730–800]
F 92	... ^D	400–700 [205–370]	1350–1470 [730–800]
F 93	... ^D	400–700 [205–370]	1350–1455 [730–790]
F 122	... ^D	400–700 [205–370]	1350–1470 [730–800]
F 911	... ^D	400–700 [205–370]	1365–1435 [740–780]
F 11, Class 1, 2, and 3	E 8018-B 2	300–600 [150–315]	1150 [620]
F 12, Class 1 and 2	E 8018-B 2	300–600 [150–315]	1150 [620]
F 21	E 9018-B 3	300–600 [150–315]	1250 [675]
F 3V, and F 3VCb	3 % Cr, 1 % Mo, ¼ % V-Ti	300–600 [150–315]	1250 [675]
F 22 Class 1	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22 Class 3	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22V	2.25 % Cr, 1 % Mo, 0.25 % V-Cb	300–600 [150–315]	1250 [675]
F 23	2.25 % Cr, 1.6 % W, 0.25 % V-Mo-Cb-B	300–600 [150–315]	1350–1470 [730–800]
F 24	2.25 % Cr, 1 % Mo, 0.25 % V	200–400 [95–205] ^E	1350–1470 [730–800] ^E
F 36, Class 1	1.15 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1100–1200 [595–650]
F 36, Class 2	1.15 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1000–1150 [540–620]
Martensitic Stainless Steels			
F 6a, Class 1	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6a, Class 2	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6b	13 % Cr, 1½ % Ni, ½ % Mo	400–700 [205–370]	1150 [620]
F 6NM	13 % Cr, 4 % Ni	300–700 [150–370]	1050 [565]
Ferritic Stainless Steels			
F XM-27Cb	26 % Cr, 1 % Mo	NR ^F	NR
F 429	E 430-16	400–700 [205–370]	1400 [760]
F 430	E 430-16	NR	1400 [760]
FR	E 8018-C2	NR	NR
Austenitic Stainless Steels			
F 304	E 308-15 or 16	NR	1900 [1040] + WQ ^G
F 304L	E 308L-15 or 16	NR	1900 [1040] + WQ
F 304H	E 308-15 or 16 ^H or E308H-XX	NR	1900 [1040] + WQ
F 304N	E 308-15 or 16	NR	1900 [1040] + WQ
F 304LN	E 308L-15 or 16	NR	1900 [1040] + WQ
F 309H	E 309-15 or 16 ^H or E309H-XX	NR	1900 [1040] + WQ
F 310	E 310-15 or 16	NR	1900 [1040] + WQ
F 310H	E 310-15 or 16 ^H	NR	1900 [1040] + WQ
F 310MoLN	E 310Mo-15 or 16	NR	1920–2010 [1050–1100] + WQ
F 316	E 316-15 or 16	NR	1900 [1040] + WQ
F 316L	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316H	E 316-15 or 16 ^H or E316H-XX	NR	1900 [1040] + WQ
F 316N	E 316-15 or 16	NR	1900 [1040] + WQ
F 316LN	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316Ti	E 316-15 or 16	NR	1900 [1040] + WQ
F 317	E 317-15 or 16	NR	1900 [1040] + WQ
F 317L	E 317L-15 or 16	NR	1900 [1040] + WQ
F 72	...	NR	...
F 73	...	NR	...
F 321 ^B	E 347-15 or 16	NR	1900 [1040] + WQ
F 321H ^B	E 347-15 or 16 ^H	NR	1925 [1050] + WQ
F 347	E 347-15 or 16	NR	1900 [1040] + WQ
F 347H	E 347-15 or 16 ^H	NR	1925 [1050] + WQ
F 347LN ^I	E 347-15 or 16	NR	...
E 348	E 347-15 or 16	NR	1900 [1040] + WQ
F 348H	E 347-15 or 16 ^H	NR	1925 [1050] + WQ
F XM-11	XM-10W	NR	NR
F XM-19	XM-19W	NR	NR
F 20	E/ER-320, 320LR	NR	1700–1850 [925–1010] + WQ
F 44	E NiCrMo-3	NR	2100 [1150] + WQ
F 45 ^B	...	...	...
F 46	...	...	...
F 47	... ^J	...	2100 [1150] + WQ

TABLE 4 Continued

Grade Symbol	Electrodes ^A	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post Weld Heat-Treatment Temperature, Minimum or Range, °F [°C]
F 48	...	...	2100 [1150] + WQ
F 49	...	...	2100 [1150] + WQ
F 58	E NiCrMo-10	...	2100 [1150] + WQ
F 62	E NiCrMo-3	NR	2025 [1105] + WQ
F 70	ERNiCr-3, or ERNiCrMo-3, or ERNiCrMo-4	NR	1900 [1040] + WQ
F 904L	E NiCrMo-3	NR	1920–2100 [1050–1150] + WQ
Ferritic-Austenitic Stainless Steels			
F 50	25 % Cr, 6 % Ni, 1.7 % Mo	NR	NR
F 51	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 52	26 % Cr, 8 % Ni, 2 % Mo	NR	NR
F 53	25 % Cr, 7 % Ni, 4 % Mo	NR	NR
F 54	25 % Cr, 7 % Ni, 3 % Mo, W	NR	NR
F 55	25 % Cr, 7 % Ni, 3.5 % Mo	NR	NR
F 57	25 % Cr, 7 % Ni, 3 % Mo, 1.5 % Cu, 1 % W	NR	NR
F 59	E Ni CrMo-10	NR	NR
F 60	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 61	26 % Cr, 9 % Ni, 3.5 % Mo	NR	NR
F 65	29 % Cr, 6.5 % Ni, 2 % Mo	NR	NR
F 66	22 % Cr, 2 % Ni, 0.25 % Mo	NR	NR
F 67	...	NR	NR
F 68	...	NR	NR
F 69	...	NR	NR
F 71	27.5 Cr, 7.6 Ni, 1 Mo, 2.3 W	NR	NR

^A Except for Grades F 91 Types 1 and 2, F 92, F 93, F 911, F 122, F 47, F 48, and F 49, electrodes shall comply with AWS Specifications A5.4/A5.4M, A5.5/A5.5M, A5.9/A5.9M, A5.11/A5.11M, A5.14/A5.14M, A5.23/A5.23M, or A5.28/A5.28M.

^B Purchaser approval required.

^C All repairs in F 91 Types 1 and 2 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW, A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables shall not exceed 1.0 %.

^D All repairs in F 92, F 93, F 911, and F 122, shall be made using welding consumables meeting the chemical requirements for the grade in Table 2.

^E Preheat and PWHT are not required for this grade for forgings whose section thickness does not exceed 0.500 in. [12.7 mm].

^F NR = not required.

^G WQ = water quench.

^H Filler metal shall additionally have 0.04 % minimum carbon.

^I Matching filler metal is available.

^J Match filler metal is available. Fabricators have also used AWS A5.14/A5.14M, Classification ERNiCrMo-3 and AWS A5.11/A5.11M, Class E, ENiCrMo-3 filler metals.

19.2 *Bar Coding*—In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

20. Keywords

20.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; ferritic/austenitic stainless steel;

ferritic stainless steel; martensitic stainless steel; nickel alloy steel; notch toughness requirements; pipe fittings; piping applications; pressure containing parts; stainless steel fittings; stainless steel forgings; steel; steel flanges; steel forgings, alloy; steel valves; temperature service applications, elevated; temperature service applications, high; wrought material

SUPPLEMENTARY REQUIREMENTS

In addition to any of the supplementary requirements of Specification A961/A961M, the following supplementary requirements shall apply only when specified by the purchaser in the order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Test Method E340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Heat Treatment Details

S2.1 The manufacturer shall furnish a detailed test report containing the information required in 18.2 and shall include all pertinent details of the heat-treating cycle given the forgings.

S3. Material for Optimum Resistance to Stress-Corrosion Cracking

S3.1 Austenitic stainless steel shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted, except, unless specifically prohibited by the purchaser, straightening of bars from which parts are machined is permitted to meet the requirements of Specification A484/A484M.

S4. Corrosion Tests

S4.1 All austenitic stainless steels shall pass intergranular corrosion tests performed in accordance with Practice E of Practices A262.

S4.2 Intergranular corrosion tests shall be performed on specimens of ferritic stainless steels as described in Practices A763.

S4.3 For both the austenitic and ferritic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S5. Special Filler Metal

S5.1 In repair-welded F 316, F 316L, F 316H, and F 316N forgings, the deposited weld metal shall conform to E 308 composition wire. Forgings repair welded with E 308 weld metal shall be marked F __ W 308.

S6. Hardness Test

S6.1 Each forging shall be hardness tested and shall meet the requirements of Table 3.

S8. Heat Treatment of Austenitic Forgings

S8.1 The purchaser shall specify the heat-treatment method (in 7.1 or in 7.3.1) that shall be employed.

S8.2 The manufacturer shall provide a test report containing the information required in 18.2 and shall include a statement of the heat-treatment method employed.

S9. Grain Size for Austenitic Grades

S9.1 Forgings made from austenitic grades other than H grades shall be tested for average grain size by Test Method E112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S10. Stabilizing Treatment

S10.1 Subsequent to the solution anneal for Grades F 321, F 321H, F 347, F 347H, F 348, and F 348H, these grades shall be given a stabilizing treatment at 1500 to 1600 °F [815 to 870 °C] for a minimum of 2 h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 19, the grade designation symbol shall be followed by the symbol "S10."

S11. Grain Size Requirements for Non-H-Grade Austenitic Steels Used Above 1000 °F [540 °C]

S11.1 Non-H grades of austenitic stainless steels shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E112. The grain size so determined shall be on a certified test report.

S12. Detection of Detrimental Phases in Austenitic/Ferritic Stainless Steels

S12.1 All austenitic/ferritic stainless steels that are included in Test Methods A923 shall meet the requirements of those test methods.

S12.2 All austenitic/ferritic stainless steels that are included in Test Method A1084 shall meet the requirements of that test method.

SPECIFICATION FOR SEAMLESS CARBON STEEL BOILER TUBES FOR HIGH-PRESSURE SERVICE



SA-192/SA-192M



(Identical with ASTM Specification A192/A192M-91.)

SPECIFICATION FOR SEAMLESS CARBON STEEL BOILER TUBES FOR HIGH-PRESSURE SERVICE



SA-192/SA-192M



(Identical with ASTM Specification A 192/A 192M-91.)

1. Scope

1.1 This specification covers minimum-wall thickness, seamless carbon steel boiler and superheater tubes for high-pressure service.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ in. to 7 in. [12.7 to 177.8 mm] outside diameter and 0.085 to 1.000 in. [2.2 to 25.4 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in [3.2 mm] inside diameter or 0.015 in. [0.4 mm] thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
- A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel

Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 4.1.1** Quantity (feet, metres, or number of lengths),
- 4.1.2** Name of material (seamless tubes),
- 4.1.3** Manufacture (hot-finished or cold-drawn),
- 4.1.4** Size (outside diameter and minimum wall thickness),
- 4.1.5** Length (specific or random),
- 4.1.6** Optional Requirements (Section 8),
- 4.1.7** Test report required (see section on Certification of Specification A 450/A 450M),
- 4.1.8** Specification designation, and
- 4.1.9** Special requirements.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

6.1 Hot-finished tubes need not be heat treated. Cold-finished tubes shall be heat treated after the final cold-finished at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max	0.035
Sulfur, max, %	0.035
Silicon, max, %	0.25

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (see Note) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding the following:

Brinell Hardness Number
(Tubes 0.200 in. [5.1 mm] and over in wall thickness)
137 HB

Rockwell Hardness
Number (Tubes less than 0.200 in. [5.1 mm] in wall thickness)
77 HRB

10. Mechanical Tests Required

10.1 Flattening Test — One flattening test shall be made on specimens from each of two tubes selected from each lot (see Note) or fraction thereof.

10.2 Flaring Test — One flaring test shall be made on specimens from each end of two tubes selected from each lot (see Note) or fraction thereof. These tubes shall be selected apart from those used for the flattening test.

10.3 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.4 Hydrostatic Test — Each tube shall be subjected to the hydrostatic pressure test, or instead of this test, a nondestructive test may be used when specified by the purchaser.

11. Forming Operations

11.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot finished or cold finished.

EXPLANATORY NOTE

NOTE — For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

SPECIFICATION FOR ALLOY-STEEL AND STAINLESS STEEL BOLTING FOR HIGH-TEMPERATURE OR HIGH PRESSURE SERVICE AND OTHER SPECIAL PURPOSE APPLICATIONS



SA-193/SA-193M



(Identical with ASTM Specification A193/A193M-12b.)

Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

1. Scope

1.1 This specification covers alloy and stainless steel bolting for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. See Specification A962/A962M for the definition of bolting. Bars and wire shall be hot-wrought and may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be carbide solution treated or carbide solution treated and strain-hardened. When strain hardened austenitic steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high temperature characteristics.

1.3 The following referenced general requirements are indispensable for application of this specification: Specification A962/A962M.

NOTE 1—The committee formulating this specification has included several steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2—For grades of alloy-steel bolting suitable for use at the lower range of high temperature applications, reference should be made to Specification A354.

NOTE 3—For grades of alloy-steel bolting suitable for use in low temperature applications, reference should be made to Specification A320/A320M.

1.4 Nuts for use with bolting are covered in Section 13.

1.5 Supplementary Requirements are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified in the purchase order or contract.

1.6 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable *M* specification designation (SI units), the inch-pound units shall apply.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 ASTM Standards:

A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A194/A194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A320/A320M Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service

A354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A788/A788M Specification for Steel Forgings, General Requirements

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

B633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel

B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
 B696 Specification for Coatings of Cadmium Mechanically Deposited
 B766 Specification for Electrodeposited Coatings of Cadmium
 E18 Test Methods for Rockwell Hardness of Metallic Materials
 E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
 E112 Test Methods for Determining Average Grain Size
 E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
 E150 Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times (Withdrawn 1984)
 E151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates (Withdrawn 1984)
 E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
 E328 Test Methods for Stress Relaxation for Materials and Structures
 E566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
 E709 Guide for Magnetic Particle Testing
 F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
 F1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
 F1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))
 F2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 *ASME Standards:*
 B18.2.1 Square and Hex Bolts and Screws
 B18.2.3.3M Metric Heavy Hex Screws
 B18.3 Hexagon Socket and Spline Socket Screws
 B18.3.1M Metric Socket Head Cap Screws

2.3 *AIAG Standard:*
 AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. General Requirements and Ordering Information

3.1 The inquiry and orders shall include the following, as required, to describe the desired material adequately:

3.1.1 Heat-treated condition (that is carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to material carbide solution treated by cooling rapidly from the rolling temperature),

3.1.2 Description of items required (that is, bars, bolts, screws, or studs),

3.1.3 Nuts, if required by purchaser, in accordance with 13.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 6.1.5.1, 6.2.6, 8.1, and 13.1.

3.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (See Supplementary Requirements S13 and S14). When coated fasteners are ordered the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4. Common Requirements

4.1 Bolting supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, macroetch (alloy steels only), marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A962/A962M, this specification shall prevail.

5. Manufacture (Process)

5.1 The steel shall be produced by any of the following processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

5.2 *Quality*—See Specification A962/A962M for requirements.

6. Heat Treatment

6.1 Ferritic Steels

6.1.1 Ferritic steels shall be allowed to cool to a temperature below the cooling transformation range immediately after rolling or forging. Materials shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a *quenching charge*), quenched in a liquid medium under substantially uniform conditions for each quenching charge, and tempered. The minimum tempering temperature shall be as specified in Tables 2 and 3.

TABLE 1 Chemical Requirements (Composition, percent)^A

Type		Ferritic Steels			
Grade	B5	B6 and B6X			
Description	5% Chromium		12 % Chromium		
UNS Designation	S41000 (410)				
	Range	Product Variation, Over or Under ^B	Range	Product Variation Over or Under ^B	
Carbon	0.10 min	0.01 under	0.08–0.15	0.01 over	
Manganese, max	1.00	0.03 over	1.00	0.03 over	
Phosphorus, max	0.040	0.005 over	0.040	0.005 over	
Sulfur, max	0.030	0.005 over	0.030	0.005 over	
Silicon	1.00 max	0.05 over	1.00 max	0.05 over	
Chromium	4.0–6.0	0.10	11.5–13.5	0.15	
Molybdenum	0.40–0.65	0.05	...	...

Type		Ferritic Steels			
Grade	B7, B7M	B16			
Description	Chromium-Molybdenum ^C		Chromium-Molybdenum-Vanadium		
	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B	
Carbon	0.37–0.49 ^D	0.02	0.36–0.47	0.02	
Manganese	0.65–1.10	0.04	0.45–0.70	0.03	
Phosphorus, max	0.035	0.005 over	0.035	0.005 over	
Sulfur, max	0.040	0.005 over	0.040	0.005 over	
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	
Chromium	0.75–1.20	0.05	0.80–1.15	0.05	
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03	
Vanadium	...	...	0.25–0.35	0.03
Aluminum, max % ^E	...	...	0.015	...

Type		Austenitic Steels, ^F Classes 1, 1A, 1D, and 2†						
Grade	B8, B8A	B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA		
UNS Designation	S30400 (304)	S34700 (347)		S31600 (316)		S30500		
	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over	0.12	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	17.0–19.0	0.20
Nickel	8.0–11.0	0.15	9.0–12.0	0.15	10.0–14.0	0.15	11.0–13.0	0.15
Molybdenum	...	...	...	...	2.00–3.00	0.10	...	...
Columbium + tantalum	...	...	10 x carbon content, min; 1.10 max	0.05 under	...	...	...	...

Type		Austenitic Steels, ^F Classes 1A, 1B, 1D, and 2					
Grade	B8N, B8NA	B8MN, B8MNA			B8MLCuN, B8MLCuNA		
UNS Designation	S30451 (304N)	S31651 (316N)			S31254		
	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B	
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.020	0.005 over	
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00	0.03 over	
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030	0.005 over	
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010	0.002 over	
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80	0.05 over	
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5	0.20	
Nickel	8.0–11.0	0.15	10.0–13.0	0.15	17.5–18.5	0.15	
Molybdenum	...	...	2.00–3.00	0.10	6.0–6.5	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22	0.02	
Copper	...	...	...	...	0.50–1.00	...

Type		Austenitic Steels ^F , Classes 1, 1A, and 2	
Grade	B8T, B8TA		
UNS Designation	S32100 (321)		
	Range	Product Variation, Over or Under ^B	
Carbon, max	0.08	0.01 over	
Manganese, max	2.00	0.04 over	
Phosphorus, max	0.045	0.010 over	
Sulfur, max	0.030	0.005 over	
Silicon, max	1.00	0.05 over	

TABLE 1 Continued

Type	Austenitic Steels ^F , Classes 1, 1A, and 2			
Grade	B8T, B8TA			
UNS Designation	S32100 (321)			
	Range	Product Variation, Over or Under ^B		
Chromium	17.0–19.0	0.20		
Nickel	9.0–12.0	0.15		
Titanium	5 x (C + N) min, 0.70 max	0.05 under		
Nitrogen	0.10 max	...		
Type	Austenitic Steels ^F , Classes 1C and 1D			
Grade	B8R, B8RA	B8S, B8SA		
UNS Designation	S20910	S21800		
	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B
Carbon, max	0.06	0.01 over	0.10	0.01 over
Manganese	4.0–6.0	0.05	7.0–9.0	0.06
Phosphorus, max	0.045	0.005 over	0.060	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	3.5–4.5	0.15
Chromium	20.5–23.5	0.25	16.0–18.0	0.20
Nickel	11.5–13.5	0.15	8.0–9.0	0.10
Molybdenum	1.50–3.00	0.10	...	...
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01
Columbium + tantalum	0.10–0.30	0.05	...	...
Vanadium	0.10–0.30	0.02	...	...
Type	Austenitic Steels ^F , Classes 1, 1A and 1D			
Grade	B8LN, B8LNA	B8MLN, B8MLNA		
UNS Designation	S30453	S31653		
	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15
Molybdenum	...	...	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01
Type	Austenitic Steels ^F , Classes 1, 1A and 1D			
Grade	B8CLN, B8CLNA			
UNS Designation	S34751 (347LN)			
	Range	Product Variation, Over or Under ^B		
Carbon, max	0.005–0.020	0.002 under, 0.005 over		
Manganese, max	2.00	0.04 over		
Phosphorus, max	0.045	0.01 over		
Sulfur, max	0.030	0.005 over		
Silicon, max	1.00	0.05 over		
Chromium	17.0–19.0	0.20		
Nickel	9.0–13.0	0.15		
Columbium	0.20–0.50,	0.05		
	15 x carbon content, min			
Nitrogen	0.06–0.10	0.01		

^A The intentional addition of Bi, Se, Te, and Pb is not permitted.

^B Product analysis—Individual determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.

^C Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

^D For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50 %, max. For the B7M grade, a minimum carbon content of 0.28 % is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

^E Total of soluble and insoluble.

^F Classes 1 and 1D are solution treated. Classes 1, 1B, and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8CLN, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, and B8MNA) and some Class 1C (B9RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

† Editorially corrected.

TABLE 2 Mechanical Requirements — Inch Products

Grade	Diameter, in.	Minimum Tempering Temperature, °F	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
Ferritic Steels							
B5 4 to 6 % chromium	up to 4, incl	1100	100	80	16	50	...
B6 13 % chromium	up to 4, incl	1100	110	85	15	50	...
B6X 13 % chromium	up to 4, incl	1100	90	70	16	50	26 HRC
B7 Chromium-molybdenum	2½ and under	1100	125	105	16	50	321 HBW or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HBW or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HBW or 35 HRC
B7M ^A Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HBW or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 HBW or 99 HRB
B16 Chromium-molybdenum-vanadium	2½ and under	1200	125	105	18	50	321 HBW or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HBW or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HBW or 35 HRC
Grade, Diameter, in.	Heat Treatment ^E	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max	
Austenitic Steels							
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, B8CLN, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96 HRB ^C	
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96HRB ^C	
Class 1A: B8A, B8CA, B8CLNA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HBW or 90 HRB	
Classes 1B and 1D: B8N, B8MN, B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HBW or 96 HRB ^C	
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HBW or 28 HRC	
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HBW or 28 HRC	
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HBW or 28 HRC	
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HBW or 28 HRC	
Class 2: B8, B8C, B8P, B8T, B8N, ^{D3/4} and under	carbide solution treated and strain hardened	125	100	12	35	321 HBW or 35 HRC	
over ¾ to 1, incl		115	80	15	35	321 HBW or 35 HRC	
over 1 to 1¼, incl		105	65	20	35	321 HBW or 35 HRC	
over 1¼ to 1½, incl		100	50	28	45	321 HBW or 35 HRC	
Class 2: B8M, B8MN, B8MLCuN ^{D3/4} and under	carbide solution treated and strain hardened	110	95	15	45	321 HBW or 35 HRC	
over ¾ to 1 incl		100	80	20	45	321 HBW or 35 HRC	
Over 1 to 1¼, incl		95	65	25	45	321 HBW or 35 HRC	

TABLE 2 Continued

Grade, Diameter, in.	Heat Treatment ^B	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
over 1¼ to 1½, incl		90	50	30	45	321 HBW or 35 HRC
Class 2B: B8, B8M2 ^D 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HBW or 35 HRC
over 2 to 2½ incl		90	65	30	40	321 HBW or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HBW or 35 HRC
Class 2C: B8M3 ^D 2 and under	carbide solution treated and strain hardened	85	65	30	60	321 HBW or 35 HRC
over 2		85	60	30	60	321 HBW or 35 HRC

^A To meet the tensile requirements, the Brinell hardness shall be over 200 HBW (93 HRB).

^B Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾ in. in diameter.

^C For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HBW (100 HRB) is permitted.

^D For diameters 1½ and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 3 Mechanical Requirements—Metric Products

Class	Diameter, [mm]	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
Ferritic Steels							
B5							
4 to 6 % chromium	up to M100, incl	593	690	550	16	50	...
B6							
13 % chromium	up to M100, incl	593	760	585	15	50	...
B6X							
13 % chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7							
Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HBW or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HBW or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HBW or 35 HRC
B7M ^A Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HBW or 99 HRB
	over M100 to M180	620	690	515	18	50	235 HBW or 99 HRB
B16							
Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HBW or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HBW or 35 HRC
	over M100 to M180	650	690	585	16	45	321 HBW or 35 HRC
Class	Diameter, mm	Heat Treatment ^B	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
Austenitic Steels							
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, B8CLN, all diameters		carbide solution treated	515	205	30	50	223 HBW or 96 HRB ^C
Class 1: B8C, B8T, all diameters		carbide solution treated	515	205	30	50	223 HBW or 96HRB ^C
Class 1A: B8A, B8CA, B8CLNA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters		carbide solution treated in the finished condition	515	205	30	50	192 HBW or 90 HRB

TABLE 3 Continued

Class Diameter, mm	Heat Treatment ^B	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
Classes 1B and 1D: B8N, B8MN, B8MLCuN, all diameters	carbide solution treated	550	240	30	40	223 HBW or 96 HRB ^C
Classes 1C and 1D: B8R, all diameters	carbide solution treated	690	380	35	55	271 HBW or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	690	380	35	55	271 HBW or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	655	345	35	55	271 HBW or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	655	345	35	55	271 HBW or 28 HRC
Class 2: B8, B8C, B8P, B8T, B8N, ^D M20 and under	carbide solution treated and strain hardened	860	690	12	35	321 HBW or 35 HRC
over M20 to M24, incl		795	550	15	35	321 HBW or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HBW or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HBW or 35 HRC
Class 2: B8M, B8MN, B8MLCuN, ^D M20 and under	carbide solution treated and strain hardened	760	655	15	45	321 HBW or 35 HRC
over M20 to M24, incl		690	550	20	45	321 HBW or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HBW or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HBW or 35 HRC
Class 2B: B8, B8M2, ^D M48 and under	carbide solution treated and strain hardened	655	515	25	40	321 HBW or 35 HRC
over M48 to M64, incl		620	450	30	40	321 HBW or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HBW or 35 HRC
Class 2C: B8M3, ^D M48 and under	carbide solution treated and strain hardened	585	450	30	60	321 HBW or 35 HRC
over M48		585	415	30	60	321 HBW or 35 HRC

^A To meet the tensile requirements, the Brinell hardness shall be over 200 HBW (93 HRB).

^B Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over M20 mm in diameter.

^C For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HBW (100 HRB) is permitted.

^D For diameters M38 and over, center (core) properties may be lower than indicated by test reports which are based on values determined at 1/2 radius.

6.1.2 Use of water quenching is prohibited for any ferritic grade when heat treatment is performed after heading or threading.

6.1.3 Except as permitted below for B6X; material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

6.1.4 B6 and B6X shall be held at the tempering temperature for a minimum time of 1 h. B6X material may be furnished in the as-rolled-and-tempered condition. Cold working after heat treatment is permitted for B6X material provided the final hardness meets the requirements of Tables 2 and 3.

6.1.5 B7 and B7M shall be heat treated by quenching in a liquid medium and tempering. For B7M fasteners, the final heat treatment, which may be the tempering operation if conducted at 1150 °F [620 °C] minimum, shall be done after all machining and forming operations, including thread rolling and any type of cutting. Surface preparation for hardness testing, nondestructive evaluation, or ultrasonic bolt tensioning is permitted.

6.1.5.1 Unless otherwise specified, material for Grade B7 may be heat treated by the Furnace, the Induction or the Electrical Resistance method.

NOTE 4—Stress-relaxation properties may vary from heat lot to heat lot or these properties may vary from one heat-treating method to another. The purchaser may specify Supplementary Requirement S8, when stress-relaxation testing is desired.

6.1.6 Material Grade B16 shall be heated to a temperature range from 1700 to 1750 °F [925 to 955 °C] and oil quenched. The minimum tempering temperature shall be as specified in Tables 2 and 3.

6.2 Austenitic Stainless Steels

6.2.1 All austenitic stainless steels shall receive a carbide solution treatment (see 6.2.2-6.2.5 for specific requirements for each class). Classes 1, 1B, 1C (Grades B8R and B8S only), 2, 2B, and 2C can apply to bar, wire, and finished fasteners. Class 1A (all grades) and Class 1C (grades B8RA and B8SA only) can apply to finished fasteners. Class 1D applies only to bar and wire and finished fasteners that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

6.2.2 *Classes 1 and 1B, and Class 1C Grades B8R and B8S*—After rolling of the bar, forging, or heading, whether done hot or cold, the material shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

6.2.3 *Class 1D*—Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, B8N, B8MN, B8R, and B8S bar shall be cooled rapidly immediately following hot working while the temperature is above 1750 °F [955 °C] so that grain boundary carbides remain in solution. Class 1D shall be restricted to applications at temperatures less than 850 °F [455 °C].

6.2.4 *Class 1A and Class 1C Grades B8RA and B8SA*—Finished fasteners shall be carbide solution treated after all rolling, forging, heading, and threading operations are complete. This designation does not apply to starting material such as bar. Fasteners shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

6.2.5 *Classes 2, 2B, and 2C*—Material shall be carbide solution treated by heating from ambient temperature and holding a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling at a rate sufficient to prevent the precipitation of the carbide. Following this treatment the material shall then be strain hardened to achieve the required properties.

NOTE 5—Heat treatment following operations performed on a limited portion of the product, such as heading, may result in non-uniform grain size and mechanical properties through the section affected.

6.2.6 If a scale-free bright finish is required; this shall be specified in the purchase order.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified

in Section 7. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A788/A788M.

9. Mechanical Properties

9.1 Tensile Properties:

9.1.1 *Requirements*—The material as represented by the tension specimens shall conform to the requirements prescribed in Tables 2 and 3 at room temperature after heat treatment. Alternatively, stainless strain hardened fasteners (Class 2, 2B, and 2C) shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Tables 2 and 3. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

9.1.2 *Full Size Fasteners, Wedge Tensile Testing*—When applicable, see 12.1.3, headed fasteners shall be wedge tested full size. The minimum full size load applied (lbf or kN) for individual sizes shall be as follows:

$$W = T_s \times A_t \quad (1)$$

where:

W = minimum wedge tensile load without fracture,

T_s = tensile strength specified in ksi or MPa in Tables 2 and 3, and

A_t = stress area of the thread section, square inches or square millimetres, as shown in the Cone Proof Load Tables in Specification A962/A962M.

9.2 Hardness Requirements:

9.2.1 The hardness shall conform to the requirements prescribed in Tables 2 and 3. Hardness testing shall be performed in accordance with either Specification A962/A962M or with Test Methods F606.

9.2.2 *Grade B7M*—The maximum hardness of the grade shall be 235 HBW or 99 HRB. The minimum hardness shall not be less than 200 HBW or 93 HRB. Conformance to this hardness shall be ensured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 9.2.1. The use of 100 % electromagnetic testing for hardness as an alternative to 100 % indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100 % examined in accordance with Practice E566. Following electromagnetic testing for hardness a random sample of a minimum of 100 pieces of each heat of steel in each lot (as defined in 12.1.1) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled or tested 100 % by indentation hardness methods.

9.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

10. Workmanship, Finish, and Appearance

10.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

10.2 Unless otherwise specified in the purchase order, bolt heads shall be in accordance with the dimensions of ASME B18.2.1 or ASME B18.2.3.3M. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used for nominal body diameters of 1¼ in [30 mm] and less. For larger sizes, the Heavy Hex Screw Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. The body diameter and head fillet radius for sizes of Heavy Hex Cap Screws and Bolts that are not shown in their respective tables in ASME B18.2.1 or ASME B18.2.3.3M may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head fasteners shall be in accordance with ASME B18.3 or ASME B18.3.1M.

11. Retests

11.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

12. Test Specimens

12.1 *Number of Tests*—For heat-treated bars, one tension test shall be made for each diameter of each heat represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size, and subjected to the same heat treatment. Not fewer than two tension tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

12.1.1 For studs, bolts, screws, and so forth, one tension test shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1⅞ [30] and under	1500 lb [780 kg] or fraction thereof
Over 1⅞ [30] to 1¾ [42], incl	4500 lb [2000 kg] or fraction thereof
Over 1¾ [42] to 2½ [64], incl	6000 lb [2700 kg] or fraction thereof
Over 2½ [64]	100 pieces or fraction thereof

12.1.2 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated

bars furnished in accordance with the requirements of this specification and tested in accordance with 12.1, provided they are not given a subsequent heat treatment.

12.1.3 *Full Size Specimens, Headed Fasteners*—Headed fasteners 1½ in. in body diameter and smaller, with body length three times the diameter or longer, and that are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 9.1.2. This testing shall be in addition to tensile testing as specified in 9.1.1. Wedge tensile testing shall be limited to product with socket head cap screw, hexagon, square, hex flange, or twelve point flange heads. The lot size shall be as shown in 12.1.1. Failure shall occur in the body or threaded section with no failure, or indications of failure, such as cracks, at the junction of the head and shank. Wedge tensile testing is not required for flat countersunk head or socket button products.

13. Nuts

13.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A194/A194M.

14. Certification

14.1 Certification is required. In addition to the requirements of Specification A962/A962M the report shall include results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), and mechanical tests, and state the method of heat treatment employed.

15. Product Marking

15.1 See Specification A962/A962M. The grade symbol shall be as shown in Table 4 and Table 5. Grade B7M shall be 100 % evaluated in conformance with the specification and shall have a line under the grade symbol.

16. Keywords

16.1 alloy steel bars; alloy steel bolting; fasteners; hardness; heat treatment ; stainless steel bolting

TABLE 4 Marking of Ferritic Steels

Grade	Grade Symbol
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M	<u>B7M</u>
B16	B16
B16 +	B16R
Supplement S12	

TABLE 5 Marking of Austenitic Steels

Class	Grade	Grade Symbol
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F or B8LN
	B8MLN	B8G or B8MLN
	B8CLN	B8Y or B8CLN
Class 1A	B8A	B8A
	B8CA	B8B or B8CA
	B8MA	B8D or B8MA
	B8PA	B8H or B8PA
	B8TA	B8J or B8TA
	B8LNA	B8L or B8LNA
	B8MLNA	B8K or B8MLNA
	B8NA	B8V or B8MA
	B8MNA	B8W or B8MNA
	B8MLCuNA	B9K or B8MLCuNA
	B8CLNA	B8Z or B8CLNA
Class 1B	B8N	B8N
	B8MN	B8Y or B8MN
	B8MLCuN	B9J or B8MLCuN
Class 1C	B8R	B9A or B8R
	B8RA	B9B or B8RA
	B8S	B9D or B8S
	B8SA	B9F or B8SA
Class 1D	B8	B94
	B8M	B95
	B8P	B96
	B8LN	B97
	B8MLN	B98
	B8N	B99
	B8MN	B100
	B8R	B101
	B8S	B102
	B8CLN	B103
Class 2	B8	<u>B8SH</u>
	B8C	<u>B8CSH</u>
	B8P	<u>B8PSH</u>
	B8T	<u>B8TSH</u>
	B8N	<u>B8NSH</u>
	B8M	<u>B8MSH</u>
	B8MN	<u>B8YSH</u>
	B8MLCuN	<u>B0JSH</u>
Class 2B	B8M2	<u>B9G or B8M2</u>
	B8	<u>B9</u>
Class 2C	B8M3	<u>B9H or B8M3</u>

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. High Temperature Tests

S1.1 Tests to determine high temperature properties shall be made in accordance with Test Methods E21, E139, and E292, and Practices E150 and E151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A320/A320M, Sections 6 and 7, shall be made as agreed between the manufacturer and the purchaser. When testing temperatures are as low as those specified in Specification A320/A320M, bolting should be ordered to that specification in preference to this specification.

S3. 100 % Hardness Testing of Grade B7M

S3.1 Each Grade B7M bolt or stud shall be tested for hardness by indentation method and shall meet the requirements specified in Tables 2 and 3.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs 2½ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 9.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253–319 HBW or 25–34 HRC.

S5. Product Marking

S5.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than ¼ in. [6 mm] in diameter and studs smaller than ⅜ in. [10 mm] in diameter and for ¼ in. [6 mm] in diameter studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

S6. Stress Relieving

S6.1 A stress-relieving operation shall follow straightening after heat treatment.

S6.2 The minimum stress-relieving temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S7. Magnetic Particle Inspection

S7.1 Bars shall be magnetic particle examined in accordance with Guide E709. Bars with indications of cracks or seams are subject to rejection if the indications extend more than 3 % of the diameter into the bar.

S8. Stress-Relaxation Testing

S8.1 Stress-Relaxation Testing, when required, shall be done in accordance with Test Methods E328. The test shall be performed at 850 °F [454 °C] for a period of 100 h. The initial

stress shall be 50 M psi [345 MPa]. The residual stress at 100 h shall be 17 M psi [117 MPa] minimum.

S9. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S9.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E112. The grain size so determined shall be reported on the Certificate of Test.

S10. Hardness Testing of Class 2 Bolting for ASME Applications

S10.1 The maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least ⅛ in. [3 mm] across, prepared by removing threads, and no more material than necessary shall be removed to prepare the flat areas. Hardness determinations shall be made at the same frequency as tensile tests.

S11. Thread Forming

S11.1 Threads shall be formed after heat treatment. Application of this supplemental requirement to grade B7M or the grades listed in 6.2.4 is prohibited.

S12. Stress Rupture Testing of Grade B16

S12.1 One test shall be made for each heat treat lot. Testing shall be conducted using a combination test bar in accordance with Test Methods E292. Rupture shall occur in the smooth section of each test specimen. The test shall be conducted at 1100 °F [595 °C] and 20 ksi [140 MPa]. The test shall be continued until the sample ruptures. Rupture life shall be 25 h minimum. Testing is not required on material less than ½ in. [12 mm] thick.

S12.2 When a purchase order for fasteners invokes S12, the grade symbol applied shall be "B16R."

S13. Coatings on Fasteners

S13.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S13.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S13.1.2 Reference to Specifications A153/A153M, B633, B695, B696, B766, or F1941, F2329, or Test Method F1940, or other standards.

S14. Marking Coated Fasteners

S14.1 Material coated with zinc shall have ZN marked after the grade symbol. Material coated with cadmium shall have CD marked after the grade symbol.

NOTE S14.1—As an example, the marking for zinc-coated B7 will now be B7ZN rather than B7.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the

greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F

[415 °C]. Therefore, application of zinc-coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium-coated fasteners should be limited to temperatures less than 300 °F [160 °C].

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SPECIFICATION FOR CARBON AND ALLOY STEEL NUTS FOR BOLTS FOR HIGH PRESSURE OR HIGH TEMPERATURE SERVICE, OR BOTH



SA-194/SA-194M



(Identical with ASTM Specification A194/A194M-12.)

Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

1. Scope

1.1 This specification covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range $\frac{1}{4}$ through 4 in. and metric M6 through M100 nominal. It also covers austenitic stainless steel nuts in the size range $\frac{1}{4}$ in. and M6 nominal and above. These nuts are intended for high-pressure or high-temperature service, or both. Grade substitutions without the purchaser's permission are not allowed.

1.2 Bars from which the nuts are made shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When annealed and strain hardened austenitic stainless steel is ordered in accordance with Supplementary Requirement S1, the purchaser should take special care to ensure that 8.2.2, Supplementary Requirement S1, and Appendix X1 are thoroughly understood.

1.3 Supplementary requirements of an optional nature are provided. These shall apply only when specified in the inquiry, contract, and order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining

values from the two systems may result in non-conformance with the standard. Within the text, the SI units are shown in brackets.

2. Referenced Documents

2.1 ASTM Standards:

- A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A276 Specification for Stainless Steel Bars and Shapes
- A320/A320M Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range
- B633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
- B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- B696 Specification for Coatings of Cadmium Mechanically Deposited
- B766 Specification for Electrodeposited Coatings of Cadmium
- E112 Test Methods for Determining Average Grain Size
- F1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
- F1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))
- F2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts,

Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 ASME Standards:

B 1.1 Unified Screw Threads

B 1.2 Gages and Gaging for Unified Inch Screw Threads

B 1.13M Metric Screw Threads

B 18.2.2 Square and Hex Nuts

B 18.2.4.6M Metric Heavy Hex Nuts

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Austenitic Grades*—All grades with a prefix of “8” or “9.”

3.1.2 *Ferritic Grades*—Grades 1, 2, 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16.

3.1.3 *Lot*—Unless otherwise specified (see Discussion below), a lot is the quantity of nuts of a single nominal size and grade produced by the same manufacturing process.

3.1.3.1 *Discussion*—When Supplementary Requirement S5 is invoked on the purchase order, the following definitions of a lot shall apply:

3.1.3.2 *For Grade 8 Nuts*—The quantity of all the nuts of a single nominal diameter and grade made from the same heat of steel and made by the same manufacturing process.

3.1.3.3 *For All Other Grade Nuts*— (see 8.2 and 8.1.2.1)—All the nuts of a single nominal diameter and grade made from the same heat number and heat treated in the same batch if batch-type heat treating equipment is used or heat treated in the same continuous run of not more than 8 h under the same conditions if continuous-type heat treating equipment is used.

3.1.4 *Type*

3.1.4.1 *For Grade 8 Nuts*—Variations within the grade designated by a letter and differentiated by chemistry and by manufacturing process.

3.1.4.2 *For Grade 6 Nuts*—Variations within the grade designated by the letter F as differentiated by chemical additions made for machineability.

3.1.5 *Series*—The dimensional relationship and geometry of the nuts as described in ASME B 18.2.2 or B 18.2.4.6M.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

4.1.1 Specification designation, year date, and grade, issue date and revision letter,

4.1.2 Quantity, number of pieces,

4.1.3 Dimensions (see Section 9),

4.1.4 Options in accordance with 8.2.2.1, 9.1, 9.2, 10.3, and 12, and

4.1.5 Supplementary Requirements, if any.

4.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (see Supplementary Requirements S7 and S8). When coated nuts are ordered, the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4.3 See Supplementary Requirement S3 for nuts to be used in low temperature applications (Specification A320/A320M).

4.4 *Proof Load Testing*—See Supplementary Requirement S9 for proof load testing of nuts manufactured to dimensions and configurations other than those covered in Tables 3 and 4.

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A962/A962M, this specification shall prevail.

6. Manufacture (Process)

6.1 Stainless steels for all types of Grade 6 and 8 nuts shall be made by one of the following processes:

6.1.1 Electric-furnace (with separate degassing and refining optional),

6.1.2 Vacuum induction furnace, or

6.1.3 Either of the above followed by electroslag remelting, or consumable-arc remelting.

6.2 The steel producer shall exercise adequate control to eliminate excessive unhomogeneity, nonmetallics, pipe, porosity, and other defects.

6.3 Grades 1 and 2 nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled, or cold-drawn bars.

6.3.1 All Grade 1 and 2 nuts shall be stress-relief annealed at a temperature of at least 1000 °F [538 °C] after forming or machining from bar with the following exceptions:

6.3.1.1 Nuts made by hot forging.

6.3.1.2 Nuts machined from hot-forged or hot-rolled bar.

6.3.1.3 Nuts machined from hot-forged/hot-rolled and cold-finished (max 10 % reduction in area) bar.

6.3.1.4 Nuts machined from cold-drawn and annealed (min 1000 °F [538 °C]) bar.

6.3.2 Grade 1 and 2 nuts made by hot forging or by machining from hot-forged or hot-rolled bars need not be given any stress relief annealing treatment.

6.4 Grades 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16 nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and shall be heat treated to meet the required mechanical properties. These grades shall be uniformly reheated to the proper austenitizing temperature (a group thus reheated being known as a quenching charge) and quenched under substantially uniform conditions for each quenching charge and tempered as shown below. Grades 2H, 2HM, 3, 4, 7, and 7M shall be liquid quenched. Grades 6 and 6F shall be quenched in liquid or inert gas. Grade 16 shall be

TABLE 1 Chemical Requirements^{A,B,C,D}

Grade Symbol	Material	UNS Number	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, ^E %	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Nitrogen, %	Other Elements, %
1	carbon		0.15 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
2, 2HM, and 2H	carbon		0.40 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
4	carbon, molybdenum		0.40–0.50	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...	...	...	...
3	Type 501		0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	...	0.40–0.65	...	...	...	...
6	Type 410	S41000	0.15	1.00	0.040	0.030	1.00	11.5–13.5	...	...	...	...	...	...
6F	Type 416	S41600	0.15	1.25	0.060	0.15 min	1.00	12.0–14.0	...	...	...	...	...	...
6F	Type 416Se	S41623	0.15	1.25	0.060	0.060	1.00	12.0–14.0	...	...	...	...	...	Selenium, 0.15 min
7, 7M	Type 4140/4142/4145, 4140H, 4142H, 4145H		0.37–0.49	0.65–1.10	0.035	0.04	0.15–0.35	0.75–1.20	...	0.15–0.25	...	...	...	...
8, 8A	Type 304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...
8C, 8CA	Type 347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	10 x carbon content, min	...	...
8CLN, 8CLNA	Type 347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	0.20–0.50, 15 x carbon content, min	0.06–0.10	...
8M, 8MA	Type 316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
8T, 8TA	Type 321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	5 x (C+N) min - 0.70 max	...	0.10	...
8F, 8FA	Type 303	S30300	0.15	2.00	0.20	0.15 min	1.00	17.0–19.0	8.0–10.0	...	...	...	...	...
8F, 8FA	Type 303Se	S30323	0.15	2.00	0.20	0.06	1.00	17.0–19.0	8.0–10.0	...	...	...	...	Selenium, 0.15 min
8P, 8PA	Type 305 with restricted carbon	S30500	0.08	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...	...	...
8N, 8NA	Type 304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	0.10–0.16	...
8LN, 8LNA	Type 304LN	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	0.10–0.16	...
8MN, 8MNA	Type 316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	...	...	0.10–0.16	...
8MLN, 8MLNA	Type 316LN	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	...	...	0.10–0.16	...
8R, 8RA ^F	XM19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	...	0.10–0.30	0.20–0.40	Vanadium, 0.10–0.30
8S, 8SA		S21800	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	...	...	...	0.08–0.18	...
8MLCuN, 8MLCuNA	S31254	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	...	...	0.18–0.22	Copper, 0.50–1.00
9C, 9CA	N08367	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	...	...	0.18–0.25	Copper 0.75
16	Chromium Molybdenum Vanadium		0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	...	0.50–0.65	...	...	...	Vanadium, 0.25–0.35 Aluminum ^B 0.015

^A The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grades 6F, 8F, and 8FA, in which Se is specified and required.

^B Total aluminum, soluble and insoluble.

^C Maximum, unless minimum or range is indicated.

^D Where ellipses (...) appear in this table there is no requirement.

^E Because of the degree to which sulfur segregates, product analysis for sulfur over 0.060 % max is not technologically appropriate.

^F As described in Specification A276.

TABLE 2 Hardness Requirements^A

Grade and Type	Completed Nuts			Sample Nut after Treatment as in 8.1.5	
	Brinell Hardness	Rockwell Hardness		Brinell Hardness, min	Rockwell Hardness B Scale, min
		C Scale	B Scale		
1	121 min	...	70 min	121	70
2	159 to 352	...	84 min	159	84
2H to 1½ in. or M36, incl	248 to 327	24 to 35	...	179	89
2H over 1½ in. or M36	212 to 327	35 max	95 min	147	79
2HM and 7M	159 to 235	...	84 to 99	159	84
3, 4, 7, and 16	248 to 327	24 to 35	...	201	94
6 and 6F	228 to 271	20 to 28	...	...	...
8, 8C, 8CLN, 8M, 8T, 8F, 8P, 8N,	126 to 300	32 max	60 min	...	...
8MN, 8LN, 8MLN, 8MLCuN, and 9C	...	...	...	...	...
8A, 8CA, 8CLNA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8LNA, 8MLNA, 8MLCuNA, and 9CA	126 to 192	...	60 to 90	...	...
8R, 8RA, 8S, and 8SA	183 to 271	25 max	88 min	...	...

^A Where ellipses (...) appear in this table there is no requirement.

TABLE 3 Proof Load Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

Nominal Size, in.	Threads per Inch	Stress Area in. ²	Proof Load, lbf ^A					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex ^B	Hex ^C	Heavy Hex ^D	Hex ^E	Heavy Hex ^F	Hex ^G
¼	20	0.0316	4 130	3 820	4 770	4 300	5 570	4 770
5/16	18	0.0524	6 810	6 290	7 860	7 070	9 170	7 860
3/8	16	0.0774	10 080	9 300	11 620	10 460	13 560	11 620
7/16	14	0.1063	13 820	12 760	15 940	14 350	18 600	15 940
½	13	0.1419	18 450	17 030	21 280	19 160	24 830	21 280
9/16	12	0.182	23 660	21 840	27 300	24 570	31 850	27 300
5/8	11	0.226	29 380	27 120	33 900	30 510	39 550	33 900
¾	10	0.334	43 420	40 080	50 100	45 090	58 450	50 100
7/8	9	0.462	60 060	55 440	69 300	62 370	80 850	69 300
1	8	0.606	78 780	72 720	90 900	81 810	106 000	90 900
1 1/8	8	0.790	102 700	94 800	118 500	106 700	138 200	118 500
1 1/4	8	1.000	130 000	120 000	150 000	135 000	175 000	150 000
1 3/8	8	1.233	160 200	148 000	185 000	166 500	215 800	185 000
1 1/2	8	1.492	194 000	170 040	223 800	201 400	261 100	223 800
			All Types of Grade 8, Grades 9C and 9CA					
			Heavy Hex ^H		Hex ^I			
			¼	20	0.0316	2 540	2 380	
			5/16	18	0.0524	4 190	3 930	
			3/8	16	0.0774	6 200	5 810	
			7/16	14	0.1063	8 500	7 970	
			½	13	0.1419	11 350	10 640	
			9/16	12	0.182	14 560	13 650	
			5/8	11	0.226	18 080	16 950	
			¾	10	0.334	26 720	25 050	
			7/8	9	0.462	36 960	34 650	
			1	8	0.606	48 480	45 450	
			1 1/8	8	0.790	63 200	59 250	
			1 1/4	8	1.000	80 000	75 000	
			1 3/8	8	1.233	98 640	92 450	
			1 1/2	8	1.492	119 360	111 900	

^A See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.

^B Based on proof stress of 130 000 psi.

^C Based on proof stress of 120 000 psi.

^D Based on proof stress of 150 000 psi.

^E Based on proof stress of 135 000 psi.

^F Based on proof stress of 175 000 psi.

^G Based on proof stress of 150 000 psi.

^H Based on proof stress of 80 000 psi.

^I Based on proof stress of 75 000 psi.

TABLE 4 Proof Load Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

Nominal Size, mm	Threads Pitch	Stress Area mm ²	Proof Load, kN ^A					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex ^B	Hex ^C	Heavy Hex ^D	Hex ^E	Heavy Hex ^F	Hex ^G
M6	1.0	20.1	18.0	16.6	20.8	18.7	29.2	20.8
M8	1.25	36.6	32.8	30.2	37.9	34.0	44.1	37.9
M10	1.50	58.0	51.9	47.9	60.0	53.9	69.9	60.0
M12	1.75	84.3	75.5	69.5	87.3	78.4	101.6	87.3
M14	2.0	115.0	102.9	94.9	119.0	107.0	138.6	119.0
M16	2.0	157.0	140.5	129.5	162.5	146.0	189.2	162.5
M20	2.5	245.0	219.3	202.1	253.6	227.8	295.2	253.6
M22	2.5	303.0	271.2	249.9	313.6	281.8	365.1	313.6
M24	3.0	353.0	315.9	291.2	365.4	328.3	425.4	365.4
M27	3.0	459.0	411.0	378.7	475.1	426.9	553.4	475.1
M30	3.5	561.0	502.1	462.8	580.6	521.7	676.0	580.6
M36	4.0	817.0	731.2	674.0	845.6	759.8	984.5	845.6

Nominal Size, mm	Thread Pitch	All Types of Grade 8, and Grades 9C and 9CA		Hex ^I
		Stress Area, mm ²	Heavy Hex ^H	
M6	1.0	20.1	11.1	10.4
M8	1.25	36.6	20.1	18.8
M10	1.50	58.0	31.9	29.9
M12	1.75	84.3	46.4	43.4
M14	2.0	115.0	63.3	59.2
M16	2.0	157.0	86.4	80.9
M20	2.5	245.0	134.8	126.2
M22	2.5	303.0	166.7	156.0
M24	3.0	353.0	194.2	181.8
M27	3.0	459.0	252.5	236.4
M30	3.5	561.0	308.6	288.9
M36	4.0	817.0	449.4	420.8

^A See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.^B Based on proof stress of 895 MPa.^C Based on proof stress of 825 MPa.^D Based on proof stress of 1035 MPa.^E Based on proof stress of 930 MPa.^F Based on proof stress of 1205 MPa.^G Based on proof stress of 1035 MPa.^H Based on proof stress of 550 MPa.^I Based on proof stress of 515 MPa.

heated to a temperature range from 1700 to 1750 °F (925 to 955 °C) and oil quenched.

Grade	Minimum Tempering Temperature, °F	
	[°C]	
2H	850 [455]	
2HM	1150 [620]	
3	1050 [565]	
4	1100 [595]	
6 and 6F	1100 [595]	
7	1100 [595]	
7M	1150 [620]	
16	1200 [650]	

Nuts machined from bar heat treated in accordance with this specification need not be reheat-treated. For Grade 2HM and 7M nuts, a final stress relief shall be done at or above the minimum tempering temperature after all forming, machining, and tapping operations. This final stress relief may be the tempering operation.

6.4.1 Grade 6 and 6F nuts shall be tempered for a minimum of 1 h at the temperature.

6.5 Grades 8, 8C, 8CLN, 8M, 8T, 8F, 8P, 8N, 8MN, 8R, 8S, 8LN, 8MLN, 8MLCuN, and 9C nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled or cold-drawn bars.

6.6 Grades 8A, 8CA, 8CLNA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, 8MLCuNA, and 9CA nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8. Mechanical Requirements

8.1 Hardness Test:

8.1.1 Requirements:

8.1.1.1 All nuts shall meet the hardness requirements specified in Table 2.

8.1.1.2 Sample nuts of Grades 1, 2, 2H, 2HM, 3, 4, 7, 7M, and 16 which have been given the treatment described in 8.1.5 shall meet the minimum hardness specified in Table 2.

8.1.2 *Number of Tests*— (Grades 1, 2, 2H, 3, 4, 7, and 16 and all types of Grade 6):

8.1.2.1 Tests on the number of sample nuts in accordance with the following table shall be performed by the manufacturer following all production heat treatments:

Lot Size	Samples
Up to 800	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

8.1.2.2 In addition, a hardness test shall be performed by the manufacturer in accordance with 8.1.5 on one sample nut selected from each nominal diameter and series from each grade and heat number following completion of all production heat treatments.

8.1.3 *Number of Tests, Grades 2HM and 7M:*

8.1.3.1 Each nut shall be tested by Brinell or Rockwell methods to ensure product conformance.

8.1.3.2 In addition, 8.1.2.2 shall be met.

8.1.4 *Number of Tests, All Types of Grade 8*—Tests on the number of sample nuts in accordance with 8.1.2.1 shall be performed by the manufacturer.

8.1.5 *Test 2*—In addition to the testing required by 8.1.2.1 the manufacturer shall also perform hardness tests on sample nuts after the following test heat treatment. After completion of all production heat treatments heat the specimen nuts to the temperatures indicated below for 24 h, then slow cool. Test at room temperature.

Grade ^A	Temperature, °F [°C]
1	850 [455]
2, 2H, 2HM	1000 [540]
3, 4, 7, 7M	1100 [590]
16	1200 [650]

^ANuts intended to be coated with zinc or cadmium (marked in accordance with the requirements of Supplementary Requirement S8) are not subjected to the requirements of 8.1.5 (See Appendix X2).

8.1.5.1 *Special Requirement, Grades 2HM and 7M*—Preparation of Grades 2HM and 7M nuts for hardness test and the hardness test itself shall be performed with consideration to (1) protect legibility of markings; (2) minimize exterior dimensional changes; and (3) maintain thread fit.

8.2 *Proof Load Test:*

8.2.1 *Requirements*—The nuts listed in Tables 3 and 4 shall be capable of withstanding the proof loads specified therein. Proof load testing of nuts manufactured to dimensions and configurations other than those covered in Table 3 or Table 4 is only required when S9 is specified in the order or inquiry.

8.2.2 *Number of Tests:*

8.2.2.1 The manufacturer shall test the number of nuts specified in 8.1.2.1 following all production heat treatments. Nuts that would require a proof load in excess of 160 000 lb/f or 705 kN shall, unless Supplementary Requirements S1 or S4 are invoked in the purchase order or contract, be proof load tested per Section 8 or cross sectional hardness tested per Annex A3 of Test Methods and Definitions A370. Proof Load tests prevail over hardness tests in the event a conflict exists relative to minimum strength.

8.2.3 *Test Method*—The test shall be run using a threaded mandrel or a test bolt in accordance with Specification A962/A962M.

8.3 *Cone Proof Load Test:*

8.3.1 *Requirements*—This test shall be performed only when visible surface discontinuities become a matter of issue between the manufacturer and the purchaser. Nuts in the size range ¼ to 1½ in. inclusive and M6 to M36 inclusive shall be proof load tested. Nuts not in this size range and all types of Grade 8 nuts are not subject to this test. Also, nuts manufactured to dimensions and configurations other than those covered by Specification A962/A962M, ASME B 1.1, ASME B 1.13M, ASME B 18.2.2, and ASME B 18.2.4.6M are not subject to the cone proof load test. The cone proof load applied shall be determined in accordance with the Cone Proof Load requirements in Specification A962/A962M (tables or formulae or both) based upon the proof stresses shown in Table 5 and Table 6 of Specification A194/A194M.

8.3.2 *Number of Tests*—The manufacturer shall sample and test the number of nuts specified in 8.1.2.1. The lot shall be considered acceptable if the sample nut(s) withstand(s) application of the cone proof load without failure.

9. Dimensions

9.1 Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ASME B 18.2.2 and ASME B 18.2.4.6M. Unless otherwise specified, the American National Standard Heavy Hex Series shall be used and nuts shall be either double chamfered or have a machined or forged washer face, at the option of the manufacturer, and, conform to the angularity requirements of ASME B 18.2.2 and ASME B 18.2.4.6M.

9.2 Unless otherwise specified, threads shall be in accordance with ASME B 1.1 or ASME B 1.13M, and shall be gaged in accordance with ASME B 1.2 and ASME B 1.13M as described in 9.2.1 and 9.2.2.

9.2.1 Nuts up to and including 1 in. nominal size shall be UNC Series Class 2B fit. Metric nuts up to and including M24 nominal size shall be coarse thread series tolerance 6H.

TABLE 5 Proof Stress Using 120° Hardened Steel Cone — Inch

Type	Grade 1	Proof Stress — psi, Minimum	
		Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	120 000	135 000	150 000
Heavy Hex	130 000	150 000	175 000

TABLE 6 Proof Stress Using 120° Hardened Steel Cone — Metric

Type	Grade 1	Proof Stress – MPa, Minimum	
		Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	825	930	1035
Heavy Hex	895	1035	1205

9.2.2 Nuts over 1 in. nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished. Metric nuts over M24 nominal size shall be coarse thread series tolerance 6H.

10. Workmanship, Finish, and Appearance

10.1 Nuts shall be free of defects and shall be good commercial finish.

10.2 If visible surface imperfections in size ¼ through 1½ in. and M6 through M36 and in any grade other than Grade 8 become a matter of issue between the manufacturer and the purchaser, the cone proof load test described in 8.3 shall be employed.

10.3 If a scale-free bright finish is required, this shall be specified on the purchase order.

11. Retests

11.1 Provisions for retests by the purchaser and his representative are specified in Supplementary Requirement S2.

12. Certification

12.1 In addition to the requirements of Specification A962/A962M, the certification shall include the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), mechanical tests, and the minimum tempering temperature for nuts of Grades 2H, 2HM, 3, 4, 6, 6F, 7, and 7M.

13. Product Marking

13.1 In addition to the requirements of Specification A962/A962M, nuts shall be legibly marked on one face with the grade symbol representing the grade, type and applicable manufacturing process shown in Table 7. Marking of wrench flats or bearing surfaces is not permitted unless agreed upon between manufacturer and purchaser.

TABLE 7 Grade Symbol Marking of Nuts^A

Grade and Type	Nuts Hot-Forged or Cold-Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 6.6
1	1	1B	...
2	2	2B	...
2H ^B	2H	2HB	...
2HM ^{B,C}	2HM	2HMB	...
3	3	3B	...
4	4	4B	...
4L ^D	4L	4BL	...
6	6	6B	...
6F	6F	6FB	...
7	7	7B	...
7L ^D	7L	7BL	...
7M ^{B,C}	7M	7MB	...
7ML ^{B,D}	7ML	7MLB	...
8	8	8B	8A
8C	8C	8CB	8CA
8CLN	8CLN	8CLNB	8CLNA
8M	8M	8MB	8MA
8T	8T	8TB	8TA
8F	8F	8FB	8FA
8P	8P	8PB	8PA
8N	8N	8NB	8NA
8MN	8MN	8MNB	8MNA
8R	8R	8RB	8RA
8S	8S	8SB	8SA
8LN	8LN	8LNB	8LNA
8MLN	8MLN	8MLNB	8MLNA
8MLCuN	8MLCuN	8MLCuNB	8MLCuNA
9C	9C	9CB	9CA
16	16	16B	...

^A Where ellipses (...) appear in this table there is no requirement.

^B The letters H and M indicate heat-treated nuts (see Section 6).

^C An underline as a marking requirement for grades 2HM and 7M has been removed but is permitted.

^D See Supplementary Requirement S3.

14. Keywords

14.1 bolting; chemical analysis; coated; marking on fasteners; plated

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Strain-Hardened Austenitic Steel Nuts

S1.1 Strain hardened Grades 8, 8C, 8T, 8M, 8F, 8P, 8N, or 8MN nuts may be specified. When Supplementary Requirement S1 is invoked in the order, nuts shall be machined from cold drawn bars or shall be cold forged to shape. No subsequent heat treatment shall be performed on the nuts. Nuts made in accordance with this requirement shall be proof load tested in accordance with 8.2.2.1 and shall withstand the proof load specified in Table S1.1 and Table S1.2. Testing nuts requiring proof loads over 160 000 lbf or 705 kN is only required when Supplementary Requirement S4 is invoked. The hardness limits of Table 2 do not apply to strain hardened nuts. Nuts made in accordance with this requirement shall be marked with the Grade symbol underlined.

S2. Retests by Purchaser's Representative

S2.1 The purchaser's representative may select two nuts per keg (200-lb unit [90-kg]) for sizes $\frac{5}{8}$ in. and M16 and smaller, one nut per keg for sizes over $\frac{5}{8}$ in. and M16 up to and including $1\frac{1}{2}$ in. and M36, and one nut per every two kegs for sizes larger than $1\frac{1}{2}$ in. and M36, which shall be subjected to the tests specified in Section 8.

S3. Low-Temperature Requirements for Grade 4, Grade 7 or Grade 7M Nuts

S3.1 When low-temperature requirements are specified for Grade 4 or Grade 7 nuts, the Charpy test procedures and requirements as defined in Specification A320/A320M for

Grade L7 shall apply. When low-temperature requirements are specified for Grade 7M nuts, the Charpy test procedures and requirements as defined in Specification A320/A320M for Grade L7M shall apply. Depending on the size of nuts, separate test samples of the same heat may be required and shall be processed through heat treatment with the nuts for which the test is to apply. Impact testing is not required when the bar stock or nut is smaller than $\frac{5}{8}$ in. [16 mm] in diameter.

S3.2 An "L" shall be added to the marking, as shown in Table 7, for nuts so tested.

S4. Proof Load Tests of Large Nuts

S4.1 Proof load testing of nuts requiring proof loads of over 160 000 lbf or 705 kN is required. Testing shall be performed in accordance with 8.2 to the loads required in Table S4.1 and Table S4.2. The maximum load will be based entirely on the equipment available.

S5. Control of Product by Heat Number

S5.1 When control of nuts by actual heat analysis is required and this supplementary requirement is specified, the manufacturer shall identify the completed nuts in each shipment by the actual heat number. When this supplementary requirement is specified, a certificate including the results of the actual production tests of each test lot together with the heat chemical analysis shall be furnished by the manufacturer.

TABLE S1.1 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

Nominal Size, in.	Threads per in.	Stress Area, in. ²	Proof Load, lbf ^A			
			Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex ^B	Hex ^C	Heavy Hex ^D	Hex ^B
$\frac{1}{4}$	20	0.0316	3 480	3 160	3 950	3 480
$\frac{5}{16}$	18	0.0523	5 760	5 240	6 550	5 760
$\frac{3}{8}$	16	0.0774	8 510	7 740	9 675	8 510
$\frac{7}{16}$	14	0.1063	11 690	10 630	13 290	11 690
$\frac{1}{2}$	13	0.1419	15 610	14 190	17 740	15 610
$\frac{9}{16}$	12	0.182	20 020	18 200	22 750	20 020
$\frac{5}{8}$	11	0.226	24 860	22 600	28 250	24 860
$\frac{3}{4}$	10	0.334	36 740	33 400	41 750	36 740
$\frac{7}{8}$	9	0.462	46 200	41 580	53 130	46 200
1	8	0.606	60 600	54 540	69 690	60 600
$1\frac{1}{8}$	8	0.790	75 050	67 150	82 950	75 050
$1\frac{1}{4}$	8	1.000	95 000	85 000	105 000	95 000
$1\frac{3}{8}$	8	1.233	110 970	98 640	123 300	110 970
$1\frac{1}{2}$	8	1.492	134 280	119 360	149 200	134 280

^A The proof load for jam nuts shall be 46 % of the tabulated value.

^B Based on proof stress of 110 000 psi up to $\frac{3}{4}$ in.; 100 000 psi $\frac{7}{8}$ to 1 in.; 95 000 psi $1\frac{1}{8}$ to $1\frac{1}{4}$ in.; 90 000 psi $1\frac{3}{8}$ to $1\frac{1}{2}$ in.

^C Based on proof stress of 100 000 psi up to $\frac{3}{4}$ in.; 90 000 psi $\frac{7}{8}$ to 1 in.; 85 000 psi $1\frac{1}{8}$ to $1\frac{1}{4}$ in.; 80 000 psi $1\frac{3}{8}$ to $1\frac{1}{2}$ in.

^D Based on proof stress of 125 000 psi up to $\frac{3}{4}$ in.; 115 000 psi $\frac{7}{8}$ to 1 in.; 105 000 psi $1\frac{1}{8}$ to $1\frac{1}{4}$ in.; 100 000 psi $1\frac{3}{8}$ to $1\frac{1}{2}$ in.

TABLE S1.2 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

Nominal Size, mm	Thread Pitch	Stress Area, mm ²	Proof Load, kN ^A			
			Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex ^B	Hex ^C	Heavy Hex ^D	Hex ^B
M6	1.0	20.1	15.3	13.9	17.3	15.3
M8	1.25	36.6	27.8	25.3	31.3	27.8
M10	1.50	58.0	44.1	40.0	49.9	44.1
M12	1.75	84.3	64.1	58.2	72.5	64.1
M14	2.0	115.0	87.4	79.4	98.9	87.4
M16	2.0	157.0	119.3	108.3	135.0	119.3
M20	2.5	245.0	186.2	169.0	210.9	186.2
M22	2.5	303.0	209.0	187.9	240.9	209.0
M24	3.0	353.0	243.5	218.9	280.6	243.5
M27	3.0	459.0	300.6	268.5	332.7	300.6
M30	3.5	561.0	367.5	328.2	406.7	367.5
M36	4.0	817.0	506.5	449.4	563.7	506.5

^A The proof load for jam nuts shall be 46 % of the tabulated value.^B Based on proof stress of 760 MPa up to M20 mm; 690 MPa M22 to M24 mm; 655 MPa M27 to M30; and 620 MPa for M36.^C Based on proof stress of 690 MPa up to M20 mm; 620 MPa M22 to M24 mm; 585 MPa M27 to M30; and 550 MPa for M36.^D Based on proof stress of 860 MPa up to M20 mm; 795 MPa M22 to M24 mm; 725 MPa M27 to M30 mm; and 690 MPa for M36.**TABLE S4.1 Proof Load for Large Heavy Hex Nuts — Inch^A**

Nominal Size, in.	Threads per in.	Stress Area, in. ²	Proof Load, lbf ^B		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
1 ⁵ / ₈	8	1.78	231 400	267 000	311 500
1 ³ / ₄	8	2.08	270 400	312 000	364 000
1 ⁷ / ₈	8	2.41	313 300	361 500	421 800
2	8	2.77	360 100	415 500	484 800
2 ¹ / ₄	8	3.56	462 800	534 000	623 000
2 ¹ / ₂	8	4.44	577 200	666 000	777 000
2 ³ / ₄	8	5.43	705 900	814 500	950 250

^A ASME B18.2.2 in the size range over 1¹/₂ in. provides dimensions only for heavy hex nuts. Refer to 8.3.1.^B Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table S1.1. The proof load for jam nuts shall be 46 % of the tabulated load.**TABLE S4.2 Proof Load for Large Heavy Hex Nuts — Metric^A**

Nominal Size, mm	Thread Pitch	Stress Area, mm ²	Proof Load, kN ^B		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
M42	4.5	1120	1002.4	1159.2	1349.6
M48	5	1470	1315.7	1521.4	1771.4
M56	5.5	2030	1816.9	2101.0	2446.2
M64	6	2680	2398.6	2773.8	3229.4
M72	6	3460	3096.7	3581.1	4169.3

^A ASME B 18.2.4.6M in the size range over M36 provides dimensions only for heavy hex nuts. Refer to 7.3.1.^B Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 4 or Table S1.2. The proof load for jam nuts shall be 46 % of the tabulated load.

S6. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S6.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E112. The grain size so determined shall be reported on the Certificate of Test.

S7. Coating on Nuts

S7.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S7.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

NOTE S7.1—Modification of thread dimensions may result in loss of load carrying ability.

S7.1.2 Reference to Specifications A153/A153M, B633, B695, B696, B766, F1941, F2329, or Test Method F1940, or other standards.

S8. Marking Coated Nuts

S8.1 Nuts coated with zinc shall have ZN marked after the grade symbol. Nuts coated with cadmium shall have CD marked after the grade symbol.

NOTE S8.1—As an example, the marking for zinc-coated 2H fasteners will now be 2HZN rather than 2H*.

S9. Proof Load Testing

S9.1 Proof load tests of nuts made to dimensions, thread pitch, and configurations other than those covered in Table 3 or Table 4 shall be made using loads agreed upon between the manufacturer and the purchaser.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-

section reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F

[415 °C]. Therefore, application of zinc coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium coated fasteners should be limited to temperatures less than 300 °F [160 °C].

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, NICKEL



SA-203/SA-203M



(Identical with ASTM Specification A203/A203M-17.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel

1. Scope

1.1 This specification covers nickel-alloy steel plates intended primarily for welded pressure vessels.

1.2 Plates under this specification are available with four strength levels and two nickel compositions as follows:

Grade	Nominal Nickel Content %	Yield Strength, min,		Tensile Strength, min, ksi [MPa]	
		ksi [MPa]		ksi [MPa]	
A	2.25	37 [255]		65 [450]	
B	2.25	40 [275]		70 [485]	
D	3.50	37 [255]		65 [450]	
E	3.50	40 [275]		70 [485]	
F	3.50				
	2 in. [50 mm] and under	55 [380]		80 [550]	
	Over 2 in. [50 mm]	50 [345]		75 [515]	

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 All plates shall be thermally treated as follows:

TABLE 1 Chemical Requirements

Elements	Composition, %			
	Grade A	Grade B	Grade D	Grades E and F
Carbon, max: ^A				
Up to 2 in. [50 mm] in thickness	0.17	0.21	0.17	0.20
Over 2 in. to 4 in. [100 mm] incl. in thickness	0.20	0.24	0.20	0.23
Over 4 in. [100 mm] in thickness	0.23	0.25	...	...
Manganese, max:				
Heat analysis:				
2 in. [50 mm] and under	0.70	0.70	0.70	0.70
Over 2 in. [50 mm]	0.80	0.80	0.80	0.80
Product analysis:				
2 in. [50 mm] and under	0.78	0.78	0.78	0.78
Over 2 in. [50 mm]	0.88	0.88	0.88	0.88
Phosphorus, max ^A	0.025	0.025	0.025	0.025
Sulfur, max ^A	0.025	0.025	0.025	0.025
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Nickel:				
Heat analysis	2.10–2.50	2.10–2.50	3.25–3.75	3.25–3.75
Product analysis	2.03–2.57	2.03–2.57	3.18–3.82	3.18–3.82

^A Applies to both heat and product analyses.

TABLE 2 Tensile Requirements

	Grades A and D		Grades B and E		Grade F	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength						
2 in. [50 mm] and under	65–85	[450–585]	70–90	[485–620]	80–100	[550–690]
Over 2 in. [50 mm]	65–85	[450–585]	70–90	[485–620]	75–95	[515–655]
Yield strength, min						
2 in. [50 mm] and under	37	[255]	40	[275]	55	[380]
Over 2 in. [50 mm]	37	[255]	40	[275]	50	[345]
Elongation in 8 in. [200 mm] min, % ^A		19		17		...
Elongation in 2 in. [50 mm] min, % ^{A,B}		23		21		20

^A See Specification A20/A20M for elongation adjustments.

^B See 7.1.1.

5.1.1 All plates of Grades A, B, D, and E shall be normalized except as permitted by 5.1.1.1.

5.1.1.1 If approved by the purchaser for Grades A, B, D, and E, cooling rates faster than air cooling are permissible for improvement of the toughness, provided the plates are subsequently tempered at not less than 1100°F [595°C] for not less than ½ h.

5.1.2 All plates of Grade F shall be heat treated by heating into the austenitic range, quenching in water, and tempering at not less than 1100°F [595°C] for not less than ½ h.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test Requirements*—The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For plates that have been heat treated in accordance with 5.1.1.1 or 5.1.2 and have a nominal thickness of ¾ in. [20 mm] and under, the 1½-in. (40-mm) wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation. When this specimen is used, the elongation shall be not less than 23 %.

7.2 Impact Test Requirements:

7.2.1 Plates of Grades A, B, D, and E that have been heat treated in accordance with 5.1.1.1 shall be Charpy V-notch impact tested. The impact test shall meet 20 ft · lbf [27 J]. The test temperature and orientation shall be a matter of agreement between the purchaser and supplier.

7.2.2 Grade F plates shall be impact tested in accordance with Supplementary Requirement S5 in Specification A20/A20M.

8. Keywords

8.1 alloy steel plate; nickel alloy steel; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Those which are considered suitable for use with this specification are listed below by title.

- | | |
|--|--|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in accordance with Specification A435/A435M, |
| S2. Product Analysis, | S9. Magnetic Particle Examination, |
| S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, | S11. Ultrasonic Examination in accordance with Specification A577/A577M, |
| S4.1 Additional Tension Test, | S12. Ultrasonic Examination in accordance with Specification A578/A578M, and |
| S5. Charpy V-Notch Impact Test, | S17. Vacuum Carbon-Deoxidized Steel. |
| S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness), | |
| S7. High-Temperature Tension Test, | |

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MOLYBDENUM



SA-204/SA-204M



(Identical with ASTM Specification A204/A204M-18.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum

1. Scope

1.1 This specification covers molybdenum-alloy steel plates, intended particularly for welded boilers and other pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
A	65–85 [450–585]
B	70–90 [485–620]
C	75–95 [515–655]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

TABLE 1 Chemical Requirements

Element	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max: ^A			
Up to 1 in. [25 mm] incl. in thickness	0.18	0.20	0.23
Over 1 in. to 2 in. [50 mm] incl. in thickness	0.21	0.23	0.26
Over 2 in. to 4 in. [100 mm] incl. in thickness	0.23	0.25	0.28
Over 4 in. [100 mm] in thickness	0.25	0.27	0.28
Manganese, max:			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorous, max ^A	0.025	0.025	0.025
Sulfur, max ^A	0.025	0.025	0.025
Silicon:			
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:			
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64

^A Applies to both heat and product analyses.

TABLE 2 Tensile Requirements

	Grade A		Grade B		Grade C	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength	65–85	[450–585]	70–90	[485–620]	75–95	[515–655]
Yield strength, min ^A	37	[255]	40	[275]	43	[295]
Elongation in 8 in. [200 mm], min, % ^B	19		17		16	
Elongation in 2 in. [50 mm], min, % ^B	23		21		20	

^A Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

^B See Specification A20/A20M for elongation adjustment.

5. Heat Treatment

5.1 Plates 1½ in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized, normalized and tempered, or stress relieved.

5.2 Plates over 1½ in. [40 mm] in thickness shall be normalized or normalized and tempered.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with

Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The plates, as represented by the tension-test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 alloy steel plate; molybdenum-alloy; pressure containing parts; pressure vessel steel plate

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed in this section by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,
S8. Ultrasonic Examination in accordance with Specification A435/A435M,
S9. Magnetic Particle Examination,
S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and
S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR SEAMLESS CARBON-MOLYBDENUM ALLOY-STEEL BOILER AND SUPERHEATER TUBES



SA-209/SA-209M



(21)

(Identical with ASTM Specification A209/A209M-03(2017).)

Standard Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, seamless, carbon-molybdenum alloy-steel, boiler and superheater tubes.

1.2 This specification covers tubes ½ to 5 in. [12.7 to 127 mm] inclusive, in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness.

1.3 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

3. General Requirements

3.1 Product furnished under this specification shall conform to the requirements of Specification A1016/A1016M, includ-

ing any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A1016/A1016M constitutes nonconformance with this specification. In case of conflict with the requirements of this specification and Specification A1016/A1016M, this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

4.2 The tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

4.3 *Heat Treatment*—Hot-finished tubes shall be heat treated at a temperature of 1200 °F [650 °C] or higher. Cold-finished tubes shall, after the final cold finishing, be heat treated at a temperature of 1200 °F [650 °C] or higher, or tubing may be furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature shall be 1200 °F [650 °C].

5. Chemical Composition

5.1 The steel shall conform to the requirements given in Table 1.

5.2 Product Analysis

5.2.1 An analysis shall be made by the manufacturer of one billet or one tube from each heat. The chemical composition thus determined, shall conform to the requirements given in Table 1.

5.2.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (See 7.1) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

TABLE 1 Chemical Composition Requirements

Element	Composition, %		
	Grade T1	Grade T1a	Grade T1b
Carbon	0.10–0.20	0.15–0.25	0.14 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.10–0.50	0.10–0.50	0.10–0.50
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65

6. Mechanical Properties

6.1 Tensile Requirements

6.1.1 The material shall conform to the requirements given in Table 2.

6.1.2 Table 3 gives the computed minimum elongation values for each $\frac{1}{32}$ -in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00] \quad (1)$$

where:

E = elongation in 2 in. [50 mm], %, and,

t = actual thickness of specimen, in. [mm].

6.2 *Hardness Requirements*—The tubes shall have a hardness not exceeding the values given in Table 4.

6.3 Number of Tests

6.3.1 *Tension Test*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (See 7.2)

6.3.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot (See 7.1)

6.3.3 *Flaring Test*—One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (See 7.1)

6.3.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (See 7.2)

TABLE 2 Tensile Requirements

	Grade T1	Grade T1b	Grade T1a
Tensile strength, min, ksi [MPa]	55 [380]	53 [365]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	28 [195]	32 [220]
Elongation in 2 in. or 50 mm, min, %	30	30	30
For longitudinal strip tests a deduction shall be made for each $\frac{1}{32}$ -in. [0.8- mm] decrease in wall thickness below $\frac{9}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage	1.50 ^A	1.50 ^A	1.50 ^A
When standard round 2-in. or 50-mm gage length or smaller proportionally sized specimen with the gage length equal to 4D (four times the diameter) is used	22	22	22

^ATable 3 gives the computed minimum values.

TABLE 3 Computed Minimum Values

	Wall Thickness		Elongation in 2 in. or 50 mm, min, % ^A
	in.	mm	
$\frac{5}{16}$ (0.312)		8	30
$\frac{9}{32}$ (0.281)		7.2	29
$\frac{1}{4}$ (0.250)		6.4	27
$\frac{7}{32}$ (0.219)		5.6	26
$\frac{9}{16}$ (0.188)		4.8	24
$\frac{5}{32}$ (0.156)		4	22
$\frac{1}{8}$ (0.125)		3.2	21
$\frac{9}{32}$ (0.094)		2.4	20
$\frac{1}{16}$ (0.062)		1.6	18

^ACalculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4 Hardness Requirements

	Brinell Hardness	Rockwell Hardness
	Number (Tubes 0.200 in. [5.1 mm] and over in Wall Thickness), HBW	Number (Tubes less than 0.200 in. [5.1 mm] in Wall Thickness), HRB
Grade T 1	146	80
Grade T 1a	153	81
Grade T 1b	137	77

7. Sampling

7.1 *Flattening, Flaring, and Product Analysis*—For flattening, flaring, and product analysis requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes given in Table 5.

7.2 *Tension and Hardness Tests*—For tension and hardness tests, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

TABLE 5 Number of Tubes in a Lot Heat Treated by the Continuous Process

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

8. Forming Operations

8.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

9. Product Marking

9.1 In addition to the marking prescribed in Specification A1016/A1016M, the marking shall include whether the tube is hot-finished or cold-finished.

10. Keywords

10.1 boiler tubes; carbon-molybdenum; seamless steel tube; steel tube; superheater tubes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Surface Condition

S1.1 If pickling or shot blasting, or both, are required, this shall be specifically stated in the order. Details of this supplemental requirement shall be agreed upon between the manufacturer and the purchaser.

SPECIFICATION FOR SEAMLESS MEDIUM-CARBON STEEL BOILER AND SUPERHEATER TUBES



SA-210/SA-210M

(Identical with ASTM Specification A210/A210M-95 except for editorial differences in Table 2.)

SPECIFICATION FOR SEAMLESS MEDIUM-CARBON STEEL BOILER AND SUPERHEATER TUBES



SA-210/SA-210M

(Identical with ASTM Specification A 210/A 210M-95 except for editorial differences in Table 2.)

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless medium-carbon steel, boiler tubes and boiler flues, including safe ends (Note 1), arch and stay tubes, and superheater tubes.

NOTE 1 — This type is not suitable for safe ending by forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ in. to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520, shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless tubes),

3.1.3 Grade,

3.1.4 Manufacture (hot-finished or cold-finished),

3.1.5 Size (outside diameter and minimum wall thickness),

3.1.6 Length (specific or random),

3.1.7 Optional requirements (Sections 7 and 10),

3.1.8 Test report required (see Certification Specification of Specification A 450/A 450M),

3.1.9 Specification designation, and

3.1.10 Special requirements

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 *Steelmaking Practice* — The steel shall be killed.

5.2 The tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

6.1 Hot-finished tubes need not be heat treated. Cold-finished tubes shall be given a subcritical anneal, a full anneal, or a normalizing heat treatment after the final cold-finishing process.

7. Surface Condition

7.1 If pickling or shot blasting or both are required, this shall be specifically stated in the order.

8. Chemical Composition

8.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube or billet per heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2 — For flattening and flaring requirements, the term “lot” applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 3 — For tensile and hardness test requirements, the term “lot” applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

10.2 Table 4 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm, %, and
 t = actual thickness of specimen, in. [mm].

11. Hardness Requirements

11.1 The tubes shall have a hardness not exceeding the following: 79 HRB or 143 HB for Grade A-1, 89 HRB or 179 HB for Grade C.

12. Mechanical Tests Required

12.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 3).

12.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube from each lot (Note 2), but not the one used for the flaring test. Tears or breaks occurring at the 12 or 6 o'clock positions on Grade C tubing with sizes of 2.375 in. [60.3 mm] in outside diameter and smaller shall not be considered a basis for rejection.

12.3 Flaring Test — One flaring test shall be made on specimens from each end of the one finished tube from each lot (Note 2,) but not the one used for the flattening test.

12.4 Hardness Test — Brinell or Rockwell hardness test shall be made on specimens from two tubes from each lot (Note 3).

12.5 Hydrostatic or Nondestructive Electric Test — Each tube shall be subjected to the hydrostatic, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

13. Forming Operations

13.1 When inserted in the boiler, tubes shall stand expanding and beading without showing cracks or flaws. When properly manipulated, superheater tubes shall stand all forging, welding and bending operations necessary for application without developing defects.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot-finished or cold-finished.

15. Keywords

15.1 boiler tubes; carbon; seamless steel tube; steel tube; superheater tubes

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Grade A-1	Grade C
Carbon ^A , max	0.27	0.35
Manganese	0.93 max	0.29–1.06
Phosphorus, max	0.035	0.035
Sulfur, max	0.035	0.035
Silicon, min	0.10	0.10

^A For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. (50.8 mm) and over in diameter and 0.200 in. (5.1 mm) and over in wall thickness	not more than 50 tubes
2 in. (50.8 mm) and over in outside diameter and under 0.200 in. (5.1 mm) in wall thickness	not more than 75 tubes
Less than 2 in. (50.8 mm) but over 1 in. (25.4 mm) in outside diameter or over 1 in. in outside diameter and under 0.200 in. (5.08 mm) in wall thickness	not more than 75 tubes
1 in. (25.4 mm) or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

	Grade A-1	Grade C
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal strip tests, a deduction shall be made for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness under $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.50 ^A	1.50 ^A
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4D (four times the diameter) is used	22	20

^A See Table 4 for the computed minimum values.

TABLE 4
COMPUTED MINIMUM ELONGATION VALUES⁴

Wall Thickness, in. [mm]	Elongation in 2 in. or 50 mm, min, %
$\frac{5}{16}$ (0.312) [8]	30
$\frac{9}{32}$ (0.281) [7.2]	28
$\frac{1}{4}$ (0.250) [6.4]	27
$\frac{7}{32}$ (0.219) [5.6]	26
$\frac{3}{16}$ (0.188) [4.8]	24
$\frac{5}{32}$ (0.156) [4]	22
$\frac{1}{8}$ (0.125) [3.2]	21
$\frac{3}{32}$ (0.094) [2.4]	20
$\frac{1}{16}$ (0.062) [1.6]	18
0.062 to 0.035 [1.6 to 0.9], excl	17
0.035 to 0.022 [0.9 to 0.6], excl	16
0.022 to 0.015 [0.6 to 0.4], incl	16

⁴ Calculated elongation requirements shall be rounded to the nearest whole number.

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SPECIFICATION FOR SEAMLESS FERRITIC AND AUSTENITIC ALLOY-STEEL BOILER, SUPERHEATER, AND HEAT-EXCHANGER TUBES



SA-213/SA-213M

(21)

(Identical with ASTM Specification A213/A213M-18b except for the additional H Grade requirements in para. 6.2.)

Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

1. Scope

1.1 This specification covers seamless ferritic and austenitic steel boiler, superheater, and heat-exchanger tubes, designated Grades T5, TP304, etc. These steels are listed in Tables 1 and 2.

1.2 Grades containing the letter, H, in their designation, have requirements different from those of similar grades not containing the letter, H. These different requirements provide higher creep-rupture strength than normally achievable in similar grades without these different requirements.

1.3 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{8}$ in. [3.2 mm] in inside diameter to 5 in. [127 mm] in outside diameter and 0.015 to 0.500 in. [0.4 to 12.7 mm], inclusive, in minimum wall thickness or, if specified in the order, average wall thickness. Tubing having other diameters may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E112 Test Methods for Determining Average Grain Size

2.2 AWS Specifications

A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A941.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for products under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless tubes),

4.1.3 Grade (Tables 1 and 2),

4.1.4 Condition (hot finished or cold finished),

4.1.5 Heat treatment type (Table 3).

4.1.6 Controlled structural characteristics (see 6.3),

TABLE 1 Chemical Composition Limits, %^A, for Low Alloy Steel

Grade	UNS Designation	Composition, %														
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Boron	Niobium ^E	Nitrogen	Aluminum	Tungsten	Other Elements
T2	K11547	0.10–0.20	0.30–0.61	0.025	0.025 ^B	0.10–0.30	...	0.50–0.81	0.44–0.65	...	...	...	...	...	...
T5	K41545	0.15	0.30–0.60	0.025	0.025	0.50	...	4.00–6.00	0.45–0.65	...	...	...	...	...	...
T5b	K51545	0.15	0.30–0.60	0.025	0.025	1.00–2.00	...	4.00–6.00	0.45–0.65	...	...	...	...	...	...
T5c	K41245	0.12	0.30–0.60	0.025	0.025	0.50	...	4.00–6.00	0.45–0.65	...	...	...	...	...	Ti 4xC–0.70
T9	K90941	0.15	0.30–0.60	0.025	0.025	0.25–1.00	...	8.00–10.00	0.90–1.10	...	...	...	...	...	...
T11	K11597	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...	...	...	...
T12	K11562	0.05–0.15	0.30–0.61	0.025	0.025 ^B	0.50	...	0.80–1.25	0.44–0.65	...	...	...	...	...	...
T17	K12047	0.15–0.25	0.30–0.61	0.025	0.025	0.15–0.35	...	0.80–1.25	...	0.15	...	...	...	...	...
T21	K31545	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	...	2.65–3.35	0.80–1.06	...	...	...	...	...	...
T22	K21590	0.05–0.15	0.30–0.60	0.025	0.025	0.50	...	1.90–2.60	0.87–1.13	...	...	...	...	...	...
T23	K40712	0.04–0.10	0.10–0.60	0.030	0.010	0.50	0.40	1.90–2.60	0.05–0.30	0.20–0.30	0.0010–0.006	0.02–0.08	0.015	0.030	1.45–1.75 Ti 0.005–0.060 Ti/N ≥ 3.5 ^C	
T24	K30736	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	...	2.20–2.60	0.90–1.10	0.20–0.30	0.0015–0.007	...	0.012	0.02	...	
T36	K21001	0.10–0.17	0.80–1.20	0.030	0.025	0.25–0.50	1.00–1.30	0.30	0.25–0.50	0.02	...	0.015–0.045	0.02	0.050	...	
T91 Type 1	K90901	0.07–0.14	0.30–0.60	0.020	0.010	0.20–0.50	0.40	8.0–9.5	0.85–1.05	0.18–0.25	...	0.06–0.10	0.030–0.070	0.02	...	
T91 Type 2 Heat	K90901	0.08–0.12	0.30–0.50 ^D	0.020 ^D	0.005 ^D	0.20–0.40 ^D	0.20 ^D	8.0–9.5 ^D	0.85–1.05	0.18–0.25	0.001 ^D	0.06–0.10	0.035–0.070 ^D	0.020 ^D	0.05 ^D	Ti 0.01 ^D Zr 0.01 ^D Cu 0.10 ^D
Product		0.07–0.13							0.80–1.05	0.16–0.27		0.05–0.11			Sb 0.003 ^D Sn 0.010 ^D As 0.010 ^D N/Al 4.0 min	
T92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50	0.40	8.5–9.5	0.30–0.60	0.15–0.25	0.001–0.006	0.04–0.09	0.030–0.070	0.02	1.5–2.00	Ti 0.01 Zr 0.01
T93	K91350	0.05–0.10	0.20–0.70	0.020	0.008	0.05–0.50	0.20	8.50–9.50	...	0.15–0.30	0.007–0.015	^F	0.005–0.015	0.030	2.5–3.5	Co 2.5–3.5 Nd 0.010–0.060 O 0.0050
T115 Heat	K91060	0.08–0.13	0.20–0.50	0.020	0.005	0.15–0.45	0.25	10.0–11.0	0.40–0.60	0.18–0.25	0.001	0.02–0.06	0.030–0.070	0.02	...	Ti 0.01 Zr 0.01 Cu 0.10 As 0.010 Sn 0.010 Sb 0.003 W 0.05 N/Al 4.0 min CNB ^G 10.5 max

TABLE 1 Continued

Grade	UNS Designation	Composition, %														
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Boron	Niobium ^E	Nitrogen	Aluminum	Tungsten	Other Elements
Product		0.07–0.14	0.20–0.50	0.020	0.005	0.15–0.45	0.25	10.0–11.0	0.37–0.63	0.16–0.27	0.001	0.02–0.07	0.030–0.070	0.02	...	Ti 0.01 Zr 0.01 Cu 0.10 As 0.010 Sn 0.010 Sb 0.003 W 0.05 Cu
T122	K91271	0.07–0.14	0.70	0.020	0.010	0.50	0.50	10.0–11.5	0.25–0.60	0.15–0.30	0.0005–0.005	0.04–0.10	0.040–0.100	0.02	1.50–2.50	0.30–1.70 Ti 0.01 Zr 0.01
T911	K91061	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40	8.5–9.5	0.90–1.10	0.18–0.25	0.0003–0.006	0.06–0.10	0.040–0.090	0.02	0.90–1.10	Ti 0.01 Zr 0.01

^A Maximum, unless range or minimum is indicated. Where ellipses (...) appear in this table, there is no requirement, and analysis for the element need not be determined or reported.

^B It is permissible to order T2 and T12 with a sulfur content of 0.045 max. See 16.3.

^C Alternatively, in lieu of this ratio minimum, the material shall have a minimum hardness of 275 HV in the hardened condition, defined as after austenitizing and cooling to room temperature but prior to tempering. Hardness testing shall be performed at mid-thickness of the product. Hardness test frequency shall be two samples of product per heat treatment lot and the hardness testing results shall be reported on the material test report.

^D Applies to both heat and product analyses.

^E The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

^F Grade T93 shall have a Nb + Ta content of 0.05–0.12 %.

^G Chromium-Nickel Balance is defined as $CNB = (Cr + 6Si + 4Mo + 1.5W + 11V + 5Nb + 9Ti + 12Al) - (40C + 30N + 4Ni + 2Mn + 1Cu)$.

TABLE 2 Chemical Composition Limits, %^A, for Austenitic and Ferritic Stainless Steel

Grade	UNS Designation	Composition											
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^B	Niobium ^N	Titanium	Other Elements
TP201	S20100	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...	...	...
TP202	S20200	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	0.25	...	...	...
XM-19 ^C	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	0.10–0.30	...	V 0.10–0.30
	S21500	0.06–0.15	5.5–7.0	0.045	0.030	0.20–1.00	14.0–16.0	9.0–11.0	0.80–1.20	...	0.75–1.25	...	B 0.003–0.009, V 0.15–0.40
TP304 ^C	S25700	0.02	2.00	0.025	0.010	6.5–8.0	8.0–11.5	22.0–25.0	0.50	...	...	...	...
	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...
TP304L	S30403	0.035 ^D	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	...	...	...	...
TP304H ^C	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...
	S30432	0.07–0.13	1.00	0.040	0.010	0.30	17.0–19.0	7.5–10.5	...	0.05–0.12	0.30–0.60	...	Al 0.003–0.030, B 0.001–0.010, Cu 2.5–3.5
TP304N ^C	S30434	0.07–0.14	2.00	0.040	0.010	1.00	17.5–19.5	9.0–12.0	...	...	0.10–0.40 ^E	0.10–0.25 ^F	B 0.001–0.004 Cu 2.50–3.50
	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...	...
TP304LN ^C	S30453	0.035 ^D	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...	...
	S30615	0.016–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	...	Al 0.8–1.5
TP309S ^C	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	...	...	Ce 0.03–0.08
	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...	...
TP309LMoN	S30925	0.025	2.00	0.040	0.030	0.70	23.0–26.0	13.0–16.0	0.5–1.2	0.25–0.40	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	10xC–1.10	...	...
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	10xC-1.10	...	...
TP309HCB ^C	S30942	0.03–0.10	2.00	0.040	0.030	1.00	21.0–23.0	14.5–16.5	...	0.10–0.20	0.50–0.80	...	B=0.001–0.005
	S31002	0.02	2.00	0.020	0.015	0.15	24.0–26.0	19.0–22.0	0.10	0.10	...	...	...
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...	...
TP310MoCbN	S31025	0.10	1.50	0.030	0.030	1.00	19.5–23.0	23.0–26.0	1.0–2.0	0.10–0.25	0.10–0.40	0.20	B 0.002–0.010
	S31035	0.04–0.10	0.60	0.025	0.015	0.40	21.5–23.5	23.5–26.5	...	0.20–0.30	0.40–0.60	...	W 3.0–4.0 Co 1.0–2.0 Cu 2.5–3.5 B 0.002–0.008
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	10xC-1.10	...	...
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	10xC-1.10	...	...
TP310HCbN	S31042	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	0.15–0.35	0.20–0.60	...	...
TP310MoLN ^C	S31050	0.025	2.00	0.020	0.030	0.40	24.0–26.0	21.0–23.0	2.00–3.00	0.10–0.16	...	...	...
	S31060	0.05–0.10	1.00	0.040	0.030	0.50	22.0–24.0	10.0–12.5	...	0.18–0.25	...	...	Ce + La 0.025–0.070 B 0.001–0.010
TP31254 ^C	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.22	...	...	Cu 0.50–1.00
TP31266 ^C	S31266	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	5.2–6.2	0.35–0.60	...	...	Cu 1.00–2.00 W 1.50–2.50

TABLE 2 Continued

Grade	UNS Designation	Composition											
		Carbon	Manga- nese	Phospho- rus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^B	Niobium ^N	Titanium	Other Elements
C	S31272	0.08–0.12	1.50–2.00	0.030	0.015	0.30–0.70	14.0–16.0	14.0–16.0	1.00–1.40	...	...	0.30–0.60	B 0.004–0.008
C	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	...	...	Cu 0.50–1.50
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
TP316L	S31603	0.035 ^D	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0	2.00–3.00	...	...	...	...
TP316Ti	S31635	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	5X (C + N)– 0.70	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...	...
TP316LN	S31653	0.035 ^D	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...	...
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...	...
TP317LM	S31725	0.03	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...	Cu 0.75
TP317LMN	S31726	0.03	2.00	0.045	0.030	1.00	17.0–20.0	13.5–17.5	4.0–5.0	0.10–0.20	...	...	Cu 0.75
C	S31730	0.030	2.00	0.040	0.010	1.00	17.0–19.0	15.0–16.5	3.0–4.0	0.045	...	...	Cu 4.0–5.0
C	S32050	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	...	...	Cu 0.40
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	5(C + N)– 0.70	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	4(C + N)– 0.70	...
C	S32615	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	...	...	...	Cu 1.50– 2.50
C	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	0.60–1.00	...	Ce 0.05– 0.10, Al 0.025
C	S34565	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	0.10	...	...
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–20.0	9.0–13.0	...	...	10xC–1.10	...	...
TP347W	S34705	0.05	2.00	0.040	0.030	1.00	17.0–20.0	8.00–11.0	...	0.10–0.25	0.25–0.50	...	V 0.20–0.50 W 1.50–2.60
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	8xC–1.10	...	...
TP347HFG	S34710	0.06–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	8xC–1.10	...	...
TP347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	0.06–0.10	0.20–0.50 ^F	...	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	^G	...	Co 0.20, Ta 0.10
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	^H	...	Co 0.20, Ta 0.10
...	S35045	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	...	0.15–0.60	Al 0.15–0.60 Cu 0.75
XM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...	...
...	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	...	...	...	Cu 0.75–1.50 Al 0.30
Alloy 20	N08020	0.070	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	2.00–3.00	...	^M	...	Cu 3.00–4.00
	N08028	0.030	2.50	0.030	0.030	1.0	26.0–28.0	30.0–34.0	3.0–4.0	...	...	...	Cu 0.6–1.4
	N08029	0.020	2.0	0.025	0.015	0.6	26.0–28.0	30.0–34.0	4.0–5.0	...	...	...	Cu 0.6–1.4
C	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.00–7.00	0.18–0.25	...	...	Cu 0.75
800	N08800	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	...	...	Cu 0.75 Al 0.15–0.60 Ti 0.15–0.60 Fe' 39.5 min

TABLE 2 Continued

Grade	UNS Designation	Composition											
		Carbon	Manga- nese	Phospho- rus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^B	Niobium ^N	Titanium	Other Elements
800H	N08810	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...			Cu 0.75 Al 0.15–0.60 Ti 0.15–0.60 Fe ^J 39.5 min
...	N08811	0.06–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...			Cu 0.75 Al 0.15–0.60 ^J Ti 0.15–0.60 ^J Fe ^J 39.5 min
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10			Cu 1.00–2.00
...	N08925	0.020	1.00	0.045	0.030	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.10–0.20	...	...	Cu 0.80–1.50
...	N08926	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.15–0.25	...	...	Cu 0.50–1.50
TP444	S44400	0.03	1.00	0.040	0.030	1.00	17.5–19.5	^K	1.75–2.50	0.035	...	^L	...

^AMaximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.

^BThe method of analysis for Nitrogen shall be a matter of agreement between the purchaser and the producer.

^CFor these alloys, there is no common grade designation. The UNS number uniquely identifies these alloys.

^DFor small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in Grades TP304L, TP304LN, TP316L, and TP316LN.

^EGrade S30434 shall have (Ti + ½ Nb) of not less than 2 times and not more than 4 times the carbon content.

^FGrade TP347LN shall have an Nb content of not less than 15 times the carbon content.

^GGrade TP348 shall have an Nb + Ta content of not less than 10 times the carbon content and not more than 1.10 %.

^HGrade TP348H shall have an Nb + Ta content of not less than 8 times the carbon content and not more than 1.10 %.

^IIron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

^JAl + Ti shall be 0.85 % min; 1.20 % max.

^KGrade TP444 shall have Ni + Cu = 1.00 max.

^LGrade TP444 shall have Ti + Nb content not less than 0.20 + 4(C+N) and not more than 0.80 %.

^MN08020 shall have an Nb + Ta content of not less than 8 times the carbon content and not more than 1.00%.

^NThe terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

TABLE 3 Heat Treatment and Grain Size Requirements^A

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning/ Stabilizing Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No. ^B
Ferritic Alloy Steels						
T2	K11547	full or isothermal anneal; or normalize and temper; or subcritical anneal	...	...	...	...
T5	K41545	full or isothermal anneal; or normalize and temper	...	...	1200 to 1350 [650 to 730]	...
T5b	K51545	full or isothermal anneal; or normalize and temper	...	...	1250 [675]	...
T5c	K41245	subcritical anneal	...	air or furnace	1350 [730] ^C	...
T9	S50400	full or isothermal anneal; or normalize and temper	...	...	1250 [675]	...
T11	K11597	full or isothermal anneal; or normalize and temper	...	...	1200 [650]	...
T12	K11562	full or isothermal anneal; or normalize and temper; or subcritical anneal	...	...	1200 to 1350 [650 to 730]	...
T17	K12047	full or isothermal anneal; or normalize and temper	...	...	1200 [650]	...
T21	K31545	full or isothermal anneal; or normalize and temper	...	...	1250 [675]	...
T22	K21590	full or isothermal anneal; or normalize and temper	...	...	1250 [675]	...
T23	K40712	normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800]	...
T24	K30736	normalize and temper	1800–1870 [980–1020]	<i>D</i>	1350–1420 [730–770]	...
T36	K21001	normalize and temper	1650 [900]	<i>E</i>	1100 [595]	...
T91 Types 1 and 2	K90901	normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800]	...
T92	K92460	normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800]	...
T93	K91350	normalize and temper	1960–2140 [1070–1170]	...	1380–1455 [750–790]	...
T115	K91060	normalize and temper	1920–2010 [1050–1100]	...	1380–1455 [750–790]	...
T122	K91261	normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800]	...
T911	K91061	normalize and temper	1900–1975 [1040–1080]	<i>D</i>	1365–1435 [740–780]	...
Austenitic Stainless Steels						
TP201	S20100	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP202	S20200	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
XM-19	S20910	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S21500	solution treatment	1900 [1040] ^{F,G}	water or other rapid cool	...	...
	S25700	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP304	S30400	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP304L	S30403	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP304H	S30409	solution treatment	1900 [1040]	water or other rapid cool	...	7
	S30432	solution treatment	2000 [1100] ^F	water or other rapid cool	...	...
	S30434	solution treatment	2120 [1160]	water or other rapid cool	...	...

TABLE 3 Continued

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning/ Stabilizing Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No. ^B
TP304N	S30451	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP304LN	S30453	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S30615	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP309S	S30815	solution treatment	1920 [1050]	water or other rapid cool	...	...
	S30908	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP309H	S30909	solution treatment	1900 [1040]	water or other rapid cool	...	7
TP309LMoN	S30925	solution treatment	1920 [1050]	water or other rapid cool	...	7
TP309Cb	S30940	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP309HCb	S30941	solution treatment	1900 [1040] ^H	water or other rapid cool	...	7
	S30942	solution treatment	2120 [1160]	water or other rapid cool	...	6
TP310S	S31002	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S31008	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP310H	S31009	solution treatment	1900 [1040]	water or other rapid cool	...	7
TP310MoCbN	S31025	solution treatment	2100 [1150]	water or other rapid cool	...	7
	S31035	solution treatment	2160–2280 [1180–1250]	water or other rapid cool	...	...
TP310Cb	S31040	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP310HCb	S31041	solution treatment	1900 [1040] ^H	water or other rapid cool	...	7
TP310HCbN	S31042	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	7
TP310MoLN	S31050	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S31060	solution treatment	1975–2160 [1080–1180] ^F	water or other rapid cool	...	7
TP316	S31254	solution treatment	2100 [1150]	water or other rapid cool	...	...
	S31266	solution treatment	2100 [1150]	water or other rapid cool	...	...
	S31272	solution treatment	1920 [1050]	water or other rapid cool	...	...
	S31277	solution treatment	2050 [1120] ^F	water or other rapid cool	...	...
TP316L	S31600	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP316H	S31603	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP316Ti	S31609	solution treatment	1900 [1040]	water or other rapid cool	...	7
TP316N	S31635	solution treatment	1900 [1040]	water or other rapid cool	...	...
TP316LN	S31651	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP317	S31653	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP317L	S31700	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S31703	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP321	S31725	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S31730	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP321H	S32050	solution treatment	2100 [1150] ^F	water or other rapid cool	...	...
	S32100	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP321H	S32109	solution treatment	cold worked: 2000 [1090] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
	S32615	solution treatment	1900 [1040] ^F	water or other rapid cool	...	3 or finer
	S32716	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S33228	solution treatment	2050 [1120]	water or other rapid cool	...	...
	S34565	solution treatment	2050–2140 [1120–1170]	water or other rapid cool	...	...
TP347	S34700	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP347W	S34705	solution treatment	2000 [1100]	water or other rapid cool	...	7-10
TP347H	S34709	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
	S34710	solution treatment, ^I	2150 [1175] ^F	water or other rapid cool	...	7-10
TP347LN	S34751	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP348	S34800	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP348H	S34809	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
	S35045	solution treatment	2000 [1100] ^F	still air cool or faster	...	...
XM-15	S38100	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	S38815	solution treatment	1950 [1065] ^F	water or other rapid cool	...	...
Alloy 20	N08020	stabilization treatment	1700-1850 ^F [925- 1010]	water or other rapid cool	...	...
	N08028	solution treatment	2000 ^F [1100]	water or other rapid cool	...	...
800	N08029	solution treatment	2000 ^F [1100]	water or other rapid cool	...	...
	N08367	solution treatment	2025 [1105] ^F	water or other rapid cool	...	...
800H	N08800	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
	N08810	solution treatment	2050 [1120] ^F	water or other rapid cool	...	5
	N08811	solution treatment	2100 [1150] ^F	water or other rapid cool	...	5

TABLE 3 *Continued*

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning/ Stabilizing Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No. ^B
	N08904	solution treatment	2000 [1100] ^F	water or other rapid cool	...	...
	N08925	solution treatment	2010–2100 [1100–1150]	water or other rapid cool	...	...
	N08926	solution treatment	2010–2100 [1100–1150]	water or other rapid cool	...	...
Ferritic Stainless Steels						
TP444	S44400	subcritical anneal	...	...	1400 [760]	...

^A Where ellipses (...) appear in this table there is no requirement.

^B ASTM Grain Size No. listed, or coarser, unless otherwise indicated.

^C Approximately, to achieve properties.

^D Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

^E Accelerated air cooling or liquid quenching shall be permitted for Class 2.

^F Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of tubes, heat treated by either separate solution annealing or by direct quenching, passing Practices A262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S4). Note that Practices A262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.

^G A maximum solution treating temperature of 2100 °F [1150 °C] is recommended for UNS S21500.

^H A solution treating temperature above 1950 °F [1065 °C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the indicated grades. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table.

^I Solution treatment shall be preceded by a softening heat treatment prior to cold-working. The softening temperature shall be at least 90 °F [50 °C] higher than the solution heat treatment temperature, which shall be at 2150 °F [1180 °C] minimum.

4.1.7 Size (outside diameter and minimum wall thickness, unless average wall thickness is specified),

4.1.8 Length (specific or random),

4.1.9 Hydrostatic Test or Nondestructive Electric Test (see 10.1),

4.1.10 Specification designation and year of issue,

4.1.11 Increased sulfur (for machinability, see Note B, Table 1, and 16.3), and

4.1.12 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A1016/A1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A1016/A1016M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A1016/A1016M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Manufacture and Condition*—Tubes shall be made by the seamless process and shall be either hot finished or cold finished, as specified. Grade TP347HFG shall be cold finished.

6.2 Heat Treatment:

6.2.1 *Ferritic Alloy and Ferritic Stainless Steels*—The ferritic alloy and ferritic stainless steels shall be reheated for heat treatment in accordance with the requirements of Table 3. Heat treatment shall be carried out separately and in addition to heating for hot forming.

6.2.2 *Austenitic Stainless Steels*—All austenitic tubes shall be furnished in the heat-treated condition, and shall be heat treated in accordance with the requirements of Table 3.

Other than for Grades S30815, S30942, S31272, S33228, S30432, and H grades, seamless tubing immediately following hot forming may be individually quenched in the water or rapidly cooled by other means, provided that the temperature of the tubes after hot forming is not less than the minimum specified solution temperature (direct quenched). For H grades, as well as Grades S30815, S30942, S31272, S33228, and S30432, the tubes shall be reheated to the specified solution treatment temperature for the required time before quenching.

6.3 If any controlled structural characteristics are required, these shall be so specified in the order as to be a guide as to the most suitable heat treatment.

7. Chemical Composition

7.1 Composition Requirements:

7.1.1 The alloy steels shall conform to the chemical requirements given in Table 1.

7.1.2 The stainless steels shall conform to the chemical requirements given in Table 2.

7.2 Product Analysis:

7.2.1 An analysis of either one billet or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

8. Grain Size

8.1 Grain size shall be as given in Table 3, as determined in accordance with Test Methods E112.

8.2 Grain size determinations, to demonstrate compliance with 8.1, shall be made on one end of one finished tube from each lot. See 15.1.

9. Mechanical Properties

9.1 Tensile Requirements:

9.1.1 The material shall conform to the requirements as to tensile properties given in Table 4.

9.1.2 Table 5 gives the computed minimum elongation values for each $\frac{1}{32}$ -in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown in Table 5, the minimum elongation value shall be determined by the following equations. For Grades T23, T24, T91, T92, T115, T122, T911, and S44400: $E = 32t + 10.00$ [$E = 1.25t + 10.00$]. For Grade T36: $E = 32t + 5.0$ [$E = 1.25t + 5.0$]. For grade T93: $E = 32t + 9.00$ [$E = 1.25t + 9.00$]. For all other ferritic alloy grades: $E = 48t + 15.00$ [$E = 1.87t + 15.00$].

where:

E = elongation in 2 in. [50 mm], %, and
 t = actual thickness of specimen, in. [mm].

9.1.3 One tension test shall be made on a specimen from one tube for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes. See 15.2.

9.2 Hardness Requirements:

9.2.1 The material shall conform to the hardness requirements given in Table 4. See 15.2.

9.2.2 Brinell, Vickers, or Rockwell hardness tests shall be made on specimens from two tubes from each lot. See 15.2.

9.3 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot. See 15.1.

9.4 *Flaring Test*—One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot. See 15.1.

9.5 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or thinner than 0.015 in. [0.4 mm] in thickness.

10. Hydrostatic or Nondestructive Electric Test

10.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

11. Forming Operations

11.1 Tubes, when inserted in a boiler or tube sheet, shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. See Note 1.

NOTE 1—Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly chromium-containing steels with chromium of 4% and higher. Therefore, operations that involve

heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

12. Repair by Welding

12.1 Repair welding shall be performed in conformance with Specification A1016/A1016M.

12.2 All repair welds in T91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair T91 Types 1 and 2 shall not exceed 1.0%.

12.3 All repair welds in T92, T93, T911, and T122, shall be made using welding consumables meeting the chemical requirements for the grade in Table 1.

13. Permissible Variations from the Specified Wall Thickness

13.1 Permissible variations from the specified minimum wall thickness shall be in accordance with Specification A1016/A1016M.

13.2 Permissible variations from the specified average wall thickness shall be $\pm 10\%$ of the specified average wall thickness for cold formed tubes and, unless otherwise specified by the purchaser, shall be in accordance with Table 6 for hot formed tubes.

14. Surface Condition

14.1 Ferritic alloy cold-finished steel tubes shall be free of scale and suitable for inspection. A slight amount of oxidation is not considered scale.

14.2 Ferritic alloy hot-finished steel tubes shall be free of loose scale and suitable for inspection.

14.3 Stainless steel tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

14.4 Any special finish requirement shall be subject to agreement between the supplier and the purchaser.

15. Sampling

15.1 For flattening, flaring, and grain size requirements, the term lot applies to all tubes, prior to cutting, of the same size (see 4.1.7) that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace or when the heat-treated condition is obtained directly by quenching after hot forming, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 7.

15.2 For tensile and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same size (see 4.1.7) that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat

TABLE 4 Tensile and Hardness Requirements

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, % ^{B,C}	Hardness ^A	
					Brinell/Vickers	Rockwell
<i>Low Alloy Steels:</i>						
T5b	K51545	60 [415]	30 [205]	30	179 HBW/ 190HV	89 HRB
T9	K90941	60 [415]	30 [205]	30	179 HBW/ 190HV	89 HRB
T12	K11562	60 [415]	32 [220]	30	163 HBW/ 170 HV	85 HRB
T23	K40712	74 [510]	58 [400]	20	220 HBW/ 230 HV	97 HRB
T24	K30736	85 [585]	60 [415]	20	250 HBW/ 265 HV	25 HRC
T36 Class 1	K21001	90 [620]	64 [440]	15	250 HBW/ 265 HV	25 HRC
T36 Class 2	K21001	95.5 [660]	66.5 [460]	15	250 HBW/ 265 HV	25 HRC
T91 Types 1 and 2	K90901	85 [585]	60 [415]	20	190 to 250 HBW/ 196 to 265 HV	90 HRB to 25 HRC
T92	K92460	90 [620]	64 [440]	20	250 HBW/ 265 HV	25 HRC
T93	K91350	90 [620]	64 [440]	19	250 HBW/ 265 HV	25 HRC
T115	K91060	90 [620]	65 [450]	20	190 to 250 HBW/ 196 to 265 HV	90 HRB to 25 HRC
T122	K91271	90 [620]	58 [400]	20	250 HBW/ 265 HV	25 HRC
T911	K91061	90 [620]	64 [440]	20	250 HBW/ 265 HV	25 HRC
All other low alloy grades		60 [415]	30 [205]	30	163 HBW/ 170 HV	85 HRB
<i>Austenitic Stainless Steels:</i>						
TP201	S20100	95 [655]	38 [260]	35	219 HBW/ 230 HV	95 HRB
TP202	S20200	90 [620]	45 [310]	35	219 HBW/ 230 HV	95 HRB
XM-19	S20910	100 [690]	55 [380]	35	250 HBW/ 265 HV	25 HRC
...	S21500	78 [540]	33 [230]	35	192 HBW/ 200 HV	90 HRB
...	S25700	78 [540]	35 [240]	50	217 HBW	95 HRB
TP304	S30400	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP304L	S30403	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
TP304H	S30409	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S30432	86 [590]	34 [235]	35	219 HBW/ 230 HV	95 HRB
...	S30434	73 [500]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP304N	S30451	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
TP304LN	S30453	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S30615	90 [620]	40 [275]	35	192 HBW/ 200 HV	90 HRB
...	S30815	87 [600]	45 [310]	40	217 HBW	95 HRB
TP309S	S30908	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP309H	S30909	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP309LMoN	S30925	93 [640]	38 [260]	30	256 HBW/270 HV	100 HRB
TP309Cb	S30940	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP309HCb	S30941	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S30942	86 [590]	34 [235]	35	219 HBW/ 230 HV	95 HRB

TABLE 4 Continued

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, % ^{B,C}	Hardness ^A	
					Brinell/Vickers	Rockwell
...	S31002	73 [500]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310S	S31008	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310H	S31009	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310MoCbN	S31025	93 [640]	39 [270]	30	256 HBW/ 270 HV	100 HRB
	S31035	95 [655]	45 [310]	40	220 HBW/ 230 HV	96 HRB
TP310Cb	S31040	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310HCb	S31041	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310HCbN	S31042	95 [655]	43 [295]	30	256 HBW	100 HRB
TP310MoLN	S31050					
T ≤ 0.25 in. [6 mm]		84 [580]	39 [270]	25	217 HBW	95 HRB
t > 0.25 in. [6 mm]		78 [540]	37 [255]	25	217 HBW	95 HRB
...	S31060	87 [600]	41 [280]	40	217 HBW	95 HRB
...	S31254					
T ≤ 0.187 in. [5 mm]		98 [675]	45 [310]	35	220 HBW/ 230 HV	96 HRB
T > 0.187 in. [5 mm]		95 [655]	45 [310]	35	220 HBW/ 230 HV	96 HRB
...	S31266	109 [750]	61 [420]	35	...	B100
...	S31272	65 [450]	29 [200]	35	217 HBW	95 HRB
...	S31277	112 [770]	52 [360]	40	241 HBW	100 HRB
TP316	S31600	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316L	S31603	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
TP316H	S31609	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316Ti	S31635	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316N	S31651	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
TP317	S31700	75 [515]	30 [205]	34	192 HBW/ 200 HV	90 HRB
TP317L	S31703	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S31725	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S31730	70 [480]	25 [175]	35	...	90 HRB
...	S32050	98 [675]	48 [330]	40	256 HBW	100 HRB
TP321	S32100	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP321H	S32109	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S32615	80 [550]	32 [220]	25	192 HBW/ 200 HV	90 HRB
...	S32716	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
...	S33228	73 [500]	27 [185]	30	192 HBW/ 200 HV	90 HRB
...	S34565	115 [790]	60 [415]	35	241 HBW	100 HRB
TP347	S34700	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347W	S34705	90 [620]	38 [260]	30	219 HBW/ 230 HV	95 HRB
TP347H	S34709	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347HFG	S34710	80 [550]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347LN	S34751	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP348	S34800	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP348H	S34809	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB

TABLE 4 Continued

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, % ^{B,C}	Hardness ^A	
					Brinell/Vickers	Rockwell
...	S35045	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
XM-15	S38100	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S38815	78 [540]	37 [255]	30	256 HBW	100 HRB
Alloy 20	N08020	80 [550]	35 [240]	30	217 HBW	95 HRB
	N08028	73 [500]	31 [214]	40	...	...
	N08029	73 [500]	31 [214]	40	...	...
...	N08367	...	...	...	...	...
...	≤3/16 in. wall	100 [690]	45 [310]	30	...	100 HRB
...	>3/16 in. wall	95 [655]	45 [310]	30	241 HBW	...
800	N08800	...	...	...	...	...
...	cold-worked annealed	75 [515]	30 [205]	30	192 HBW/ 200 HV	90 HRB
...	hot-finished annealed	65 [450]	25 [170]	30	192 HBW/ 200 HV	90 HRB
800H	N08810	65 [450]	25 [170]	30	192 HBW/ 200 HV	90 HRB
...	N08811	65 [450]	25 [170]	30	192 HBW/ 200 HV	90 HRB
...	N08904	71 [490]	31 [215]	35	192 HBW/ 200 HV	90 HRB
...	N08925	87 [600]	43 [295]	40	217 HBW	95 HRB
...	N08926	94 [650]	43 [295]	35	256 HBW	100 HRB
Ferritic Stainless Steels						
TP444	S44400	60[415]	40[275]	20	217 HBW/ 230 HV	96 HRB

^AMax, unless a range or a minimum is specified.

^BWhen standard round 2 in. or 50 mm gauge length or smaller proportionally sized specimens with gauge length equal to 4D (4 times the diameter) is used, the minimum elongation shall be 22 % for all low alloy grades except T23, T24, T91, T92, T93, T115, T122, and T911; and except for TP444.

^CFor longitudinal strip tests, a deduction from the basic minimum elongation values of 1.00 % for TP444, T23, T24, T91, T92, T93, T115, T122, and T911, and of 1.50 % for all other low alloy grades for each 1/32-in. [0.8-mm] decrease in wall thickness below 5/16 in. [8 mm] shall be made.

TABLE 5 Computed Minimum Values^A

Wall Thickness		Elongation in 2 in. or 50 mm, min, %			
in.	mm	S44400, T23, T24, T91 Types 1 and 2, T92, T115, T122, and T911	T93	T 36	All Other Ferritic Grades
5/16 [0.312]	8	20	19	15	30
9/32 [0.281]	7.2	19	18	14	29
1/4 [0.250]	6.4	18	17	13	27
7/32 [0.219]	5.6	17	16	12	26
3/16 [0.188]	4.8	16	15	11	24
5/32 [0.156]	4	15	14	10	23
1/8 [0.125]	3.2	14	13	9	21
3/32 [0.094]	2.4	13	12	8	20
1/16 [0.062]	1.6	12	11	7	18
0.062 to 0.035, excl	1.6 to 0.9	12	11	7	17
0.035 to 0.022, excl	0.9 to 0.6	11	10	6	17
0.022 to 0.015 incl	0.6 to 0.4	11	10	6	16

^ACalculated elongation requirements shall be rounded to the nearest whole number.

treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when the heat-treated condition is obtained directly by quenching after hot forming, a lot shall include all tubes of the same size and heat, heat

treated in the same furnace at the same temperature, time at heat, and furnace speed; or all tubes of the same size and heat, hot formed and quenched in the same production run, except as prescribed in 9.1.3.

TABLE 6 Permitted Variations in Average Wall Thickness for Hot Formed Tubes

NPS [DN] Designator	Tolerance in %, from specified	
	Over	Under
1/8 to 2 1/2 [6 to 65] incl, all t/D ratios ^A	20	12.5
Above 2 1/2 [65], t/D ≤ 5 % ^A	22.5	12.5
Above 2 1/2 [65], t/D > 5 % ^A	15	12.5

^A t = specified wall thickness D = specified outside diameter

TABLE 7 Number of Tubes in a Lot Heat Treated by the Continuous Process or by Direct Quench After Hot Forming

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

16. Product Marking

16.1 In addition to the marking prescribed in Specification A1016/A1016M, the marking shall include: the condition, hot finished or cold finished; and the wall designation, minimum wall or average wall.

16.2 For the austenitic stainless steels having a grain size requirement (see Table 3) the marking shall also include the heat number and heat-treatment lot identification.

16.3 When either T2 or T12 are ordered with higher sulfur contents as permitted by Note B of Table 1, the marking shall include the letter, S, following the grade designation: T2S or T12S.

16.4 For T91, the marking shall also include the type.

17. Keywords

17.1 alloy steel tubes; austenitic stainless steel; boiler tubes; ferritic stainless steel; heat exchanger tubes; high-temperature applications; seamless steel tubes; steel tubes; superheater tubes; temperature service applications-high

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1500 to 1650 °F [815 to 900 °C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and supplier.

S2. Stabilizing Heat Treatment

S2.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP310HCbN, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S3. Unstraightened Tubes

S3.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the minimum yield strength of Table 4 shall be reduced by 5 ksi [35 MPa].

S3.2 On the certification, and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter “U” (for example, 304-U, 321-U, etc.).

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

NOTE S4.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S2 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL HEAT-EXCHANGER AND CONDENSER TUBES



SA-214/SA-214M

(Identical with ASTM Specification A214/A214M-90a except for editorial differences in 7.2.)

SPECIFICATION FOR ELECTRIC-RESISTANCE- WELDED CARBON STEEL HEAT-EXCHANGER AND CONDENSER TUBES



SA-214/SA-214M

(Identical with ASTM Specification A 214/A 214M-90a except for editorial differences in 7.2.)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded, carbon steel tubes to be used for heat exchangers, condensers, and similar heat-transfer apparatus.

1.2 The tubing sizes usually furnished to this specification are to 3 in. [76.2 mm] in outside diameter, inclusive. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 The purchaser shall specify in the order the outside diameter and minimum wall thickness. The inside diameter shall not be specified.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (electric-resistance-welded tubes),

4.1.3 Size (outside diameter and minimum wall thickness),

4.1.4 Length (specific or random),

4.1.5 Optional requirements (Section 8 and 10.5),

4.1.6 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.7 Specification designation, and

4.1.8 Special requirements.

5. Manufacture

5.1 Tubes shall be made by electric-resistance welding.

6. Heat Treatment

6.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace. Cold drawn tubes shall be heat treated

after the final cold-draw pass at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, max, %	0.18
Manganese, %	0.27–0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 250 pieces; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 72 HRB.

10. Mechanical Tests Required

10.1 *Flattening Test* — One flattening test shall be made on specimens from each of two tubes from each lot (Note) or fraction thereof.

10.2 *Flange Test* — One flange test shall be made on specimens from each of two tubes from each lot (Note) or fraction thereof.

10.3 *Reverse Flattening Test* — One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

10.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.5 *Hydrostatic or Nondestructive Electric Test* — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

11. Surface Condition

11.1 The finished tubes shall be free of scale. A slight amount of oxidation shall not be considered as scale.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

12.2 The manufacturer’s name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

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**SPECIFICATION FOR STEEL CASTINGS, CARBON,
SUITABLE FOR FUSION WELDING FOR
HIGH-TEMPERATURE SERVICE**



SA-216/SA-216M

(Identical with ASTM Specification A216/A216M-07 except for the addition of 2.3 and editorial differences in 2.1 and 10.1.)

SPECIFICATION FOR STEEL CASTINGS, CARBON, SUITABLE FOR FUSION WELDING FOR HIGH-TEMPERATURE SERVICE



SA-216/SA-216M

(Identical with ASTM Specification A 216/A 216M-07 except for the addition of 2.3 and editorial differences in 2.1 and 10.1.)

1. Scope

1.1 This specification covers carbon steel castings for valves, flanges, fittings, or other pressure-containing parts for high-temperature service and of quality suitable for assembly with other castings or wrought-steel parts by fusion welding.

1.2 Three grades, WCA, WCB, and WCC, are covered in this specification. Selection will depend upon design and service conditions, mechanical properties, and the high temperature characteristics.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A 985/A 985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts

E 165 Test Method for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP 55 Steel Castings for Valve, Flanges, and Fittings, and Other Components (Visual Method)

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications

3. General Conditions for Delivery

3.1 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 Steel investment castings furnished to this specification shall conform to the requirements of Specification A 985/A 985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 985/A 985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 985/A 985M, Specification A 985/A 985M shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification,

4.1.4 Whether the castings are to be produced using the investment casting process, and

4.1.5 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the annealed, or normalized, or normalized and tempered condition unless Supplementary Requirement S15 is specified.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometer.

7. Chemical Composition

7.1 The steel shall be in accordance with the requirements as to chemical composition prescribed in Table 1.

8. Tensile Requirements

8.1 Steel used for the castings shall be in accordance with the requirements as to tensile properties prescribed in Table 2.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under ASME Section IX.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²], shall be radiographed to the same standards that are used to inspect the castings.

10.3 Castings containing any repair weld that exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.² [65 cm²] in area, or that was made to correct hydrostatic test defects, shall be stress relieved or heat treated after welding. This mandatory stress relief or heat treatment shall be in accordance with the procedure qualification used.

11. Keywords

11.1 carbon steel; high temperature; pressure-containing parts; steel castings

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade WCA UNS J02502	Grade WCB UNS J03002	Grade WCC UNS J02503
Carbon, max	0.25 ^A	0.30 ^B	0.25 ^C
Manganese, max	0.70 ^A	1.00 ^B	1.20 ^C
Phosphorus, max	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045
Silicon, max	0.60	0.60	0.60
Specified residual elements:			
Copper, max	0.30	0.30	0.30
Nickel, max	0.50	0.50	0.50
Chromium, max	0.50	0.50	0.50
Molybdenum, max	0.20	0.20	0.20
Vanadium, max	0.03	0.03	0.03
Total of these specified residual elements, max ^D	1.00	1.00	1.00

^A For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10%.

^B For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% Mn above the specified maximum will be permitted up to a maximum of 1.28%.

^C For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted to a maximum of 1.40%.

^D Not applicable when Supplementary Requirement S11 is specified.

TABLE 2
TENSILE REQUIREMENTS

	Grade WCA	Grade WCB	Grade WCC
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]
Yield strength, ^A min, ksi [MPa]	30 [205]	36 [250]	40 [275]
Elongation in 2 in. [50 mm], min, % ^B	24	22	22
Reduction of area, min, %	35	35	35

^A Determine by either 0.2% offset method or 0.5% extension-under-load method.

^B When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements		<u>CE maximum</u>
S2. Destruction Tests	Maximum specified section thickness less than or equal to 1 in. [25 mm]	0.43
S3. Bend Test	Maximum specified section thickness greater than 1 in. [25 mm]	0.45

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Guide E 709 or Test Method E 165.

S11. Carbon Equivalent

S11.1 When specified on the order, the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
WCA	0.50
WCB	0.50
WCC	0.55

S11.2 Carbon equivalent (*CE*) shall be determined as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S15. Quench and Temper Heat-Treatment

S16. Requirements for Carbon Steel Castings for Hydrofluoric Acid Alkylation Service

S16.1 Castings shall be provided in the normalized or normalized and tempered heat-treated condition.

S16.2 The maximum carbon equivalent shall be as follows:

Maximum specified section thickness less than or equal to 1 in. [25 mm]

Maximum specified section thickness greater than 1 in. [25 mm]

S16.3 Determine the carbon equivalent (*CE*) as follows:

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

S16.4 Vanadium and niobium maximum content based upon heat analysis shall be:

NOTE 1 — Niobium = columbium

Maximum vanadium	0.02 wt%
Maximum niobium	0.02 wt%
Maximum vanadium plus niobium	0.03 wt%

S16.5 The sum of the nickel and copper contents, based upon heat analysis, shall not exceed 0.15 wt%.

S16.6 The minimum carbon content shall be 0.18 wt%. The maximum carbon content shall be as required for the appropriate grade.

S16.7 Welding consumables for repair welds shall be of the low-hydrogen type. E60XX electrodes shall not be used and the resulting weld chemistry shall meet the same chemistry requirements as the base metal.

S16.8 In addition to the requirements for product marking in the specification, an “HF-N” stamp or marking shall be provided on each casting to identify that the casting complies with this supplementary requirement.

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SPECIFICATION FOR STEEL CASTINGS, MARTENSITIC STAINLESS AND ALLOY, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR HIGH-TEMPERATURE SERVICE



SA-217/SA-217M



(Identical with ASTM Specification A217/A217M-07.)

SPECIFICATION FOR STEEL CASTINGS, MARTENSITIC STAINLESS AND ALLOY, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR HIGH-TEMPERATURE SERVICE



SA-217/SA-217M



(Identical with ASTM Specification A 217/A 217M-07.)

1. Scope

1.1 This specification covers martensitic stainless steel and alloy steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1) intended primarily for high-temperature and corrosive service (Note 2).

1.2 One grade of martensitic stainless steel and nine grades of ferritic alloy steel are covered. Selection will depend on design and service conditions, mechanical properties, and the high-temperature and corrosion-resistant characteristics (Note 3).

NOTE 1 — Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M. Low alloy quench-and-tempered grades equivalent to Specification A 217/A 217M grades may be found in both Specifications A 352/A 352M and A 487/A 487M.

NOTE 2 — The grades covered by this specification represent materials that are generally suitable for assembly with other castings or wrought steel parts by fusion welding. It is not intended to imply that these grades possess equal degrees of weldability; therefore, it is the responsibility of the purchaser to establish for himself a suitable welding technique. Since these grades possess varying degrees of suitability for high-temperature and corrosion-resistant service, it is also the responsibility of the purchaser to determine which grade shall be furnished, due consideration being given to the requirements of the applicable construction codes.

NOTE 3 — The committee formulating this specification has included nine grades of materials that are considered to represent basic types of ferritic alloy steels suitable for valves, flanges, fittings, and other pressure-containing parts. Additional alloy steels that may better fulfill certain types of service will be considered for inclusion in this specification by the committee as the need becomes apparent.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining

values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 217 and SI units for materials ordered to Specification A 217M.

2. Referenced Documents

2.1 ASTM Standards:

- A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
- A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
- A 487/A 487M Specification for Steel Castings Suitable for Pressure Service
- A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
- A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
- A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
- A 985/A 985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts
- E 165 Test Method for Liquid Penetrant Examination
- E 709 Guide for Magnetic Particle Examination

3. General Conditions for Delivery

3.1 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification A 703/A 703M including any supplementary

requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 Steel investment castings furnished to this specification shall conform to the requirements of Specification A 985/A 985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 985/A 985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 985/A 985M, Specification A 985/A 985M shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification,

4.1.4 Whether the castings are to be produced using the investment casting process, and

4.1.5 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the normalized and tempered conditions; Grades WC1, WC4, WC5, WC6, and CA15 shall be tempered at 1100°F [595°C] min; Grades WC9, C5, C12, and WC11 shall be tempered at 1250°F [675°C] min; Grade C12A shall be normalized at 1900–1975°F [1040–1080°C] and tempered at 1350–1470°F [730–800°C].

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Chemical Composition

6.1 The steel shall be in accordance with the requirements as to chemical composition prescribed in Table 1 (Note 4).

NOTE 4 — The role of alloying elements in the development of Grade C12A has been extensively investigated. V and Cb contribute to precipitation strengthening by forming fine and coherent precipitation of M(C,N)X

carbo-nitrides in the ferrite matrix. V also precipitates as VN during tempering or during creep. The two elements are more effective in combination. Therefore, the addition of strong nitride-forming elements, those with a stronger affinity for nitrogen than Cb and V, as deoxidation agents, interferes with these high-temperature strengthening mechanisms.

7. Tensile Requirements

7.1 Steel used for the castings shall be in accordance with the requirements as to tensile properties prescribed in Table 2.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 3.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

9.2 Weld repaired Grade C12A castings shall be post-weld heat treated at 1350–1470°F [730–800°C].

9.3 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²], shall be radiographed to the same standards that are used to inspect the castings.

9.4 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test, or when

the depth of the cavity prepared for welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.² [65 cm²]. All castings with major repair welds shall be thermally stress relieved or completely reheat-treated. This mandatory stress relief or reheat-treatment shall be in accordance with the qualified procedure used. Major

repairs shall be inspected to the same quality standards that are used to inspect the castings.

10. Keywords

10.1 alloy steel; high temperature; martensitic stainless steel; pressure containing; steel castings

TABLE 1
CHEMICAL REQUIREMENTS

Grade Identification Symbol UNS Number	Composition, %										
	Carbon Molybdenum	Nickel Chromium Molybdenum	Nickel Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum Vanadium	Chromium
	WC1 J12524	WC4 J12082	WC5 J22000	WC6 J12072	WC9 J21890	WC11 J11872	C5 J42045	C12 J82090	C12A J84090	CA15 J91150	
Carbon	0.25	0.05–0.20	0.05–0.20	0.05–0.20	0.05–0.18	0.15–0.21	0.20	0.20	0.08–0.12	0.15	
Manganese	0.50–0.80	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.35–0.65	0.30–0.60	1.00	
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.020	0.04	0.04	0.030	0.040	
Sulfur	0.045	0.045	0.045	0.045	0.045	0.015	0.045	0.045	0.010	0.040	
Silicon	0.60	0.60	0.60	0.60	0.60	0.30–0.60	0.75	1.00	0.20–0.50	1.50	
Nickel	...	0.70–1.10	0.60–1.00	...	...	...	...	...	0.40	1.00
Chromium	...	0.50–0.80	0.50–0.90	1.00–1.50	2.00–2.75	1.00–1.50	4.00–6.50	8.00–10.00	8.0–9.5	11.5–14.0	
Molybdenum	0.45–0.65	0.45–0.65	0.90–1.20	0.45–0.65	0.90–1.20	0.45–0.65	0.45–0.65	0.90–1.20	0.85–1.05	0.50	
Columbium	...	...	...	...	...	...	...	...	0.060–0.10	...
Nitrogen	...	...	...	...	...	...	...	...	0.030–0.070	...
Vanadium	...	...	...	...	...	...	...	...	0.18–0.25	...
Specified Residual Elements											
Aluminum	...	...	...	...	...	0.01	...	...	0.02	...
Copper	0.50	0.50	0.50	0.50	0.50	0.35	0.50	0.50	...	...
Nickel	0.50	...	...	0.50	0.50	0.50	0.50	0.50	...	...
Chromium	0.35	...	...	...	...	...	...	...	...	...
Titanium	...	...	...	...	...	...	...	...	0.01	...
Tungsten	0.10	0.10	0.10	0.10	0.10	...	0.10	0.10	...	...
Vanadium	...	...	...	...	...	0.03	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	0.01	...
Total content of these residual elements	1.00	0.60	0.60	1.00	1.00	1.00	1.00	1.00			

NOTE — All values are maximum unless otherwise indicated.

TABLE 2
TENSILE REQUIREMENTS

Grade	Tensile Strength, ksi [MPa]	Yield Strength, ^A min, ksi [MPa]	Elongation in 2 in. [50 mm], min, % ^B	Reduction of Area, min, %
WC1	65 [450] to 90 [620]	35 [240]	24	35
WC4, WC5, WC6, WC9	70 [485] to 95 [655]	40 [275]	20	35
WC11	80 [550] to 105 [725]	50 [345]	18	45
C5, C12	90 [620] to 115 [795]	60 [415]	18	35
C12A	85 [585] to 110 [760]	60 [415]	18	45
CA15	90 [620] to 115 [795]	65 [450]	18	30

^A Determine by either 0.2% offset method or 0.5% extension-under-load method.

^B When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

TABLE 3
MINIMUM PREHEAT TEMPERATURES

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
WC1	$\frac{5}{8}$ and under	50 [10]
	Over $\frac{5}{8}$ [15.9]	250 [120]
WC4	All	300 [150]
WC5	All	300 [150]
WC6	All	300 [150]
WC9	All	400 [200]
WC11	All	300 [150]
C5	All	400 [200]
C12	All	400 [200]
C12A	All	400 [200]
CA15	All	400 [200]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements**S2. Destruction Tests****S3. Bend Tests****S4. Magnetic Particle Inspection****S5. Radiographic Inspection****S10. Examination of Weld Preparation**

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Test Method E 165 or Guide E 709.

S13. Hardness Test**S21. Heat Treatment Furnace Record****S22. Heat Treatment****S51. Mandatory Postweld Heat Treatment**

S51.1 All castings with repair welds shall receive a mandatory thermal stress relief or complete reheat treatment in accordance with the qualified procedure after all weld repairs.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MANGANESE-VANADIUM-NICKEL



SA-225/SA-225M



(Identical with ASTM Specification A225/A225M-17.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium- Nickel

1. Scope

1.1 This specification covers manganese-vanadium-nickel alloy steel plates intended primarily for welded layered pressure vessels.

1.2 Plates under this specification are available in two grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
C	105–135 [725–930]
D	
3 in. [75 mm] and under	80–105 [550–725]
Over 3 in. [75 mm]	75–100 [515–690]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels
 A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
 A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
 A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

TABLE 1 Chemical Requirements

Elements	Composition, %	
	Grade C	Grade D
Carbon, max ^A	0.25	0.20
Manganese, max:		
Heat analysis	1.60	1.70
Product analysis	1.72	1.84
Phosphorus, max ^A	0.025	0.025
Sulfur, max ^A	0.025	0.025
Silicon:		
Heat analysis	0.15–0.40	0.10–0.50
Product analysis	0.13–0.45	0.08–0.56
Vanadium:		
Heat analysis	0.13–0.18	0.10–0.18
Product analysis	0.11–0.20	0.08–0.20
Nickel:		
Heat analysis	0.40–0.70	0.40–0.70
Product analysis	0.37–0.73	0.37–0.73

^A Applies to both heat and product analyses.

TABLE 2 Tensile Requirements

	Grade C		Grade D	
	ksi	[MPa]	ksi	[MPa]
Tensile strength:				
All thicknesses	105–135	[725–930]		
3 in. [75 mm] and under			80–105	[550–725]
Over 3 in. [75 mm]			75–100	[515–690]
Yield strength, min: ^A				
All thicknesses	70	[485]		
3 in. [75 mm] and under			60	[415]
Over 3 in. [75 mm]			55	[380]
Elongation in 8 in. [200 mm], min, % ^B			...	
Elongation in 2 in. [50 mm], min, % ^B		20		19
Elongation in 5D, min, % ^B				17

^A Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

^B See Specification A20/A20M for elongation adjustment.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Grade D plates of all thicknesses and Grade C plates of thicknesses over 2 in. [50 mm] shall be normalized.

5.2 Grade C plates 2 in. [50 mm] and under in thickness are usually supplied in the as-rolled condition. The plates may be ordered normalized or stress-relieved, or both.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1, unless otherwise modified in accordance with

Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7.2 For plates with a nominal thickness of 3/4 in. [20 mm] and under, the 1 1/2-in. [40-mm] wide rectangular specimen may be used and the elongation determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

8. Keywords

8.1 alloy steel plates; manganese-vanadium-nickel steel plate; plate for pressure vessels; pressure containing parts

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

- | | |
|--|--|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in accordance with Specification A435/A435M, |
| S2. Product Analysis, | S9. Magnetic Particle Examination, |
| S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, | S11. Ultrasonic Examination in accordance with Specification A577/A577M, |
| S4.1 Additional Tension Test, | S12. Ultrasonic Examination in accordance with Specification A578/A578M, and |
| S5. Charpy V-Notch Impact Test, | S17. Vacuum Carbon-Deoxidized Steel. |
| S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness), | |
| S7. High-Temperature Tension Test, | |

SPECIFICATION FOR CHROMIUM-VANADIUM ALLOY STEEL SPRING WIRE



SA-231/SA-231M

(Identical with ASTM Specification A231/A231M-96 except that certification requirements in para. 13.1 are mandatory.)

SPECIFICATION FOR CHROMIUM-VANADIUM ALLOY STEEL SPRING WIRE



SA-231/SA-231M

(Identical with ASTM Specification A 231/A 231M-96 except that certification requirements in para. 13.1 are mandatory.)

1. Scope

1.1 This specification covers round chromium-vanadium alloy steel spring wire having properties and quality intended for the manufacture of springs used at moderately elevated temperatures. This wire shall be either in the annealed and cold-drawn or oil-tempered condition as specified by the purchaser.

1.2 The values stated in either SI (metric) units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A 752 Specification for General Requirements for Wire Rods and Coarse Round Wire, Alloy Steel
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 ANSI Standard:

- B 32.4M Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products

2.3 Military Standard:

- MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 Federal Standard:

- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.5 AIAG Standard:

- AIAGB-5 02.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 Orders for material under this specification should include the following information for each ordered item:

3.1.1 Quantity (mass);

3.1.2 Name of material (chromium-vanadium alloy steel wire);

3.1.3 Wire diameter (Table 1 and Table 2);

3.1.4 Packaging (Section 14);

3.1.5 Cast or heat analysis report (if requested) (5.2);

3.1.6 Certification and test report (Section 13); and

3.1.7 ASTM designation and date of issue.

NOTE 1 — A typical ordering description is as follows: 20,000 kg oil-tempered chromium-vanadium alloy steel wire, size 6.00 mm in 150 kg coils to ASTM A 231M dated_____, or for inch-pound units, 40 000 lb oil-tempered chromium-vanadium alloy steel spring wire, size 0.250 in. in 350 lb coils to ASTM A 231 dated_____.

4. Materials and Manufacture

4.1 The steel may be made by any commercially accepted steel-making process. The steel may be either ingot cast or strand cast.

4.2 The finished wire shall be free from detrimental pipe and undue segregation.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition specified in Table 3.

5.2 Cast or Heat Analysis — Each cast or heat of steel shall be analyzed by the manufacturer to determine the

percentage of elements prescribed in Table 3. This analysis shall be made from a test specimen preferably taken during the pouring of the cast or heat. When requested, this shall be reported to the purchaser and shall conform to the requirements of Table 3.

5.3 Product Analysis (formerly Check Analysis) — An analysis may be made by the purchaser from finished wire representing each cast or heat of steel. The chemical composition thus determined, as to elements required or restricted, shall conform to the product (check) analysis requirements specified in Table 5 of Specification A 752.

5.4 For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

6. Mechanical Properties

6.1 Annealed and Cold Drawn — When purchased in the annealed and cold-drawn condition, the wire shall have been given a sufficient amount of cold working to meet the purchaser's coiling requirements and shall be in a suitable condition to respond properly to heat treatment. In special cases the hardness, if desired, shall be stated in the purchase order.

6.2 Oil Tempered — When purchased in the oil-tempered condition, the tensile strength and minimum percent reduction of area, sizes 2.50 mm or 0.105 in. and coarser, of the wire shall conform to the requirements as shown in Table 1 or Table 2.

6.2.1 Number of Tests — One test specimen shall be taken for each ten coils, or fraction thereof, in a lot. Each cast or heat in a given lot shall be tested.

6.2.2 Location of Tests — Test specimens shall be taken from either end of the coil.

6.2.3 Test Method — The tension test shall be made in accordance with Test Methods and Definitions A 370.

6.3 Wrap Test:

6.3.1 Oil tempered or cold drawn wire 4.00 mm or 0.162 in. and smaller in diameter shall wind on itself as an arbor without breakage. Larger diameter wire up to and including 8.00 mm or 0.312 in. in diameter shall wrap without breakage on a mandrel twice the wire diameter. The wrap test is not applicable to wire over 8.00 mm or 0.312 in. in diameter.

6.3.2 Number of Tests — One test specimen shall be taken for each ten coils, or fraction thereof, in a lot. Each cast or heat in a given lot shall be tested.

6.3.3 Location of Test — Test specimens shall be taken from either end of the coil.

6.3.4 Test Method — The wrap test shall be made in accordance with Supplement IV of Test Methods and Definitions A 370.

7. Metallurgical Properties

7.1 Surface Condition:

7.1.1 The surface of the wire as received shall be free of rust and excessive scale. No serious die marks, scratches, or seams may be present. Based upon examination of etched end specimen, seams shall not exceed 3.5% of the wire diameter, or 0.25 mm or 0.010 in., whichever is the smaller as measured on a transverse section.

7.1.2 Number of Tests — One test specimen shall be taken for each ten coils, or fraction thereof, in a lot. Each cast or heat in a given lot shall be tested.

7.1.3 Location of Test — Test specimens shall be taken from either or both ends of the coil.

7.1.4 Test Method — The surface shall be examined after etching in a solution of equal parts of hydrochloric acid and water that has been heated to approximately 80° C. Test ends shall be examined using 10× magnification. Any specimen which shows questionable seams of borderline depth shall have a transverse section taken from the unetched area, properly mounted and polished and examined to measure the depth of the seam.

8. Dimensions and Permissible Variations

8.1 The permissible variations in the diameter of the wire shall be as specified in Table 4 or Table 5.

9. Workmanship and Appearance

9.1 Annealed and Cold Drawn — The wire shall not be kinked or improperly cast. To test for cast, a few convolutions of wire shall be cut loose from the coil and placed on a flat surface. The wire shall lie flat on itself and not spring up nor show a wavy condition.

9.2 Oil Tempered — The wire shall be uniform in quality and temper and shall not be wavy or crooked.

9.3 Each coil shall be one continuous length of wire properly coiled. Welds made prior to cold drawing are permitted. If unmarked welds are unacceptable to the purchaser, special arrangements should be made with the manufacturer at the time of the purchase.

9.4 Appearance — The surface shall be smooth and free of defects such as seams, pits, die marks, and other defects tending to impair the use of the wire for springs. Any additional surface requirements must be negotiated at the time of entry of the order.

10. Retests

10.1 If any test specimen exhibits obvious defects or shows the presence of a weld, it may be discarded and another specimen substituted.

11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

12. Rejection and Rehearing

12.1 Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the manufacturer as soon as possible so that an investigation may be initiated.

12.2 The material must be adequately protected and correctly identified in order that the manufacturer may make a proper investigation.

13. Certification

13.1 A manufacturer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. A report of the test results shall be furnished.

13.2 The certification shall include the specification number, year date of issue, and revision letter, if any.

14. Packaging, Marking, and Loading for Shipment

14.1 The coil mass, dimensions, and the method of packaging shall be as agreed upon between the manufacturer and purchaser.

14.2 The size of the wire, purchaser's order number, ASTM Specification number, heat number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

14.3 Unless otherwise specified in the purchaser's order, packing, marking, and loading for shipments shall be in accordance with those procedures recommended by Practices A 700.

14.4 *For Government Procurement:*

14.4.1 Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

14.5 Bar Coding — In addition to the previously-stated identification requirements, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG B-5 02.00, Primary Metals Identification Tag Application. The bar code may be applied to a substantially affixed tag.

15. Keywords

15.1 alloy; chromium-vanadium; spring; wire

TABLE 1
TENSILE REQUIREMENTS, SI UNITS ^A

Diameter, ^B mm	Tensile Strength, MPa		Reduction of Areas, Min., %
	Min.	Max.	
0.50	2060	2260	^C
0.55	2050	2240	^C
0.60	2030	2220	^C
0.65	2010	2200	^C
0.70	2000	2160	^C
0.80	1980	2140	^C
0.90	1960	2120	^C
1.00	1940	2100	^C
1.10	1920	2080	^C
1.20	1900	2060	^C
1.40	1860	2020	^C
1.60	1820	1980	^C
1.80	1800	1960	^C
2.00	1780	1930	^C
2.20	1750	1900	^C
2.50	1720	1860	45
2.80	1680	1830	45
3.00	1660	1800	45
3.50	1620	1760	45
4.00	1580	1720	40
4.50	1560	1680	40
5.00	1520	1640	40
5.50	1480	1620	40
6.00	1460	1600	40
6.50	1440	1580	40
7.00	1420	1560	40
8.00	1400	1540	40
9.00	1380	1520	40
10.00	1360	1500	40
11.00	1340	1480	40
12.00	1320	1460	40

^A Tensile strength values for intermediate diameters may be interpolated.

^B Preferred sizes. For a complete list, refer to ANSI B 32.4M, Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products.

^C The reduction of area test is not applicable to wire diameters under 2.34 mm.

TABLE 2
TENSILE REQUIREMENTS, INCH-POUND UNITS ^A

Diameter, ^B in.	Tensile Strength, ksi		Reduction of Areas, Min., %
	Min.	Max.	
0.020	300	325	^C
0.032	290	315	^C
0.041	280	305	^C
0.054	270	295	^C
0.062	265	290	^C
0.080	255	275	^C
0.105	245	265	45
0.135	235	255	45
0.162	225	245	40
0.192	220	240	40
0.244	210	230	40
0.283	205	225	40
0.312	203	223	40
0.375	200	220	40
0.438	195	215	40
0.500	190	210	40

^A Tensile strength values for intermediate diameters may be interpolated.

^B Preferred sizes. For a complete list, refer to ANSI B 32.4M, Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products.

^C The reduction of area test is not applicable to wire diameters under 0.092 in.

TABLE 3
CHEMICAL REQUIREMENTS

Element	Analysis, %
Carbon	0.48-0.53
Manganese	0.70-0.90
Phosphorus	0.040 max.
Sulfur	0.040 max.
Silicon	0.15-0.35
Chromium	0.80-1.10
Vanadium	0.15 min.

TABLE 4
PERMISSIBLE VARIATIONS IN WIRE DIAMETER,
SI UNITS ⁴

Diameter, mm	Permissible Variations, plus and Minus, mm	Permissible Out-of Round, mm
To 0.70, incl.	0.02	0.02
Over 0.70 to 2.00, incl.	0.03	0.03
Over 2.00 to 9.00, incl.	0.05	0.05
Over 9.00	0.08	0.08

⁴ For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E 29.

TABLE 5
PERMISSIBLE VARIATIONS IN WIRE DIAMETER,
INCH-POUND UNITS ⁴

Diameter, in.	Permissible Variations, Plus and Minus, mm	Permissible Out-of Round, mm
0.020 to 0.028, incl.	0.0008	0.0008
Over 0.028 to 0.075, incl.	0.001	0.001
Over 0.075 to 0.375, incl.	0.002	0.002
Over 0.375 to 0.500, incl.	0.003	0.003

⁴ For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E 29.

SPECIFICATION FOR CHROMIUM-VANADIUM ALLOY STEEL VALVE SPRING QUALITY WIRE



SA-232/SA-232M



(Identical with ASTM Specification A232/A232M-91.)

SPECIFICATION FOR CHROMIUM-VANADIUM ALLOY STEEL VALVE SPRING QUALITY WIRE



SA-232/SA-232M



(Identical with ASTM Specification A 232/A 232M-91.)

1. Scope

1.1 This specification covers the highest quality of round chromium-vanadium alloy steel valve spring wire, uniform in quality and temper, intended for the manufacture of valve springs and other springs requiring high-fatigue properties when used at moderately elevated temperatures. This wire shall be either in the annealed and cold-drawn or oil-tempered condition as specified by the purchaser.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 ANSI Standard:

- B32.4 Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products

2.3 Federal Standard:

- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.4 Military Standard:

- MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. Ordering Information

3.1 Orders for material under this specification should include the following information for each ordered item:

- 3.1.1** Quantity (mass),
- 3.1.2** Name of material (chromium-vanadium alloy steel valve spring quality wire),
- 3.1.3** Dimensions (Table 1 and Section 8),
- 3.1.4** Condition (Section 6),
- 3.1.5** Packaging (Section 14),
- 3.1.6** Heat analysis report, if requested (Section 5.2),
- 3.1.7** Certification or test report, or both, if specified (Section 13), and
- 3.1.8** ASTM designation and year of issue.

NOTE 1 — A typical ordering description is as follows: 20 000 kg oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 6.00 mm in 150 kg coils to ASTM A 232/A 232M dated _____, or for inch-pound units, 40 000 lb oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 0.250 in. in 350-lb coils to ASTM A 232/A 232M dated _____.

4. Materials and Manufacture

4.1 The steel may be made by any commercially accepted steel making process. The steel may be either ingot cast or strand cast.

4.2 The finished wire shall be free from detrimental pipe and undue segregation.

5. Chemical Requirements

5.1 The steel shall conform to the requirements for chemical composition specified in Table 2.

5.2 Heat Analysis — Each heat of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 2. This analysis shall be made

from a test specimen preferably taken during the pouring of the heat. When requested, this shall be reported to the purchaser and shall conform to the requirement of Table 2.

5.3 Product Analysis — An analysis may be made by the purchaser from finished wire representing each heat of steel. The average of all the separate determinations made shall be within the limits specified in the analysis column. Individual determinations may vary to the extent shown in the product analysis tolerance column, except that the several determinations of a single element in any one heat shall not vary both above and below the specified range.

5.4 For referee purposes, Test Methods, Practices and Terminology A 751 shall be used.

6. Mechanical Requirements

6.1 Annealed and Cold Drawn — When purchased in the annealed and cold-drawn condition, the wire shall have been given a sufficient amount of cold working to meet the purchaser's coiling requirements and shall be in a suitable condition to respond properly to heat treatment. In special cases the hardness, if desired, shall be stated in the purchase order.

6.2 Oil Tempered — When purchased in the oil-tempered condition, the tensile strength and minimum percent reduction of area, sizes 2.50 mm [0.105 in.] and coarser, of the wire shall conform to the requirements prescribed in Table 1.

6.2.1 Number of Tests — One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each heat in a given lot shall be tested.

6.2.2 Location of Tests — Test specimens shall be taken from either end of the coil.

6.2.3 Test Method — The tension test shall be made in accordance with Test Methods and Definitions A 370.

6.3 Wrap Test:

6.3.1 Oil-tempered or cold-drawn wire 4.00 mm [0.162 in.] and smaller in diameter shall wind on itself as an arbor without breakage. Larger diameter wire up to and including 8.00 mm [0.312 in.] in diameter shall wrap without breakage on a mandrel twice the wire diameter. The wrap test is not applicable to wire over 8.00 mm [0.312 in.] in diameter.

6.3.2 Number of Tests — One test specimen shall be taken for each five coils or fraction thereof, in a lot. Each heat in a given lot shall be tested.

6.3.3 Location of Test — Test specimens shall be taken from either end of the coil.

6.3.4 Test Method — The wrap test shall be made in accordance with Test Methods and Definitions A 370.

7. Metallurgical Requirements

7.1 Surface Condition:

7.1.1 The surface of the wire as received shall be free of imperfections such as pits, die marks, scratches, seams, and other defects tending to impair the fatigue value of the springs.

7.1.2 Number of Tests — One test specimen shall be taken from each end of every coil.

7.1.3 Test Method — The surface shall be examined after etching in a solution of equal parts of hydrochloric acid and water that has been heated to approximately 80°C for a sufficient length of time to remove up to approximately 1% of the diameter of the wire. Test ends shall be examined using 10× magnification.

7.2 Decarburization:

7.2.1 Transverse sections of the wire properly mounted, polished, and etched shall show no completely decarburized (carbon-free) areas when examined at a magnification of 100 diameters. Partial decarburization shall not exceed a depth of 0.025 mm [0.001 in.] on wire 5.00 mm [0.192 in.] and smaller or 0.038 mm [0.0015 in.] on larger than 5.00 mm [0.192 in.].

7.2.2 To reveal the decarburization more accurately in the untempered wire, the specimen shall be hardened and tempered before microscopical examination. Prior to hardening, the specimen shall be filed flat on one side enough to reduce the diameter at least 20%. The subsequent mounted specimen shall show the flattened section, as well as the original wire edge. Any decarburization on this flattened section shall necessitate a new specimen for examination.

7.2.3 Number of Tests — One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each in a given lot shall be tested.

7.2.4 Location of Tests — Test specimens may be taken from either end of the coil.

8. Dimensions and Permissible Variations

8.1 The permissible variations in the diameter of the wire shall be specified in Table 3.

8.2 Number of Tests — One test specimen shall be taken from each end of every coil.

9. Workmanship, Finish, and Appearance

9.1 Annealed and Cold Drawn — The wire shall not be kinked or improperly cast. To test for cast, a few convolutions of wire shall be cut loose from the coil and placed on a flat surface. The wire shall lie substantially flat on itself and not spring up nor show a wavy condition.

9.2 Oil Tempered—The wire shall be uniform in quality and temper and shall not be wavy or crooked.

9.3 Each coil shall be one continuous length of wire properly coiled and firmly tied.

9.4 No welds are permitted in the finished product and any welds made during processing must be removed.

10. Retests

10.1 If any test specimen exhibits obvious defects it may be discarded and another specimen substituted.

11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

12. Rejection and Rehearing

12.1 Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported to the manufacturer as soon as possible so that an investigation may be initiated.

12.2 The material must be adequately protected and correctly identified in order that the manufacturer may make a proper investigation.

13. Certification

13.1 When specified in the purchase order or contract, a manufacturer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

13.2 The certification shall include the specification number, year date of issue, and revision letter, if any.

14. Packaging, Marking, and Loading for Shipment

14.1 The coil mass, dimensions, and the method of packaging shall be agreed upon between the manufacturer and purchaser.

14.2 The size of the wire, purchaser's order number, ASTM specification number, heat number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

14.3 Unless otherwise specified in the purchaser's order, packaging, marking, and loading for shipments shall be in accordance with those procedures recommended by Practice A 700.

14.4 For Government Procurement—Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

TABLE 1
TENSILE REQUIREMENTS^A
SI Units

Diameter ^B mm	MPa, min	MPa, max	Reduction of Area, min, %
0.50	2060	2260	C
0.55	2050	2240	C
0.60	2030	2220	C
0.65	2010	2200	C
0.70	2000	2160	C
0.80	1980	2140	C
0.90	1960	2120	C
1.00	1940	2100	C
1.10	1920	2080	C
1.20	1900	2060	C
1.40	1860	2020	C
1.60	1820	1980	C
1.80	1800	1960	C
2.00	1780	1930	C
2.20	1750	1900	C
2.50	1720	1860	45
2.80	1680	1830	45
3.00	1660	1800	45
3.50	1620	1760	45
4.00	1580	1720	40
4.50	1560	1680	40
5.00	1520	1640	40
5.50	1480	1620	40
6.00	1460	1600	40
6.50	1440	1580	40
7.00	1420	1560	40
8.00	1400	1540	40
9.00	1380	1520	40
10.00	1360	1500	40
11.00	1340	1480	40
12.00	1320	1460	40

Inch-Pound Units			
Diameter, in.	ksi, min	ksi, max	Reduction of Area, min, %
0.020	300	325	C
0.032	290	315	C
0.041	280	305	C
0.054	270	295	C
0.062	265	290	C
0.080	255	275	C
0.105	245	265	45
0.135	235	255	45
0.162	225	245	40
0.192	220	240	40
0.244	210	230	40
0.283	205	225	40
0.312	203	223	40
0.375	200	220	40
0.438	195	215	40
0.500	190	210	40

^A Tensile strength values for intermediate diameters may be interpolated.

^B Preferred sizes. For a complete list, refer to ANSI B32.4.

^C The reduction of area test is not applicable to wire under 2.50 mm [0.105 in.] in diameter.

TABLE 2
CHEMICAL REQUIREMENTS

	Analysis, %	Product Analysis Tolerance, %
Carbon	0.48–0.53	±0.02
Manganese	0.70–0.90	±0.03
Phosphorus	0.020 max	+0.005
Sulfur	0.035 max	+0.005
Silicon	0.15–0.35	±0.02
Chromium	0.80–1.10	±0.05
Vanadium	0.15 min	–0.01

TABLE 3
PERMISSIBLE VARIATIONS IN WIRE DIAMETER^A
SI Units

Diameter, mm	Permissible Variations, plus and minus, mm	Permissible Out-of-Round, mm
to 2.0, incl	0.02	0.02
Over 2.0 to 4.00, incl	0.03	0.03
Over 4.00 to 9.00, incl	0.04	0.04
Over 9.00	0.05	0.05

Inch-Pound		
Diameter, in.	Permissible Variations, plus and minus, in.	Permissible Out-of-Round, in.
0.020 to 0.075, incl	0.0008	0.0008
Over 0.075 to 0.148, incl	0.001	0.001
Over 0.148 to 0.375, incl	0.0015	0.0015
Over 0.375 to 0.500, incl	0.002	0.002

^A For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E 29.

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SPECIFICATION FOR PIPING FITTINGS OF WROUGHT CARBON STEEL AND ALLOY STEEL FOR MODERATE AND HIGH-TEMPERATURE SERVICE



SA-234/SA-234M



(21)

(Identical with ASTM Specification A234/A234M-19.)

For welded and filler metal products ordered to Section III, Division 1, Supplementary Requirement S4 is mandatory.

Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

1. Scope

1.1 This specification covers wrought carbon steel and alloy steel fittings of seamless and welded construction covered by the latest revision of ASME B16.9, B16.11, MSS-SP-79, MSS-SP-83, MSS-SP-95, and MSS-SP-97. These fittings are for use in pressure piping and in pressure vessel fabrication for service at moderate and elevated temperatures. Fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A960/A960M.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements may be specified in the order.

1.3 This specification does not cover cast welding fittings or fittings machined from castings. Cast steel welding fittings are governed by Specifications A216/A216M and A217/A217M.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A960/A960M, the following list of standards apply to this specification.

2.2 ASTM Standards:

A105/A105M Specification for Carbon Steel Forgings for Piping Applications

A216/A216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A960/A960M Specification for Common Requirements for Wrought Steel Piping Fittings

2.3 ASME Standards:

B16.9 Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket Welding and Threaded

2.4 ASME Boiler and Pressure Vessel Code:

Section III

Section V

Section VIII, Division 1

Section IX

2.5 MSS Standards:

MSS-SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS-SP-79 Socket Welding Reducer Inserts

MSS-SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS-SP-95 Swage(d) Nipples and Bull Plugs

MSS-SP-97 Integrally Reinforced Forged Branch Outlet Fittings—Socket Welding, Threaded and Buttwelding Ends

2.6 ASNT Standard:

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

2.7 AWS Specifications

A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3. Ordering Information

3.1 See Specification A960/A960M.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A960/A960M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A960/A960M constitutes non-conformance with this specification. In case of a conflict between the requirements of this specification and Specification A960/A960M, this specification shall prevail.

5. Materials

5.1 The starting material for fittings shall be fully killed steel, consisting of forgings, bars, plates, sheet, and seamless or fusion-welded tubular products with filler metal added and shall conform to the chemical requirements of Table 1. Unless otherwise specified for carbon steel plates and sheet, the steel may be made to either coarse grain or fine grain practice. Grade WP9 shall be made to fine grain practice.

5.2 A starting material specification that specifically requires the addition of any element beyond those listed for the materials in Table 1 for the applicable grade of material is not permitted. This does not preclude the use of deoxidizers or the judicious use of elements for grain size control.

6. Manufacture

6.1 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious imperfections in the fittings.

6.2 Fittings NPS-4 and under may be machined from hot-forged or rolled, cold-sized, and straightened bar stock having the chemical composition of the Grade in Table 1 and the mechanical properties of the Grade in Table 2. Heat treatment shall be in accordance with Section 7. All caps machined from bar stock shall be examined by liquid penetrant or magnetic particle in accordance with S52 or S53 in Specification A960/A960M.

6.3 All welds including welds in tubular products from which fittings are made shall be (1) made by welders, welding operators, and welding procedures qualified under the provisions of ASME Section IX, (2) heat treated in accordance with Section 7 of this specification, and (3) radiographically examined throughout the entire length of each weld in accordance with Article 2, ASME Section V with acceptance limits in accordance with Paragraph UW-51 of ASME Section VIII, Division 1 of the ASME Boiler & Pressure Vessel Code. In place of radiographic examination, welds may be ultrasonically examined in accordance with Appendix 12 of Section VIII. The NDE of welds in Grades WPB, WPC, WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, and WPR may be performed either prior to or after forming. NDE of welds in Grades WP5, WP9, WP91 Types 1 and 2, WP911, WP92, WP22 Class 1, WP22 Class 3, and WP24 shall be done after forming.

6.3.1 All welds in WP91 Types 1 and 2 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the Ni+Mn content of all welding consumables used to fabricate WP91 Type 1 and Type 2 fittings shall not exceed 1.0 %.

6.3.2 All welds in WP92 and WP911 shall be made using welding consumables meeting the chemical requirements for the grade in Table 1.

6.3.3 All welds in WP115 shall be made using deposited filler metal suitable for the composition being welded. Any defects shall be thoroughly chipped or ground out before welding and each welded length shall be re-heat treated or stress relieved as required by the application specification. Alternately, the weld shall be made with the welding products and procedures of 6.3.1.

6.4 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

6.5 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35 (a) of ASME Section VIII, Division 1.

6.6 All butt-weld tees manufactured by cold-forming method(s) shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S52 or S53 in Specification A960/A960M. This examination shall be performed after final heat treat. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in

TABLE 1 Chemical Requirements

NOTE 1—All requirements are maximum unless otherwise indicated.

NOTE 2—Where an ellipsis (...) appears in this table, there is no requirement and analysis for the element need not be determined or reported.

Grade and Marking Symbol ^A	Composition, %									
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Molybdenum	Nickel	Copper	Others
WPB ^{B,C,D,E}	0.30	0.29–1.06	0.050	0.058	0.10 min	0.40	0.15 max	0.40	0.40	Vanadium 0.08
WPC ^{C,D,E}	0.35	0.29–1.06	0.050	0.058	0.10 min	0.40	0.15 max	0.40	0.40	Vanadium 0.08
WP1	0.28	0.30–0.90	0.045	0.045	0.10–0.50	...	0.44–0.65	...	...	...
WP12 CL1, WP12 CL2	0.05–0.20	0.30–0.80	0.045	0.045	0.60	0.80–1.25	0.44–0.65	...	...	...
WP11 CL1	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	1.00–1.50	0.44–0.65	...	...	...
WP11 CL2, WP11 CL3	0.05–0.20	0.30–0.80	0.040	0.040	0.50–1.00	1.00–1.50	0.44–0.65	...	...	...
WP22 CL1, WP22 CL3	0.05–0.15	0.30–0.60	0.040	0.040	0.50	1.90–2.60	0.87–1.13	...	...	...
WP24	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	2.20–2.60	0.90–1.10	...	0.75–1.25	Aluminum 0.020 Boron 0.0015–0.0070 Nitrogen 0.12 Titanium 0.06–0.10 Vanadium 0.20–0.30
WP5 CL1, WP5 CL3	0.15	0.30–0.60	0.040	0.030	0.50	4.0–6.0	0.44–0.65	...	...	...
WP9 CL1, WP9 CL3	0.15	0.30–0.60	0.030	0.030	1.00	8.0–10.0	0.90–1.10	...	...	...
WPR	0.20	0.40–1.06	0.045	0.050	...	...	...	1.60–2.24	0.75–1.25	...
WP91 Type 1	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.0–9.5	0.85–1.05	0.40	...	Vanadium 0.18–0.25 Columbium ^G 0.06–0.10 Nitrogen 0.03–0.07 Aluminum 0.02 ^F Titanium 0.01 ^F Zirconium 0.01 ^F
WP91 Type 2	0.08–0.12	0.30–0.50 ^F	0.020 ^F	0.005 ^F	0.20–0.40 ^F	8.0–9.5 ^F	0.85–1.05	0.20 ^F	0.10 ^F	Vanadium 0.18–0.25 Columbium ^G 0.06–0.10 Nitrogen 0.035–0.070 ^F Aluminum 0.020 ^F N/Al ratio ≥ 4.0 Boron 0.001 ^F Zirconium 0.01 ^F Titanium 0.01 ^F Arsenic 0.010 ^F Tin 0.010 ^F Antimony 0.003 ^F Tungsten 0.05 ^F
WP115	0.08–0.13	0.20–0.50	0.020	0.005	0.15–0.45	10.0–11.0	0.40–0.60	0.25	0.10	Vanadium 0.18–0.25 Niobium 0.02–0.06 Nitrogen 0.030–0.070 Aluminum 0.02 Titanium 0.01 Boron 0.001 Zirconium 0.01 Tungsten 0.05 Arsenic 0.010 Tin 0.010 Antimony 0.003 N/Al ratio 4.0 min CNB ^H 10.5
WP911	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	8.5–9.5	0.90–1.10	0.40	...	Vanadium 0.18–0.25 Columbium ^G 0.060–0.10 Nitrogen 0.04–0.09 Aluminum 0.02 max ^F Boron 0.0003–0.006 Tungsten 0.90–1.10 Titanium 0.01 max ^F Zirconium 0.01 max ^F
WP92	0.07–0.13	0.30–0.60	0.020	0.010	0.50	8.50–9.50	0.30–0.60	0.40	...	Aluminum 0.02 ^F Boron 0.001–0.006 Columbium ^G 0.04–0.09 Nitrogen 0.030–0.070 Titanium 0.01 ^F Tungsten 1.50–2.00 Vanadium 0.15–0.25 Zirconium 0.01 ^F

^A When fittings are of welded construction, the grade and marking symbol shown above shall be supplemented by letter "W".^B Fittings made from bar or plate may have 0.35 max carbon.

^C Fittings made from forgings may have 0.35 max carbon and 0.35 max silicon with no minimum.

^D For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted, up to a maximum of 1.65 %.

^E The sum of Copper, Nickel, Chromium, and Molybdenum shall not exceed 1.00 %.

^F Applies both to heat and product analyses.

^G Columbium (Cb) and Niobium (Nb) are alternate names for element 41 in the Periodic Table of the Elements.

^H Chromium Nickel Balance is defined as $CNB = (Cr + 6Si + 4Mo + 1.5W + 11V + 5Nb + 9Ti + 12Al) - (40C + 30N + 4Ni + 2Mn + 1Cu)$

accordance with Section 14 on Surface Quality. After the removal of any crack, the tee(s) shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6.7 Stubends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 6.3 for qualifications and 7.3.4 for post weld heat treatment.

7. Heat Treatment

7.1 *Heat Treatment Procedures*—Fittings, after forming at an elevated temperature, shall be cooled to a temperature below the critical range under suitable conditions to prevent injurious defects caused by too rapid cooling, but in no case more rapidly than the cooling rate in still air. Heat treatment temperatures specified are metal (part) temperatures. Heat-treated fittings shall be treated according to Section 7 in Specification A960/A960M.

7.2 WPB, WPC, and WPR Fittings:

7.2.1 Hot-formed WPB, WPC, and WPR fittings upon which the final forming operation is completed at a temperature above 1150 °F [620 °C] and below 1800 °F [980 °C] need not be heat treated provided they are cooled in still air.

7.2.2 Hot-formed or forged WPB, WPC, and WPR fittings finished at temperature in excess of 1800 °F [980 °C] shall subsequently be annealed, normalized, or normalized and tempered. Hot-forged fittings NPS 4 or smaller need not be heat treated.

7.2.3 WPB, WPC, and WPR fittings over NPS 12, produced by locally heating a portion of the fitting stock to any temperature for forming, shall be subsequently annealed, normalized, or normalized and tempered. Fittings such as elbows, tees, header tees, reducers and lap joint stub ends with a carbon content less than 0.26 %, NPS 12 and under, shall not require heat treatment after forming a locally heated portion of the fitting.

7.2.4 Cold-formed WPB, WPC, and WPR fittings, upon which the final forming operation is completed at a temperature below 1150 °F [620 °C], shall be normalized, or shall be stress relieved at 1100 to 1275 °F [595 to 690 °C].

7.2.5 WPB, WPC, and WPR fittings produced by fusion welding and having a nominal wall thickness at the welded joint of 3/4 in. [19 mm] or greater shall be post-weld heat treated at 1100 to 1250 °F [595 to 675 °C], or in accordance with 7.2.6.

7.2.6 At the option of the manufacturer, WPB and WPC fittings produced by any of the methods in Section 6 may be annealed, normalized, or normalized and tempered.

7.3 Fittings Other than WPB, WPC, and WPR:

7.3.1 Fittings of Grades WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, WP22 Class 1, WP22 Class 3, WP5, and WP9 shall be furnished in the annealed, isothermal-annealed, or normalized and tempered condition. If normalized and tempered, the tempering temperature for WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, and WP12 Class 2 shall not be less than 1150 °F [620 °C]; for Grades WP5, WP9, WP22 Class 1, and WP22 Class 3 the tempering temperature shall not be less than 1250 °F [675 °C].

7.3.2 Fittings of Grades WP1, WP12 Class 1, or WP12 Class 2 either hot formed or cold formed may be given a final heat treatment at 1200 °F [650 °C] instead of the heat treatment specified in 7.3.1.

7.3.3 Fittings of WP24 either hot formed or cold formed shall be furnished in the normalized and tempered condition. The normalizing temperature range shall be 1800 to 1975 °F [980 to 1080 °C]. The tempering temperature range shall be 1350 to 1470 °F [730 to 800 °C].

7.3.4 Fittings in all thicknesses produced by fusion welding after the heat treatment specified in 7.3.1 shall be post-weld heat treated at a temperature not less than prescribed above for tempering except that Grade WP1 Type 1 and Type 2 are required to be post-weld heat treated only when the nominal wall thickness at the welded joint is 1/2 in. [13 mm] or greater, and except that preheat and post weld heat treatment are not required for WP24 fittings whose section thickness does not exceed 0.500 in. [12.7 mm].

7.3.5 Except when Supplementary Requirement S1 is specified by the purchaser, Grade WP91 Type 1 and Type 2 shall be normalized at 1900 °F [1040 °C] minimum, and 1975 °F [1080 °C] maximum, and tempered in the temperature range of 1350 °F [730 °C] to 1470 °F [800 °C] as a final heat treatment.

7.3.6 Grade WP911 shall be normalized in the temperature range of 1900 to 1975 °F [1040 to 1080 °C], and tempered in the temperature range of 1365 to 1435 °F [740 to 780 °C] as a final heat treatment.

7.3.7 Grade WP92 shall be normalized at 1900 °F [1040 °C] minimum, and 1975 °F [1080 °C] maximum, and tempered in the temperature range of 1350 °F [730 °C] to 1470 °F [800 °C] as a final heat treatment.

7.3.8 Grade WP115 shall be normalized in the temperature range of 1920 °F [1050 °C] to 2010 °F [1100 °C].

7.4 *WPB and WPC Fittings Made from Bar*—Cold-finished bars reduced in cross-sectional area more than 10 % by cold drawing or cold rolling are not acceptable for use in the manufacture of these fittings unless the bars have been either stress relieved in the temperature range of 1100 to 1250 °F [595 to 675 °C], normalized, normalized and tempered, or

TABLE 2 Tensile Requirements

NOTE 1—Where an ellipsis (...) appears in this table, there is no requirement.

Grade and Marking Symbol	WPB	WPC, WP11 CL2, WP12 CL2	WP1	WP11 CL1, WP22 CL1, WP5 CL1 WP9 CL1	WPR	WP11 CL3, WP22 CL3 WP5 CL3 WP9 CL3	WP24	WP91 Types 1 and 2	WP92 WP911	WP115	WP12 CL1
Tensile strength, minimum unless a range is given ksi [MPa]	60 [415]	70 [485]	55–80 [380–550]	60 [415]	63–88 [435–605]	75 [520]	85 [585]	90 [620]	90–120 [620–840]	90 [620]	60 [415]
Yield strength, min, ksi [MPa] (0.2 % offset or 0.5 % extension- under-load)	35 [240]	40 [275]	30 [205]	30 [205]	46 [315]	45 [310]	60 [415]	60 [415]	64 [440]	65 [450]	32 [220]

	Elongation Requirements					
	Grades					
	All Grades except WPR, WP91 Type 1 and Type 2, WP115 and WP911			WPR and WP24		WP91 Types 1 and 2 WP92 WP115 WP911
	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse
Elongation:						
Standard round specimen, or small proportional specimen, min % in 4 D	22	14	20	...	20	13
Rectangular specimen for wall thickness $\frac{5}{16}$ in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. [50 mm]	30	20 ^A	28	...	...	...
Rectangular specimen for wall thickness less than $\frac{5}{16}$ in. [7.94 mm]; min % in 2 in. [50 mm] ($\frac{1}{2}$ -in. [12.7-mm] wide specimen)	<i>B</i>	<i>B</i>	<i>B</i>	...	...	...

^A WPB and WPC fittings manufactured from plate shall have a minimum elongation of 17 %.^B For each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.94 mm], a deduction of 1.5 % for longitudinal and 1.0 % for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses.

Wall Thickness		Grades			
		All Grades except WPR, WP91 Type 1 and Type 2, WP115, and WP911		WPR	WP91 Types 1 and 2, WP92, WP115, and WP911
in.	[mm]	Longitudinal	Transverse	Longitudinal	Longitudinal
$\frac{5}{16}$	(0.312)	7.94	30.0	20.0	28.0
$\frac{9}{32}$	(0.281)	7.14	28.5	19.0	26.5
$\frac{1}{4}$	(0.250)	6.35	27.0	18.0	25.0
$\frac{7}{32}$	(0.219)	5.56	25.5	...	23.5
$\frac{3}{16}$	(0.188)	4.76	24.0	...	22.0
$\frac{5}{32}$	(0.156)	3.97	22.5	...	20.5
$\frac{1}{8}$	(0.125)	3.17	21.0	...	19.0
$\frac{3}{32}$	(0.094)	2.38	19.5	...	17.5
$\frac{1}{16}$	(0.062)	1.59	18.0	...	16.0

Note—This table gives the computed minimum % elongation value for each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test

Longitudinal
Transverse

Equation

 $E = 48t + 15.00$
 $E = 32t + 10.00$

where:

 E = elongation in 2 in. or [50 mm], %, and
 t = actual thickness of specimen, in. [mm].

annealed. Mechanical testing must be performed subsequent to the final heat-treating operation.

7.5 Liquid quenching followed by tempering shall be permitted for all grades when approved by the purchaser. Minimum tempering temperature shall be 1100 °F [595 °C] for WPB, WPC, and WPR, 1150 °F [620 °C] for Grades WP1 Type 1 and Type 2, WP11 Class 1, WP11 Class 2, WP 12 Class 1, and WP12 Class 2 and 1250 °F [675 °C] for Grades WP5, WP9, WP22 Class 1, 1350 °F [730 °C] for both Grade WP91 Type 1 and Type 2 and WP911 and 1380 °F [750 °C] for Grade WP115. The tempering temperature range for WP24 shall be as in 7.3.3.

7.5.1 Liquid quenching followed by tempering for grades WP11 Class 3 and WP22 Class 3 shall be permitted at the manufacturer's option unless otherwise provided in the purchase order. The minimum tempering temperature for WP11 Class 3 shall be 1150 °F [620 °C] and for WP22 Class 3 shall be 1250 °F [675 °C].

8. Chemical Composition

8.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective materials listed in Table 1. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for the starting materials (pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 Weld metal used in the construction of carbon-steel fittings shall be mild steel analysis No. A1 of Table QW-442, Section IX of the ASME Boiler and Pressure Vessel Code, No. A2 may be used for Grade WPCW.

8.4 The molybdenum and chromium content of the deposited weld metal of alloy steel fittings shall be within the same percentage range as permitted for the base metal.

8.5 Weld metal used in the construction of WP24 fittings shall be of the composition: 2.25 % Cr, 1 % Mo, 0.25 % V.

9. Tensile Requirements

9.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2.

9.1.1 Longitudinal or transverse specimens cut from either a fitting or from the starting plate or pipe they were manufactured from shall be acceptable for the tension test. For fittings made from forgings, the test specimen shall meet the requirements of Specification A105/A105M for the tension test.

9.1.2 While Table 2 specifies elongation requirements for both longitudinal and transverse specimens, it is not the intent that both requirements apply simultaneously. Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable.

9.2 One tension test shall be made on each heat of material and in the same condition of heat treatment as the finished

fittings it represents. Where plate or pipe is used for the test specimen, the specimen thickness tested shall represent all fittings made from the same heat of material in the same heat treat condition in any thickness up to and including the tested thickness. Same heat treatment condition means that the same type of heat treatment (for example, stress relieve, normalize) and the same heat treating cycles (temperatures, time at temperature (minimum), temperature uniformity of ± 25 °F [± 14 °C], cooling method, etc.) are used (see 9.3 of Specification A960/A960M for furnace uniformity requirement).

9.3 When cold-formed fittings are furnished, samples of the raw material shall be normalized or stress relieved as required in 7.2.4. Tension tests conducted on these heat-treated samples shall be considered to be the tensile properties of the cold-formed fittings.

9.4 Records of raw material test report of the tension tests shall be certification that the material of the fitting meets the tensile requirements of this specification provided the heat treatments of the finished fitting are the same as the raw material test report. If the raw material was not tested, or the fitting is not in the same condition of heat treatment, the fitting manufacturer shall perform the required test on material representative of the finished fitting from each heat of starting material. For fittings that are not heat treated in accordance with 7.2.1 or 7.2.3, the raw material test report data can be used to represent the fitting properties provided the heat treatments are the same.

9.5 When testing of the finished fittings is requested by the purchaser, see Supplementary Requirement S51 in Specification A960/A960M.

10. Hardness

10.1 Except when only one fitting is produced, and except for Grade WP91 Type 1 and Type 2, a minimum of two pieces per batch or continuous run shall be hardness tested to ensure the fittings are within the following limits for each grade in Table 2. The purchaser may verify that the requirement has been met by testing at any location on the fitting provided such testing does not render the fitting useless.

10.1.1 Fittings of Grades WP5, WP9, and WPR—217 HBW maximum.

10.1.2 Fittings of Grade WP24 and WP911—248 HBW maximum.

10.1.3 Fittings of Grade WP92—269 HBW maximum.

10.1.4 Fittings of all other grades—197 HBW maximum.

10.2 All fittings of Grade WP91 Type 1 and Type 2 and WP115 shall be hardness tested and shall have a hardness of 190 HBW-250 HBW.

10.3 When additional hardness testing of the fittings is required, see Supplementary Requirement S57 in Specification A960/A960M.

11. Hydrostatic Tests

11.1 See Specification A960/A960M.

12. Nondestructive Examination

12.1 For WP91 Type 1 and Type 2 and WP92 fittings, one of the following examinations, as found in the Supplementary

Requirements of Specification A960/A960M, shall be performed: S52 Liquid Penetrant Examination, S53 Magnetic Particle Examination, S62 Ultrasonic Test, or S72 Nondestructive Electromagnetic (Eddy-Current) Test.

13. Dimensions

13.1 Butt-welding fittings and butt-welding short radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ASME B16.9. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ASME B16.11, MSS-SP-79, or MSS-SP-83. Swage(d) Nipples, Bull Plugs, and Integrally Reinforced Forged Branch Outlet Fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of MSS-SP-95 or MSS-SP-97.

13.2 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification may be furnished in accordance with Supplementary Requirement S58 in Specification A960/A960M.

14. Surface Finish, Appearance, and Corrosion Protection

14.1 The requirements of Specification A960/A960M apply.

15. Repair by Welding

15.1 See Specification A960/A960M.

15.2 In addition to the requirements for weld repair of Specification A960/A960M, weld repairs to WP91 Type 1 and Type 2 fittings shall meet the requirements of 6.3.1.

15.3 In addition to the requirements for weld repair of Specification A960/A960M, weld repairs to WP24 fittings shall meet the requirements of 8.5. The recommended preheat and interpass temperature ranges are 200 to 400 °F [95 to 205 °C]. Weld repairs to WP24 fittings shall be post weld heat treated at 1350 to 1470 °F [730 to 800 °C], except that preheat and post weld heat treatment are not required for WP24 fittings whose section thickness does not exceed 0.500 in. [12.7 mm].

16. Inspection

16.1 See Specification A960/A960M.

16.2 Other tests, when required by agreement, shall be made from material of the lots covered in the order.

17. Rejection and Rehearing

17.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a rehearing.

17.2 Fittings that develop defects in shopworking or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

18. Certification

18.1 Test reports are required for all fittings covered by this specification. Each test report shall meet the requirements for certification in A960/A960M as well as include the following information specific to this specification:

18.1.1 Chemical analysis results, Section 8 (Table 1), reported results shall be to the same number of significant figures as the limits specified in Table 1 for that element.

18.1.2 Tensile property results, Section 9 (Table 2), report the yield strength and tensile strength in ksi [MPa] and elongation in percent,

18.1.3 Hardness results, Section 10,

18.1.4 Type heat treatment, if any, Section 7,

18.1.5 Seamless or welded,

18.1.6 Starting material, specifically pipe, plate, etc.,

18.1.7 Statement regarding radiographic or ultrasonic examination, Section 6.3, and

18.1.8 Any supplementary testing required by the purchase order.

19. Product Marking

19.1 In addition to marking requirements of A960/A960M, the following marking requirements shall apply:

19.1.1 Butt-welding fittings shall be marked with the fitting designation for marking in accordance with Annex A1.

19.1.2 Butt-welding fittings containing welds that have been ultrasonically examined instead of radiography shall be marked U after heat identity.

19.1.3 Threaded or socket-welding fittings shall be marked with the pressure class and fitting designation for marking in accordance with Annex A1. Plugs and bushings furnished to ASME B16.11 requirements are not required to be marked.

19.1.4 When agreed upon between the purchaser and manufacturer, and specified in the order, the markings shall be painted or stenciled on the fitting or stamped on a metal or plastic tag which shall be securely attached to the fitting.

19.1.5 WP91 material shall additionally be marked with the appropriate Type.

19.2 *Bar Coding*—In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

20. Keywords

20.1 pipe fittings—steel; piping applications; pressure containing parts; pressure vessel service; temperature service applications—elevated

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order.

S1. Alternative Heat Treatment—Grade WP91 Type 1 and Type 2

S1.1 Grade WP91 Type 1 and Type 2 shall be normalized in accordance with 7.3.5 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper the entire fitting in the temperature range of 1350 °F [730 °C] to 1470 °F [800 °C] as a final heat treatment. All mechanical tests shall be made on material heat treated in accordance with 7.3.5. The certification shall reference this supplementary requirement indicating the actual tempering temperature applied. The notation "S1" shall be included with the required marking of the fitting.

S2. Restricted Vanadium Content

S2.1 The vanadium content of the fittings shall not exceed 0.03 %.

S3. Carbon Equivalent

S3.1 For grades WPB and WPC, the maximum carbon equivalent (C.E.), based on heat analysis and the following formula, shall be 0.50.

$$\text{C.E.} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15}$$

S3.2 A lower maximum carbon equivalent may be agreed upon between the purchaser and the supplier.

S3.3 The C.E. shall be reported on the test report.

S4. ASME Section III Construction

S4.1 Products welded with filler metal furnished under this specification that are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code shall be manufactured by holders of the appropriate ASME Certificate of Authorization and Certification Mark. The product is subject to all applicable requirements of Section III, including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

S4.2 The applicable ASME Partial Data Report form, signed by an Authorized Nuclear Inspector, and a material test report shall be furnished for each lot of pipe fittings.

S4.3 The material used to fabricate the pipe fittings shall conform to the applicable SA specification in ASME Boiler and Pressure Vessel Code, Section II. The welded joints shall be full penetration butt welds as obtained by double welding or by other means that will obtain the same quality of deposited weld metal on the inside and outside. Welds using metal backing strips that remain in place are prohibited.

S4.4 Each piece of pipe fitting shall be so marked as to identify each such piece of pipe fitting with the lot and the material test report.

ANNEX

(Mandatory Information)

A1. FITTING DESIGNATION FOR MARKING PURPOSES

TABLE A1.1 Fitting Designation for Marking Purposes

Grade	Class	Construction	Mandatory Marking
WPB		W (Welded construction)	WPBW ^A
		S (Seamless construction)	WPB
WPC		W (Welded construction)	WPCW ^A
		S (Seamless construction)	WPC
WP1		W (Welded construction)	WP1W ^A
		S (Seamless construction)	WP1
WP12	CL1	W (Welded construction)	WP12 CL1W ^A
		S (Seamless construction)	WP12 CL1
	CL2	W (Welded construction)	WP12 CL2W ^A
		S (Seamless construction)	WP12 CL2
WP11	CL1	W (Welded construction)	WP11 CL1W ^A
		S (Seamless construction)	WP11 CL1
	CL2	W (Welded construction)	WP11 CL2W ^A
		S (Seamless construction)	WP11 CL2
	CL3	W (Welded construction)	WP11 CL3W ^A
		S (Seamless construction)	WP11 CL3
WP22	CL1	W (Welded construction)	WP22 CL1W ^A
		S (Seamless construction)	WP22 CL1
	CL3	W (Welded construction)	WP22 CL3W ^A
		S (Seamless construction)	WP22 CL3
WP5	CL1	W (Welded construction)	WP5 CL1W ^A
		S (Seamless construction)	WP5 CL1
	CL3	W (Welded construction)	WP5 CL3 W ^A
		S (Seamless construction)	WP5 CL3
WP9	CL1	W (Welded construction)	WP9 CL1 W ^A
		S (Seamless construction)	WP9 CL1
	CL3	W (Welded construction)	WP9 CL3 W ^A
		S (Seamless construction)	WP9 CL3
WPR		W (Welded construction)	WPR W ^A
		S (Seamless construction)	WPR
WP91 Type 1		W (Welded construction)	WP91T1W ^A
		S (Seamless construction)	WP91T1
WP91 Type 2		W (Welded construction)	WP91T2W ^A
		S (Seamless construction)	WP91T2
WP92		W (Welded construction)	WP92W ^A
		S (Seamless construction)	WP92
WP115		W (Welded construction)	WP115W ^A
		S (Seamless construction)	WP115
WP911		W (Welded construction)	WP911W ^A
		S (Seamless construction)	WP911

^A Add "U" to marking if welds are ultrasonic inspected in lieu of radiography.

**SPECIFICATION FOR CHROMIUM AND
CHROMIUM-NICKEL STAINLESS STEEL PLATE, SHEET,
AND STRIP FOR PRESSURE VESSELS AND FOR
GENERAL APPLICATIONS**



SA-240/SA-240M



(Identical with ASTM Specification A240/A240M-17.)

Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

1. Scope

1.1 This specification covers chromium, chromium-nickel, and chromium-manganese-nickel stainless steel plate, sheet, and strip for pressure vessels and for general applications including architectural, building, construction, and aesthetic applications.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 This specification is expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished in inch-pound units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

E112 Test Methods for Determining Average Grain Size

E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 SAE Standard:

J 1086 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A480/A480M.

3.1.1 Definitions;

3.1.2 General requirements for delivery;

3.1.3 Ordering information;

3.1.4 Process;

3.1.5 Special tests;

3.1.6 Heat treatment;

- 3.1.7 Dimensions and permissible variations;
- 3.1.8 Workmanship, finish and appearance;
- 3.1.9 Number of tests/test methods;
- 3.1.10 Specimen preparation;
- 3.1.11 Retreatment;
- 3.1.12 Inspection;
- 3.1.13 Rejection and reheating;
- 3.1.14 Material test report;
- 3.1.15 Certification; and
- 3.1.16 Packaging, marking, and loading.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1 and shall conform to applicable requirements specified in Specification A480/A480M.

5. Mechanical Properties

5.1 The material shall conform to the mechanical properties specified in Table 2.

5.2 When specified by the purchaser, Charpy impact tests shall be performed in accordance with Supplementary Requirement S1.

5.3 When specified by the purchaser, 1 % offset yield strength shall be measured and reported in accordance with Supplementary Requirement S3.

6. Materials for High-Temperature Service

6.1 The austenitic *H* Types shall conform to an average grain size of ASTM No. 7 or coarser as measured by Test Methods E112.

6.2 Supplementary Requirement S2 shall be invoked when non-H grade austenitic stainless steels are ordered for ASME Code applications for service above 1000°F [540°C].

6.3 Grade S31060, unless otherwise specified in the purchase order, shall conform to an average grain size of ASTM No. 7 or coarser, as measured by Test Methods E112.

7. Keywords

7.1 architectural; building; chromium; chromium-nickel stainless steel; chromium-manganese-nickel stainless steel; construction; pressure vessels

TABLE 1 Chemical Composition Requirements, %^A

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
N08020	...	0.07	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	2.00–3.00	...	3.00–4.00	Cb 8xC min, 1.00 max
N08367	...	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	0.75	...
N08700	...	0.04	2.00	0.040	0.030	1.00	19.0–23.0	24.0–26.0	4.3–5.0	...	0.50	Cb 8xC min 0.40 max
N08800	800 ^G	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Fe ^H 39.5 min Al 0.15–0.60 Ti 0.15–0.60
N08810	800H ^G	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Fe ^H 39.5 min Al 0.15–0.60 Ti 0.15–0.60
N08811	...	0.06–0.10	1.50	0.040	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Fe ^H 39.5 min Ti ^I 0.25–0.60 Al ^I 0.25–0.60
N08904	904L ^G	0.020	2.00	0.045	0.035	1.00	19.0–23.0	23.0–28.0	4.00–5.00	0.10	1.00–2.00	...
N08925	...	0.020	1.00	0.045	0.030	0.50	19.0–21.0	24.0–26.0	6.00–7.00	0.10–0.20	0.80–1.50	...
N08926	...	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.00–7.00	0.15–0.25	0.50–1.50	...
S20100	201	0.15	5.50–7.50	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...	...
S20103	...	0.03	5.50–7.50	0.045	0.030	0.75	16.0–18.0	3.5–5.5	...	0.25	...	...
S20153	...	0.03	6.40–7.50	0.045	0.015	0.75	16.0–17.5	4.0–5.0	...	0.10–0.25	1.00	...
S20161	...	0.15	4.00–6.00	0.040	0.040	3.00–4.00	15.0–18.0	4.0–6.0	...	0.08–0.20	...	...
S20200	202	0.15	7.50–10.00	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	0.25	...	...
S20400	...	0.030	7.00–9.00	0.040	0.030	1.00	15.0–17.0	1.50–3.00	...	0.15–0.30	...	...
S20431	...	0.12	5.00–7.00	0.045	0.030	1.00	17.0–18.0	2.0–4.0	...	0.10–0.25	1.50–3.50	...
S20432	...	0.08	3.00–5.00	0.045	0.030	1.00	17.0–18.0	4.0–6.0	...	0.05–0.20	2.00–3.00	...
S20433	...	0.08	5.50–7.50	0.045	0.030	1.00	17.0–18.0	3.5–5.5	...	0.10–0.25	1.50–3.50	...
S20910	XM-19 ^J	0.06	4.00–6.00	0.040	0.030	0.75	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	...	Cb 0.10–0.30 V 0.10–0.30
S21400	XM-31 ^J	0.12	14.00–16.00	0.045	0.030	0.30–1.00	17.0–18.5	1.00	...	0.35 min	...	...
S21600	XM-17 ^J	0.08	7.50–9.00	0.045	0.030	0.75	17.5–22.0	5.0–7.0	2.00–3.00	0.25–0.50	...	...
S21603	XM-18 ^J	0.03	7.50–9.00	0.045	0.030	0.75	17.5–22.0	5.0–7.0	2.00–3.00	0.25–0.50	...	...
S21640	...	0.08	3.50–6.50	0.060	0.030	1.00	17.5–19.5	4.0–6.5	0.50–2.00	0.08–0.30	...	Cb 0.10–1.00
S21800	...	0.10	7.00–9.00	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	...	0.08–0.18	...	...
S21904	XM-11 ^J	0.04	8.00–10.00	0.060	0.030	0.75	19.0–21.5	5.5–7.5	...	0.15–0.40	...	...
S24000	XM-29 ^J	0.08	11.50–14.50	0.060	0.030	0.75	17.0–19.0	2.3–3.7	...	0.20–0.40	...	...
S30100	301	0.15	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	...	0.10	...	...
S30103	301L ^G	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	...	0.20	...	...
S30153	301LN ^G	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	...	0.07–0.20	...	...
S30200	302	0.15	2.00	0.045	0.030	0.75	17.0–19.0	8.0–10.0	...	0.10	...	...
S30400	304	0.07	2.00	0.045	0.030	0.75	17.5–19.5	8.0–10.5	...	0.10	...	...
S30403	304L	0.030	2.00	0.045	0.030	0.75	17.5–19.5	8.0–12.0	...	0.10	...	...
S30409	304H	0.04–0.10	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	...	...	...
S30415	...	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	...	0.12–0.18	...	Ce 0.03–0.08
S30435	...	0.08	2.00	0.045	0.030	1.00	16.0–18.0	7.0–9.0	...	...	1.50–3.00	...
S30441	...	0.08	2.00	0.045	0.030	1.0–2.0	17.5–19.5	8.0–10.5	...	0.10	1.5–2.5	Cb 0.1–0.5 W 0.2–0.8
S30451	304N	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	0.10–0.16	...	...
S30452	XM-21 ^J	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	0.16–0.30	...	...
S30453	304LN	0.030	2.00	0.045	0.030	0.75	18.0–20.0	8.0–12.0	...	0.10–0.16	...	...
S30500	305	0.12	2.00	0.045	0.030	0.75	17.0–19.0	10.5–13.0	...	...	...	...
S30530	...	0.08	2.00	0.045	0.030	0.50–2.50	17.0–20.5	8.5–11.5	0.75–1.50	...	0.75–3.50	...
S30600	...	0.018	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	0.20	...	0.50	...
S30616	...	0.020	1.50	0.030	0.015	3.9–4.7	16.5–18.5	13.0–15.5	0.50	...	0.40	Cb 0.30–0.70
S30601	...	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	0.20	0.05	0.35	...
S30615	...	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	Al 0.80–1.50
S30815	...	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	...	Ce 0.03–0.08
S30908	309S	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	...	...	...	...

TABLE 1 Continued

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
S30909	309H ^G	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	...	...	...	...
S30940	309Cb ^G	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	...	...	...	Cb 10xC min, 1.10 max
S30941	309HCb ^G	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	...	...	...	Cb 10xC min, 1.10 max
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	...	...	...	...
S31009	310H ^G	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	...	...	...	...
S31040	310Cb ^G	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	...	...	...	Cb 10xC min, 1.10 max
S31041	310HCb ^G	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	...	...	...	Cb 10xC min, 1.10 max
S31050	310 MoLN ^G	0.020	2.00	0.030	0.010	0.50	24.0–26.0	20.5–23.5	1.60–2.60	0.09–0.15	...	...
S31060	...	0.05–0.10	1.00	0.040	0.030	0.50	22.0–24.0	10.0–12.5	...	0.18–0.25	...	Ce + La 0.025–0.070 B 0.001–0.010
S31254	...	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.25	0.50–1.00	...
S31266	...	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	5.2–6.2	0.35–0.60	1.00–2.50	W 1.50–2.50
S31277	...	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	0.50–1.50	...
S31600	316	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	...
S31603	316L	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	...
S31609	316H	0.04–0.10	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
S31635	316Ti ^G	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	Ti 5 × (C + N) min, 0.70 max
S31640	316Cb ^G	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	Cb 10 × C min, 1.10 max
S31651	316N	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	...	...
S31653	316LN	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	...	...
S31655	...	0.030	2.00	0.045	0.015	1.00	19.5–21.5	8.0–9.5	0.50–1.50	0.14–0.25	1.00	...
S31700	317	0.08	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	...	...
S31703	317L	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	...	...
S31725	317LM ^G	0.030	2.00	0.045	0.030	0.75	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...
S31726	317LMN ^G	0.030	2.00	0.045	0.030	0.75	17.0–20.0	13.5–17.5	4.0–5.0	0.10–0.20	...	...
S31727	...	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	0.15–0.21	2.80–4.00	...
S31730	...	0.030	2.00	0.040	0.010	1.00	17.0–19.0	15.0–16.5	3.0–4.0	0.045	4.0–5.0	...
S31753	317LN ^G	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10–0.22	...	...
S32050	...	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	0.40	...
S32053	...	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	0.17–0.22	...	...
S32100	321	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5 × (C + N) min, 0.70 max
S32109	321H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–12.0	...	...	...	Ti 4 × (C + N) min, 0.70 max
S32615	...	0.07	2.00	0.045	0.030	4.80–6.00	16.5–19.5	19.0–22.0	0.30–1.50	...	1.50–2.50	...
S32654	...	0.020	2.00–4.00	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	0.30–0.60	...
S33228	...	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	...	Ce 0.05–0.10 Cb 0.6–1.0 Al 0.025
S33400	334 ^G	0.08	1.00	0.030	0.015	1.00	18.0–20.0	19.0–21.0	...	...	...	Al 0.15–0.60 Ti 0.15–0.60
S33425	...	0.08	1.50	0.045	0.020	1.00	21.0–23.0	20.0–23.0	2.00–3.00	...	...	Al 0.15–0.60 Ti 0.15–0.60
S33550	...	0.04–0.10	1.50	0.040	0.030	1.00	25.0–28.0	16.5–20.0	...	0.18–0.25	...	Cb 0.05–0.15 La + Ce 0.025–0.070
S34565	...	0.030	5.00–7.00	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	...	Cb 0.10
S34700	347	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	Cb 10 × C min, 1.00 max

TABLE 1 Continued

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
S34709	347H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	Cb 8 × C min, 1.00 max
S34751	347LN	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	0.06–0.10	...	Cb 0.20–0.50, 15 × C min
S34800	348	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	(Cb + Ta) 10×C min, 1.00 max
S34809	348H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	Ta 0.10 Co 0.20 (Cb + Ta) 8×C min, 1.00 max
S35045	...	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	0.75	Ta 0.10 Co 0.20 Al 0.15–0.60 Ti 0.15–0.60
S35115	...	0.030	1.00	0.045	0.015	0.50–1.50	23.0–25.0	19.0–22.0	1.50–2.50	0.20–0.30	...	...
S35125	...	0.10	1.00–1.50	0.045	0.015	0.50	20.0–23.0	31.0–35.0	2.00–3.00	...	...	Cb 0.25–0.60
S35135	...	0.08	1.00	0.045	0.015	0.60–1.00	20.0–25.0	30.0–38.0	4.0–4.8	...	0.75	Ti 0.40–1.00
S35140	...	0.10	1.00–3.00	0.045	0.030	0.75	20.0–22.0	25.0–27.0	1.00–2.00	0.08–0.20	...	Cb 0.25–0.75
S35315	...	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	...	0.12–0.18	...	Ce 0.03–0.10
S38100	XM-15 ^J	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...
S38815	...	0.030	2.00	0.040	0.020	5.50–6.50	13.0–15.0	15.0–17.0	0.75–1.50	...	0.75–1.50	Al 0.30
Duplex (Austenitic-Ferritic)												
S31200	...	0.030	2.00	0.045	0.030	1.00	24.0–26.0	5.5–6.5	1.20–2.00	0.14–0.20	...	...
S31260	...	0.03	1.00	0.030	0.030	0.75	24.0–26.0	5.5–7.5	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31803	...	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.5–6.5	2.5–3.5	0.08–0.20	...	...
S32001	...	0.030	4.00–6.00	0.040	0.030	1.00	19.5–21.5	1.00–3.00	0.60	0.05–0.17	1.00	...
S32003	...	0.030	2.00	0.030	0.020	1.00	19.5–22.5	3.0–4.0	1.50–2.00	0.14–0.20	...	...
S32101	...	0.040	4.00–6.00	0.040	0.030	1.00	21.0–22.0	1.35–1.70	0.10–0.80	0.20–0.25	0.10–0.80	...
S32202	...	0.030	2.00	0.040	0.010	1.00	21.5–24.0	1.00–2.80	0.45	0.18–0.26	...	...
S32205	2205 ^G	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.5–6.5	3.0–3.5	0.14–0.20	...	...
S32304	2304 ^G	0.030	2.50	0.040	0.030	1.00	21.5–24.5	3.0–5.5	0.05–0.60	0.05–0.20	0.05–0.60	...
S32506	...	0.030	1.00	0.040	0.015	0.90	24.0–26.0	5.5–7.2	3.0–3.5	0.08–0.20	...	W 0.05–0.30
S32520	...	0.030	1.50	0.035	0.020	0.80	24.0–26.0	5.5–8.0	3.0–4.0	0.20–0.35	0.50–2.00	...
S32550	255 ^G	0.04	1.50	0.040	0.030	1.00	24.0–27.0	4.5–6.5	2.9–3.9	0.10–0.25	1.50–2.50	...
S32750	2507 ^{G,O}	0.030	1.20	0.035	0.020	0.80	24.0–26.0	6.0–8.0	3.0–5.0	0.24–0.32	0.50	...
S32760 ^K	...	0.030	1.00	0.030	0.010	1.00	24.0–26.0	6.0–8.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00
S32808	...	0.030	1.10	0.030	0.010	0.50	27.0–27.9	7.0–8.2	0.80–1.2	0.30–0.40	...	W 2.10–2.50
S32900	329	0.08	1.00	0.040	0.030	0.75	23.0–28.0	2.0–5.00	1.00–2.00	...	...	...
S32906	...	0.030	0.80–1.50	0.030	0.030	0.80	28.0–30.0	5.8–7.5	1.50–2.60	0.30–0.40	0.80	...
S32950	...	0.030	2.00	0.035	0.010	0.60	26.0–29.0	3.5–5.2	1.00–2.50	0.15–0.35	...	...
S39274	...	0.030	1.00	0.030	0.020	0.80	24.0–26.0	6.0–8.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50
S81921	...	0.030	2.00–4.00	0.040	0.030	1.00	19.0–22.0	2.0–4.0	1.00–2.00	0.14–0.20	...	...
S82011	...	0.030	2.00–3.00	0.040	0.020	1.00	20.5–23.5	1.0–2.0	0.10–1.00	0.15–0.27	0.50	...
S82012	...	0.05	2.00–4.00	0.040	0.005	0.80	19.0–20.5	0.8–1.5	0.10–0.60	0.16–0.26	1.00	...
S82013	...	0.060	2.50–3.50	0.040	0.030	0.90	19.5–22.0	0.5–1.5	...	0.20–0.30	0.20–1.20	...
S82031	...	0.05	2.50	0.040	0.005	0.80	19.0–22.0	2.0–4.0	0.60–1.40	0.14–0.24	1.00	...
S82121	...	0.035	1.00–2.50	0.040	0.010	1.00	21.0–23.0	2.0–4.0	0.30–1.30	0.15–0.25	0.20–1.20	...
S82122	...	0.030	2.0–4.0	0.040	0.020	0.75	20.5–21.5	1.5–2.5	0.60	0.15–0.20	0.50–1.50	...
S82441	...	0.030	2.50–4.00	0.035	0.005	0.70	23.0–25.0	3.0–4.5	1.00–2.00	0.20–0.30	0.10–0.80	...
Ferritic or Martensitic (Chromium)												
S32803	...	0.015	0.50	0.020	0.0035	0.55	28.0–29.0	3.0–4.0	1.80–2.50	0.020 (C+N) 0.030	...	Cb 12×(C+N) min, 0.15–0.50
S40300	403	0.15	1.00	0.040	0.030	0.50	11.5–13.0	0.60	...	...	...	...
S40500	405	0.08	1.00	0.040	0.030	1.00	11.5–14.5	0.60	...	...	...	Al 0.10–0.30
S40900 ^L	409 ^L	...	...	...	...	...	...	...	...	...	...	...

TABLE 1 Continued

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
S40910	...	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	...	0.030	...	Ti 6×(C+N) min, 0.50 max; Cb 0.17
S40920	...	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	...	0.030	...	Ti 8×(C+N) min, Ti 0.15–0.50; Cb 0.10
S40930	...	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	...	0.030	...	(Ti+Cb) [0.08+8×(C+N)] min, 0.75 max; Ti 0.05 min
S40945	...	0.030	1.00	0.040	0.030	1.00	10.5–11.7	0.50	...	0.030	...	Cb 0.18–0.40
S40975	...	0.030	1.00	0.040	0.030	1.00	10.5–11.7	0.50–1.00	...	0.030	...	Ti 0.05–0.20
S40977	...	0.030	1.50	0.040	0.015	1.00	10.5–12.5	0.30–1.00	...	0.030	...	Ti 6×(C+N) min, 0.75 max
S41000	410	0.08–0.15	1.00	0.040	0.030	1.00	11.5–13.5	0.75	...	...	...	...
S41003	...	0.030	1.50	0.040	0.030	1.00	10.5–12.5	1.50	...	0.030	...	...
S41008	410S	0.08	1.00	0.040	0.030	1.00	11.5–13.5	0.60	...	...	...	...
S41045	...	0.030	1.00	0.040	0.030	1.00	12.0–13.0	0.50	...	0.030	...	Cb 9×(C+N) min, 0.60 max
S41050	...	0.04	1.00	0.045	0.030	1.00	10.5–12.5	0.60–1.10	...	0.10	...	...
S41500 ^M	...	0.05	0.50–1.00	0.030	0.030	0.60	11.5–14.0	3.5–5.5	0.50–1.00	...	...	...
S42000	420	0.15 min	1.00	0.040	0.030	1.00	12.0–14.0	0.75	0.50	...	...	...
S42035	...	0.08	1.00	0.045	0.030	1.00	13.5–15.5	1.0–2.5	0.2–1.2	...	...	Ti 0.30–0.50
S42200	422	0.20–0.25	0.50–1.00	0.025	0.025	0.50	11.0–12.5	0.50–1.00	0.90–1.25	...	...	V 0.20–0.30, W 0.90–1.25
S42900	429 ^G	0.12	1.00	0.040	0.030	1.00	14.0–16.0	...	...	...	...	...
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0–18.0	0.75	...	...	...	...
S43035	439	0.030	1.00	0.040	0.030	1.00	17.0–19.0	0.50	...	0.030	...	Ti [0.20+4(C+N)] min, 1.10 max; Al 0.15
S43037	...	0.030	1.00	0.040	0.030	1.00	16.0–19.0	...	...	...	...	Ti 0.10–1.00
S43100	431	0.20	1.00	0.040	0.030	1.00	15.0–17.0	1.25–2.50	...	...	...	...
S43400	434	0.12	1.00	0.040	0.030	1.00	16.0–18.0	...	0.75–1.25	...	...	...
S43600	436	0.12	1.00	0.040	0.030	1.00	16.0–18.0	...	0.75–1.25	...	...	Cb 5×C min, 0.80 max
S43932	...	0.030	1.00	0.040	0.030	1.00	17.0–19.0	0.50	...	0.030	...	(Ti+Cb) [0.20+4(C+N)] min, 0.75 max; Al 0.15
S43940	...	0.030	1.00	0.040	0.015	1.00	17.5–18.5	...	...	...	...	Ti 0.10–0.60 Cb [0.30+(3×C)] min
S44100	...	0.030	1.00	0.040	0.030	1.00	17.5–19.5	1.00	...	0.030	...	Ti 0.1–0.5 Cb [0.3 + (9× C)] min, 0.90 max
S44200	442	0.20	1.00	0.040	0.040	1.00	18.0–23.0	0.60	...	...	...	...
S44330	...	0.025	1.00	0.040	0.030	1.00	20.0–23.0	...	...	0.025	0.30–0.80	(Ti+Cb) 8×(C+N) min, 0.80 max
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	...	(Ti+Cb)[0.20+4(C+N)] min, 0.80 max
S44500	...	0.020	1.00	0.040	0.012	1.00	19.0–21.0	0.60	...	0.03	0.30–0.60	Cb 10×(C+N) min, 0.80 max
S44535	...	0.030	0.30–0.80	0.050	0.020	0.50	20.0–24.0	...	...	...	0.50	La 0.04–0.20 Ti 0.03–0.20 Al 0.50

TABLE 1 Continued

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
S44536	...	0.015	1.00	0.040	0.030	1.00	20.0–23.0	0.5	...	0.015	...	(Ti+Cb) 8X(C+N)–0.8, Cb min 0.05
S44537	...	0.030	0.8	0.050	0.006	0.1–0.6	20.0–24.0	0.5	...	0.04	0.5	Al 0.1 W 1.0–3.0 Cb 0.2–1.0 Ti 0.02–0.20 La 0.04–0.20 Ti 0.20–1.00; Ti 7(C+N) min Cb 0.05–0.20 (Ni + Cu) 0.50 (Ti+Cb) [0.20+4 (C+N)] min, 0.80 max
S44626	XM-33 ^J	0.06	0.75	0.040	0.020	0.75	25.0–27.0	0.50	0.75–1.50	0.04	0.20	...
S44627	XM-27 ^J	0.010 ^N	0.40	0.020	0.020	0.40	25.0–27.5	0.50	0.75–1.50	0.015 ^N	0.20	...
S44635	...	0.025	1.00	0.040	0.030	0.75	24.5–26.0	3.5–4.5	3.5–4.5	0.035	...	...
S44600	446	0.20	1.50	0.040	0.030	1.00	23.0–27.0	0.75	...	0.25	...	...
S44660	...	0.030	1.00	0.040	0.030	1.00	25.0–28.0	1.0–3.5	3.0–4.0	0.040	...	(Ti+Cb) 0.20 – 1.00, Ti + Cb 6x(C+N) min (C+N) 0.025 (Ti+Cb) ≥8x(C+N) (Ti+Cb) 0.20–1.00, (Ti+Cb) 6x (C+N) min (C+N) 0.025 Ti 0.07–0.30 Cb 0.10–0.60 (Ti+Cb) [0.20+4 (C+N)] min, 0.80 max
S44700	...	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	3.5–4.2	0.020	0.15	...
S44725	...	0.015	0.40	0.040	0.020	0.040	25.0–28.5	0.30	1.5–2.5	0.018	...	...
S44735	...	0.030	1.00	0.040	0.030	1.00	28.0–30.0	1.00	3.6–4.2	0.045	...	...
S44800	...	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.00–2.50	3.5–4.2	0.020	0.15	...
S46800	...	0.030	1.00	0.040	0.030	1.00	18.0–20.0	0.50	...	0.030	...	...

^A Maximum, unless range or minimum is indicated. Where ellipses (. . .) appear in this table, there is no requirement and the element need not be determined or reported.

^B Designation established in accordance with Practice E527 and SAE J 1086.

^C Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).

^D Carbon analysis shall be reported to nearest 0.01 % except for the low-carbon types, which shall be reported to nearest 0.001 %.

^E The terms Columbium (Cb) and Niobium (Nb) both relate to the same element.

^F When two minimums or two maximums are listed for a single type, as in the case of both a value from a formula and an absolute value, the higher minimum or lower maximum shall apply.

^G Common name, not a trademark, widely used, not associated with any one producer.

^H Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

^I (Al + Ti) 0.85–1.20.

^J Naming system developed and applied by ASTM.

^K Cr + 3.3 Mo + 16 N = 40 min.

^L S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.

^M Plate version of CA-6NM.

^N Product (check or verification) analysis tolerance over the maximum limit for C and N in XM-27 shall be 0.002 %.

^O Cr + 3.3 Mo + 16 N = 41 min.

TABLE 2 Mechanical Test Requirements

UNS Designation	Type ^A	Tensile Strength, min		Yield Strength, ^B min		Elongation in 2 in. or 50 mm, min, %	Hardness, max ^C		Cold Bend ^D
		ksi	MPa	ksi	MPa		Brinell, HBW	Rockwell	
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)									
N08020	...	80	550	35	240	30 ^E	217	95 HRBW	not required
N08367	...	...	...	...	...	...	...	...	...
Sheet and Strip		100	690	45	310	30	...	100 HRBW	not required
Plate		95	655	45	310	30	241	...	not required
N08700	...	80	550	35	240	30	192	90 HRBW	not required
N08800	800 ^F	75	520	30 ^G	205 ^G	30 ^H	...	...	not required
N08810	800H ^F	65	450	25 ^G	170 ^G	30	...	...	not required
N08811	...	65	450	25	170	30	...	...	not required
N08904	904L ^F	71	490	31	220	35	...	90 HRBW	not required
N08925	...	87	600	43	295	40	...	...	not required
N08926	...	94	650	43	295	35	...	...	not required
S20100	201-1 ^I	75	515	38	260	40	217	95 HRBW	...
S20100	201-2 ^I	95	655	45	310	40	241	100 HRBW	...
S20103	201L ^F	95	655	38	260	40	217	95 HRBW	not required
S20153	201LN ^F	95	655	45	310	45	241	100 HRBW	not required
S20161	...	125	860	50	345	40	255	25 HRC	not required
S20200	202	90	620	38	260	40	241	...	...
S20400	...	95	655	48	330	35	241	100 HRBW	not required
S20431	...	90	620	45	310	40	241	100 HRBW	not required
S20432	...	75	515	30	205	40	201	92 HRBW	not required
S20433	...	80	550	35	240	40	217	95 HRBW	not required
S20910	XM-19 ^J	...	...	...	...	...	...	...	...
Sheet and Strip		105	725	60	415	30	241	100 HRBW	not required
Plate		100	690	55	380	35	241	100 HRBW	not required
S21600	XM-17 ^J	...	...	...	...	...	...	...	...
Sheet and Strip		100	690	60	415	40	241	100 HRBW	not required
Plate		90	620	50	345	40	241	100 HRBW	not required
S21603	XM-18 ^J	...	...	...	...	...	...	...	...
Sheet and Strip		100	690	60	415	40	241	100 HRBW	not required
Plate		90	620	50	345	40	241	100 HRBW	not required
S21640	...	95	650	45	310	40	...	...	not required
S21800	...	95	655	50	345	35	241	100 HRBW	not required
S21904	XM-11 ^J	...	...	...	...	...	...	...	...
Sheet and Strip		100	690	60	415	40	241	100 HRBW	not required
Plate		90	620	50	345	45	241	100 HRBW	not required
S24000	XM-29 ^J	...	...	...	...	...	...	...	...
Sheet and Strip		100	690	60	415	40	241	100 HRBW	not required
Plate		100	690	55	380	40	241	100 HRBW	not required
S30100	301	75	515	30	205	40	217	95 HRBW	not required
S30103	301L ^F	80	550	32	220	45	241	100 HRBW	not required
S30153	301LN ^F	80	550	35	240	45	241	100 HRBW	not required
S30200	302	75	515	30	205	40	201	92 HRBW	not required
S30400	304	75	515	30	205	40	201	92 HRBW	not required
S30403	304L	70	485	25	170	40	201	92 HRBW	not required
S30409	304H	75	515	30	205	40	201	92 HRBW	not required
S30415	...	87	600	42	290	40	217	95 HRBW	not required
S30435	...	65	450	23	155	45	187	90 HRBW	...

TABLE 2 Continued

UNS Designation	Type ^A	Tensile Strength, min		Yield Strength, ^B min		Elongation in 2 in. or 50 mm, min, %	Hardness, max ^C		Cold Bend ^D
		ksi	MPa	ksi	MPa		Brinell, HBW	Rockwell	
S30441	...	75	515	30	205	40	201	92 HRBW	not required
S30451	304N	80	550	35	240	30	217	95 HRBW	not required
S30452	XM-21 ^J								
	Sheet and Strip	90	620	50	345	30	241	100 HRBW	not required
	Plate	85	585	40	275	30	241	100 HRBW	not required
S30453	304LN	75	515	30	205	40	217	95 HRBW	not required
S30500	305	70	485	25	170	40	183	88 HRBW	not required
S30530	...	75	515	30	205	40	201	92 HRBW	not required
S30600	...	78	540	35	240	40	...	...	...
S30616	...	86	590	36	245	40	241	100 HRBW	not required
S30601	...	78	540	37	255	30	...	...	not required
S30615	...	90	620	40	275	35	217	95 HRBW	not required
S30815	...	87	600	45	310	40	217	95 HRBW	...
S30908	309S	75	515	30	205	40	217	95 HRBW	not required
S30909	309H ^F	75	515	30	205	40	217	95 HRBW	not required
S30940	309Cb ^F	75	515	30	205	40	217	95 HRBW	not required
S30941	309HCb ^F	75	515	30	205	40	217	95 HRBW	not required
S31008	310S	75	515	30	205	40	217	95 HRBW	not required
S31009	310H ^F	75	515	30	205	40	217	95 HRBW	not required
S31040	310Cb ^F	75	515	30	205	40	217	95 HRBW	not required
S31041	310HCb ^F	75	515	30	205	40	217	95 HRBW	not required
S31050	310 MoLN ^F								
	t ≤ 0.25 in.	84	580	39	270	25	217	95 HRBW	not required
	t > 0.25 in.	78	540	37	255	25	217	95 HRBW	not required
S31060	...	87	600	41	280	40	217	95 HRBW	not required
S31254									
	Sheet and Strip	100	690	45	310	35	223	96 HRBW	not required
	Plate	95	655	45	310	35	223	96 HRBW	not required
S31266	...	109	750	61	420	35	...	...	not required
S31277	...	112	770	52	360	40	...	...	not required
S31600	316	75	515	30	205	40	217	95 HRBW	not required
S31603	316L	70	485	25	170	40	217	95 HRBW	not required
S31609	316H	75	515	30	205	40	217	95 HRBW	not required
S31635	316Ti ^F	75	515	30	205	40	217	95 HRBW	not required
S31640	316Cb ^F	75	515	30	205	30	217	95 HRBW	not required
S31651	316N	80	550	35	240	35	217	95 HRBW	not required
S31653	316LN	75	515	30	205	40	217	95 HRBW	not required
S31655	...	92	635	45	310	35	241	100 HRBW	not required
S31700	317	75	515	30	205	35	217	95 HRBW	not required
S31703	317L	75	515	30	205	40	217	95 HRBW	not required
S31725	317LM ^F	75	515	30	205	40	217	95 HRBW	not required
S31726	317LMN ^F	80	550	35	240	40	223	96 HRBW	not required
S31727	...	80	550	36	245	35	217	96 HRBW	not required
S31730	...	70	480	25	175	35	...	90 HRBW	not required
S31753	317LN	80	550	35	240	40	217	95 HRBW	not required
S32050	...	98	675	48	330	40	250	...	not required
S32053	...	93	640	43	295	40	217	96 HRBW	not required
S32100	321	75	515	30	205	40	217	95 HRBW	not required
S32109	321H	75	515	30	205	40	217	95 HRBW	not required
S32615 ^K	...	80	550	32	220	25	...	...	not required

TABLE 2 Continued

UNS Designation	Type ^A	Tensile Strength, min		Yield Strength, ^B min		Elongation in 2 in. or 50 mm, min, %	Hardness, max ^C		Cold Bend ^D
		ksi	MPa	ksi	MPa		Brinell, HBW	Rockwell	
S32654	...	109	750	62	430	40	250	...	not required
S33228	...	73	500	27	185	30	217	95 HRBW	not required
S33400	334 ^F	70	485	25	170	30	...	92 HRBW	not required
S33425	...	75	515	30	205	40	...	...	not required
S33550	...	87	600	41	280	35	217	95 HRBW	not required
S34565	...	115	795	60	415	35	241	100 HRBW	not required
S34700	347	75	515	30	205	40	201	92 HRBW	not required
S34709	347H	75	515	30	205	40	201	92 HRBW	not required
S34751	347LN	75	515	30	205	40	201	92 HRBW	not required
S34800	348	75	515	30	205	40	201	92 HRBW	not required
S34809	348H	75	515	30	205	40	201	92 HRBW	not required
S35045	...	70	485	25	170	35	...	...	not required
S35115	...	85	585	40	275	40	241	100 HRBW	not required
S35125	...	70	485	30	205	35	...	...	not required
S35135	...	...	...	...	...	...	...	...	...
Sheet and Strip	...	80	550	30	205	30	...	...	not required
Plate	...	75	515	30	205	30	...	...	not required
S35140	...	90	620	40	275	30	241	100 HRBW	not required
S35315	...	94	650	39	270	40	217	95 HRBW	not required
S38100	XM-15 ^J	75	515	30	205	40	217	95 HRBW	not required
S38815	...	78	540	37	255	30	...	...	not required
Duplex (Austenitic-Ferritic)									
S31200	...	100	690	65	450	25	293	31 HRC	not required
S31260	...	100	690	70	485	20	290	...	...
S31803	...	90	620	65	450	25	293	31 HRC	not required
S32001	...	90	620	65	450	25	...	25 HRC	not required
S32003	...	...	...	...	...	...	...	...	...
	t ≤ 0.187 in. [5.00 mm]	100	690	70	485	25	293	31 HRC	not required
	t > 0.187 in. [5.00 mm]	95	655	65	450	25	293	31 HRC	not required
S32101	...	...	...	...	...	...	...	...	...
	t ≤ 0.187 in. [5.00 mm]	101	700	77	530	30	290	31 HRC	not required
	t > 0.187 in. [5.00 mm]	94	650	65	450	30	290	31 HRC	not required
S32202	...	94	650	65	450	30	290	31 HRC	not required
S32205	2205 ^F	95	655	65	450	25	293	31 HRC	not required
S32304	2304 ^F	87	600	58	400	25	290	32 HRC	not required
S32506	...	90	620	65	450	18	302	32 HRC	not required
S32520	...	112	770	80	550	25	310	32 HRC	not required
S32550	255 ^F	110	760	80	550	15	302	32 HRC	not required
S32750	2507 ^F	116	795	80	550	15	310	32 HRC	not required
S32760	...	108	750	80	550	25	310	32 HRC ^R	not required
S32808	...	101	700	72	500	15	310	32 HRC	not required
S32900	329	90	620	70	485	15	269	28 HRC	not required
S32906	...	116	800	94	650	25.0	310	32 HRC	not required
	t < 0.4 in. [10.0 mm]	...	...	...	...	...	...	...	...
	t ≥ 0.4 in. [10.0 mm]	109	750	80	550	25.0	310	32 HRC	not required

TABLE 2 Continued

UNS Designation	Type ^A	Tensile Strength, min		Yield Strength, ^B min		Elongation in 2 in. or 50 mm, min, %	Hardness, max ^C		Cold Bend ^D
		ksi	MPa	ksi	MPa		Brinell. HBW	Rockwell	
S32950 ^L	...	100	690	70	485	15	293	32 HRC	not required
S39274	...	116	800	80	550	15	310	32 HRC	not required
S81921	...	90	620	65	450	25	293	31 HRC	not required
S82011	...	101	700	75	515	30	293	31 HRC	not required
	t ≤ 0.187 in. [5.00 mm]								
	t > 0.187 in. [5.00 mm]	95	655	65	450	30	293	31 HRC	not required
S82012	t > 0.187 in. [5.00 mm]	94	650	58	400	35	290		
	t ≤ 0.187 in. [5.00 mm]	102	700	73	500	35		31 HRC	not required
S82013	...	90	620	65	450	30	293	31 ^J	not required
S82031	t > 0.187 in. [5.00 mm]	94	650	58	400	35	290		not required
	t ≤ 0.187 in. [5.00 mm]	102	700	73	500	35		31 HRC	not required
S82121	...	94	650	65	450	25	286	30 HRC	not required
S82122	t < 0.118 in. [3.00 mm]	101	700	72	500	25	290	32 HRC	not required
	t ≥ 0.118 in. [3.00 mm]	87	600	58	400	30	290	32 HRC	not required
S82441	...								
	t < 0.4 in. [10.0 mm]	107	740	78	540	25	290	31 HRC	not required
	t ≥ 0.4 in. [10.0 mm]	99	680	70	480	25	290	31 HRC	not required
Ferritic or Martensitic (Chromium)									
S32803	...	87	600	72	500	16	241	100 HRBW	not required
S40300	403	70	485	30	205	25 ^N	217	96 HRBW	180
S40500	405	60	415	25	170	20	179	88 HRBW	180
S40900 ^M	409 ^M								
S40910	...	55	380	25	170	20	179	88 HRBW	180
S40920	...	55	380	25	170	20	179	88 HRBW	180
S40930	...	55	380	25	170	20	179	88 HRBW	180
S40945	...	55	380	30	205	22	...	80 HRBW	180
S40975	...	60	415	40	275	20	197	92 HRBW	180
S40977	...	65	450	41	280	18	180	88 HRBW	not required
S41000	410	65	450	30	205	20	217	96 HRBW	180
S41003	...	66	455	40	275	18	223	20 HRC	not required
S41008	410S	60	415	30	205	22 ^N	183	89 HRBW	180
S41045	...	55	380	30	205	22	...	80 HRBW	180
S41050	...	60	415	30	205	22	183	89 HRBW	180
S41500	...	115	795	90	620	15	302	32 HRC	not required
S42000	420	100 ^Q	690 ^Q	...	...	15	217	96 HRBW	not required
S42035	...	80	550	55	380	16	180	88 HRBW	not required
S42200	422	...	...	...	...	...	248	24 HRC	not required
S42900	429 ^F	65	450	30	205	22 ^N	183	89 HRBW	180
S43000	430	65	450	30	205	22 ^N	183	89 HRBW	180
S43035	439	60	415	30	205	22	183	89 HRBW	180

TABLE 2 Continued

UNS Designation	Type ^A	Tensile Strength, min		Yield Strength, ^B min		Elongation in 2 in. or 50 mm, min, %	Hardness, max ^C		Cold Bend ^D
		ksi	MPa	ksi	MPa		Brinell, HBW	Rockwell	
S43037	...	50	360	30	205	22	183	89	180
S43100	431	...	...	...	...	...	285	29 HRC	not required
S43400	434	65	450	35	240	22	...	89 HRBW	180
S43600	436	65	450	35	240	22	...	89 HRBW	180
S43932	...	60	415	30	205	22	183	89 HRBW	180
S43940	...	62	430	36	250	18	180	88 HRBW	not required
S44330	...	56	390	30	205	22	187	90 HRBW	not required
S44100	...	60	414	35	241	20	190	90 HRBW	not required
S44200	442	65	515	40	275	20	217	96 HRBW	180
S44400	...	60	415	40	275	20	217	96 HRBW	180
S44500	...	62	427	30	205	22	...	83 HRBW	180
S44535	...	58	400	36	250	25 ^E	...	90 ^O HRBW	not required
S44536	...	60	410	35	245	20	192	90 HRBW	180
S44537	...	65	450	46	320	18 ^P	200	93 HRBW	180
S44600	446	65	515	40	275	20	217	96 HRBW	135
S44626	XM-33 ^J	68	470	45	310	20	217	96 HRBW	180
S44627	XM-27 ^J	65	450	40	275	22	187	90 HRBW	180
S44635	...	90	620	75	515	20	269	28 HRC	180
S44660	...	85	585	65	450	18	241	100 HRBW	180
S44700	...	80	550	60	415	20	223	20 HRC	180
S44725	...	65	450	40	275	20	210	95 HRBW	180
S44735	...	80	550	60	415	18	255	25 HRC	180
S44800	...	80	550	60	415	20	223	20 HRC	180
S46800	...	60	415	30	205	22	...	90 HRBW	180

^A Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).

^B Yield strength shall be determined by the offset method at 0.2 % in accordance with Test Methods and Definitions A370. Unless otherwise specified (see Specification A480/A480M, paragraph 4.1.11, Ordering Information), an alternative method of determining yield strength may be based on total extension under load of 0.5 %.

^C Either Brinell or denoted Rockwell Hardness scale is permissible. For thin materials, see Specification A480/A480M (17.2.1) and Test Methods A370 (18.1.2) on superficial testing.

^D Bend tests are not required for chromium steels (ferritic or martensitic) thicker than 1 in. [25 mm] or for austenitic or duplex (austenitic-ferritic) stainless steels regardless of thickness.

^E Elongation for thickness, less than 0.015 in. [0.38 mm] shall be 20 % minimum, in 1 in. [25.4 mm].

^F Common name, not a trademark, widely used, not associated with any one producer.

^G Yield strength requirements shall not apply to material under 0.020 in [0.50 mm] in thickness.

^H Not applicable for thicknesses under 0.010 in. [0.25 mm].

^I Type 201 is generally produced with a chemical composition balanced for rich side (Type 201-1) or lean side (Type 201-2) austenite stability depending on the properties required for specific applications.

^J Naming system developed and applied by ASTM.

^K For S32615, the grain size as determined in accordance with the Test Methods E112, Comparison Method, Plate II, shall be No. 3 or finer.

^L Prior to Specification A240 – 89b, the tensile value for S32950 was 90 ksi.

^M S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.

^N Material 0.050 in [1.27 mm] and under in thickness shall have a minimum elongation of 20 %.

^O Hardness is required to be provided for information only, but is not required to meet a particular requirement.

^P The minimum elongation for plates thicker than 0.630 in. (16 mm) shall be 8 %.

^Q Maximum. Type 420 is usually used in the heat-treated condition (quenched and tempered to a specific range of hardness or tensile strength).

^R Hardness conversion tables for superduplex stainless steels do not exist in ASTM E140. The conversion value from HBW to HRC has been added to maintain consistency with other ASTM standards for these superduplex stainless steels.

SUPPLEMENTARY REQUIREMENTS

A supplementary requirement shall apply only when specified in the purchase order.

S1. Charpy Impact Testing of Plate

S1.1 Charpy impact tests shall be conducted in accordance with Test Methods and Definitions A370.

S1.2 *Number of Tests*—One impact test (three specimens) shall be made from one plate per heat treatment lot in the final heat treated condition.

S1.3 *Orientation of Test Specimens*—Unless specified as transverse specimens (long axis of the specimen transverse to the final rolling direction, root of the notch perpendicular to the rolling face) on the purchase order, the orientation of the specimens shall be longitudinal (long axis of the specimen parallel to the final rolling direction, root of the notch perpendicular to the rolling face). The manufacturer is permitted to test transverse specimens provided that such tests meet the acceptance criteria applicable to longitudinal specimens. Unless otherwise specified on the purchase order, the specimens shall be taken so as to include the mid-thickness of the product.

S1.4 *Test Temperature*—The purchaser shall specify the test temperature. The manufacturer is permitted to test specimens at a temperature lower than that specified by the purchaser, provided that such tests shall meet the acceptance criteria applicable to specimens tested at the specified temperature (see the note below).

NOTE S1.1—Test Methods A923, Method B, applicable to some duplex (austenitic-ferritic) stainless steels as listed in Test Methods A923, uses a Charpy impact test for the purpose of determining the absence of detrimental intermetallic phases. Method B specifies a test temperature and acceptance criterion, expressed as impact energy, for each type of steel covered. It may be economical for the Charpy impact tests performed on duplex stainless steels covered in both Specification A240 and Test Methods A923 to be performed at the lower of the temperatures specified by this supplementary requirement and Test Methods A923 Method B, with measurement of both lateral expansion and impact energy.

S1.5 *Acceptance Limit*—Unless otherwise specified on the purchase order, each of the three specimens tested shall show a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

S1.6 *Records*—The recorded results shall include the specimen orientation, specimen size, test temperature, absorbed energy values (if required), and lateral expansion opposite the notch.

S2. Materials for High-Temperature Service

S2.1 Unless an H grade has been ordered, this supplementary requirement shall be specified for ASME Code applications for service above 1000°F [540°C].

S2.2 The user is permitted to use an austenitic stainless steel as the corresponding H grade when the material meets all requirements of the H grade including chemistry, annealing temperature, and grain size (see Section 6).

S2.3 The user is permitted to use an L grade austenitic stainless steel for service above 1000°F [540°C], subject to the applicable allowable stress table of the ASME Code, when the material meets all requirements of this specification and the grain size is ASTM No. 7 or coarser as determined in accordance with Test Methods E112. The grain size shall be reported on a Certified Test Report.

S3. One Percent Offset Yield Strength

S3.1 If reporting of 1 % offset yield strength is specified on the purchase order; the material shall meet the strength requirements shown in Table S3.1.

S3.2 The mechanical properties, including 1 % offset yield strength and all other required properties shall be reported on a Material Test Report.

TABLE S3.1 Tensile and Yield Strength Requirements

NOTE 1—These values apply only for material of 1.5 inches (38 mm) nominal thickness or less.

UNS	Grade	Tensile Strength, min., Ksi [MPa]	0.2 % Offset Yield Strength, Min., Ksi [MPa]	1 % Offset Yield Strength, Min., Ksi [MPa]
S31603	316L	70 [485]	25 [170]	38 [260]
S31600	316	75 [515]	30 [205]	38 [260]
S31653	316LN	75 [515]	30 [205]	46 [320]
S30403	304L	70 [485]	25 [170]	35 [240]
S30400	304	75 [515]	30 [205]	36 [250]
S30453	304LN	75 [515]	30 [205]	45 [310]
S30451	304N	80 [550]	35 [240]	45 [310]
S32100	321	75 [515]	30 [205]	35 [240]

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SPECIFICATION FOR WELDED AUSTENITIC STEEL BOILER, SUPERHEATER, HEAT-EXCHANGER, AND CONDENSER TUBES



SA-249/SA-249M

(21)

(Identical with ASTM Specification A249/A249M-16a except for deletion of S5, which allows lower mechanical properties, and for Section I only, S9 is mandatory when 100% joint efficiency is required; title for Supplementary Requirement S9 is revised.)

Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat- Exchanger, and Condenser Tubes

1. Scope

1.1 This specification covers nominal-wall-thickness welded tubes and heavily cold worked welded tubes made from the austenitic steels listed in Table 1, with various grades intended for such use as boiler, superheater, heat exchanger, or condenser tubes.

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309S, TP309Cb, TP310S, TP310Cb, TP316, TP321, TP347, and TP348, and are intended for high-temperature service such as for superheaters and reheaters.

1.3 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{8}$ in. [3.2 mm] in inside diameter to 12 in. [304.8 mm] in outside diameter and 0.015 to 0.320 in. [0.4 to 8.1 mm], inclusive, in wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.5 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.7 The following safety hazards caveat pertains only to the test method described in the Supplementary Requirements of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific warning statement is given in Supplementary Requirement S7, Note S7.1.

2. Referenced Documents

2.1 ASTM Standards:

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E112 Test Methods for Determining Average Grain Size

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 ASME Boiler and Pressure Vessel Code:
Section VIII

2.3 Other Standard:

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

TABLE 1 Chemical Requirements, %^A

Grade	UNS Designation ^B	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^C	Copper	Other
TP 201	S20100	0.15	5.50–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...	...
TP 201LN	S20153	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	...	0.10–0.25	1.00	...
TP 202	S20200	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	0.25	...	...
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	...	Nb ^G 0.10–0.30 V 0.10–0.30
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	...	0.20–0.40	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...
TP304L ^D	S30403	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...
...	S30415	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	...	0.12–0.18	...	Ce 0.03–0.08
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...
TP304LN ^D	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...
TP305	S30500	0.12	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...	...
...	S30615	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	...
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	...	Ce 0.03–0.08
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...

Grade	UNS Designation ^B	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^C	Copper	Other
...	S30601	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	0.20	0.05	0.35	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	...	Nb 10x C-1.10
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	...	Nb 10x C-1.10
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	18.0–22.0	...	...	...	Nb 10x C-1.10
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	Nb 10x C-1.10
...	S31050	0.030	2.00	0.030	0.015	0.40	24.0–26.0	21.0–23.0	2.00–3.00	0.10–0.16	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.25	0.50–1.00	...
...	S31266	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	5.2–6.2	0.35–0.60	1.00–2.50	W 1.50–2.50
...	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	0.50–1.50	...
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316L ^D	S31603	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
TP316LN ^D	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
...	S31655	0.030	2.00	0.045	0.015	1.00	19.5–21.5	8.0–9.5	0.50–1.50	0.14–0.25	1.00	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	...	...	...	...
TP317L	S31703	0.030	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...

Grade	UNS Designation ^B	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^C	Copper	Other
...	S31725	0.030	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...
...	S31726	0.030	2.00	0.045	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	0.10–0.20	...	...
...	S31727	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	0.15–0.21	2.8–4.0	...
...	S32050	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	0.40	...

TABLE 1 Continued

...	S32053	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	0.17–0.22	...	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)-0.70
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)-0.70
...	S32615	0.07	2.00	0.045	0.030	4.80–6.00	16.5–19.5	19.0–22.0	0.30–1.50	...	1.50–2.50	...
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	0.30–0.60	...
...	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–333.0	...	...	...	Nb 0.60–1.00 Ce 0.05–0.10 Al0.025 Nb 0.10
...	S34565	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	...	Nb 10xC-1.10
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Nb 8xC-1.10
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Nb+Ta) 10xC-1.10 Ta 0.10 Co 0.20
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Nb+Ta) 8xC-1.10 Ta 0.10 Co 0.20
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Al 0.15–0.60 Ti 0.15–0.60
...	S35045	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...
...	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	...	0.75–1.50	Al 0.30 max
Alloy 20	N08020	0.070	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	2.00–3.00	...	3.00–4.00	Nb 8 × C min. to 1.00 max
...	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	0.75	...
800	N08800	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60 Fe ^E 39.5 min
800H	N08810	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60 Fe ^E 39.5 min

TABLE 1 *Continued*

...	N08811	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.25–0.60 ^F Ti 0.25–0.60 ^F Fe ^E 39.5 min
...	N08926	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.15–0.25	0.50–1.50	...
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10	1.00–2.00	...

^A Maximum, unless otherwise indicated.

^B New designation established in accordance with Practice E527 and SAE J1086.

^C The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

^D For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in Grades TP 304L and TP 316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall are those less than 0.049 in. [1.2 mm] in minimum wall thickness.

^E Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

^F (Al + Ti) = 0.85 to 1.20.

^G The term Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

- 3.1.1 Quantity (feet, metres, or number of lengths),
- 3.1.2 Name of material welded tubes (WLD) or heavily cold worked tubes (HCW),
- 3.1.3 Grade (Table 1),
- 3.1.4 Size (outside diameter and nominal wall thickness),
- 3.1.5 Length (specific or random),
- 3.1.6 Optional requirements (13.6),
- 3.1.7 Test report required (see Certification Section of Specification A1016/A1016M),
- 3.1.8 Specification designation, and
- 3.1.9 Special requirements and any supplementary requirements selected.
- 3.1.9.1 If Supplementary Requirement S7 is specified, include weld decay ratio per S11.1.1.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A1016/A1016M, unless otherwise provided herein.

5. Manufacture

5.1 The welded (WLD) tubes shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

5.1.1 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both weld and base metal or in weld metal only. The method of cold working may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

5.1.2 Heavily cold worked (HCW) tubes shall be made by applying cold working of not less than 35 % reduction in both wall and weld to a welded tube prior to the final anneal. No filler metal shall be used in the making of the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW 51.

6. Heat Treatment

6.1 All material shall be furnished in the heat-treated condition in accordance with the requirements of Table 2.

6.2 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S4).

6.3 N08020 shall be supplied in the stabilization treatment condition.

7. Chemical Composition

7.1 The heat analysis shall conform to the requirements as to chemical composition given in Table 1.

8. Product Analysis

8.1 An analysis of either one length of flat-rolled stock or one tube shall be made for each heat. The chemical composition thus determined shall conform to the requirements given in Section 7.

8.2 A product analysis tolerance of Table A1.1 in Specification A480/A480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

8.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (See 13.9.1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

9. Tensile Requirements

9.1 The material shall conform to the tensile properties prescribed in Table 3.

10. Hardness Requirements

10.1 The tubes shall have a Rockwell hardness number not exceeding the values specified in Table 3.

11. Reverse-Bend Test Requirement

11.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks, or of overlaps resulting from the reduction in thickness of the weld areas by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

NOTE 1—The reverse bend test is not applicable when the specified wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions the reverse flattening test of Specification A1016/A1016M shall apply.

12. Grain Size Requirement

12.1 The grain size of Grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E112, shall be No. 6 or coarser.

12.2 The grain size of Grades TP304H, TP316H, TP321H, TP347H and TP348H, as determined in accordance with Test Methods E112, shall be No. 7 or coarser.

TABLE 2 Heat Treatment Requirements

Grade	UNS Number	Solutioning Temperature, min or range	Quenching Method
All grades not individually listed below		1900 °F [1040 °C]	A
...	S30601	2010 to 2140 °F [1100 to 1170 °C]	B
...	S30815	1920 °F [1050 °C]	B
TP309HCb	S30941	1900 °F [1040 °C] ^C	B
TP310H	S31009	1900 °F [1040 °C]	B
TP310HCb	S31041	1900 °F [1040 °C] ^C	B
...	S31254	2100 °F [1150 °C]	B
...	S31266	2100 °F [1150 °C]	B
...	S31277	2050 °F [1120 °C]	B
TP316H	S31609	1900 °F [1040 °C]	B
...	S31727	1975 °F [1080 °C]– 2155 °F [1180 °C]	B
...	S32053	1975 °F [1080 °C]– 2155 °F [1180 °C]	B
TP321	S32100	1900 °F [1040 °C] ^C	B
TP321H	S32109	2000 °F [1100 °C] ^C	B
...	S32654	2100 °F [1150 °C]	B
...	S33228	2050 °F [1120 °C]	B
...	S34565	2050 °F [1120 °C]– 2140 °F [1170 °C]	B
TP347	S34700	1900 °F [1040 °C] ^C	B
TP347H	S34709	2000 °F [1100 °C] ^C	B
TP348	S34800	1900 °F [1040 °C] ^C	B
TP348H	S34809	2000 °F [1100 °C] ^C	B
...	S35045	2000 °F [1100 °C]	D
...	S38815	1950 °F [1065 °C]	B
Alloy 20	N08020	1700–1850 °F [925–1010 °C] stabilization treatment	B
...	N08367	2025 °F [1110 °C]	B
800	N08800	1900 °F [1040 °C]	B
800H	N08810	2050 °F [1120 °C]	B
...	N08811	2100 °F [1150 °C]	B
...	N08904	2000 °F [1100 °C]	B
...	N08926	2010 °F [1105 °C]	B

^A Quenched in water or rapidly cooled by other methods, at a rate sufficient to prevent reprecipitation of chromium carbides, as demonstrated by the capability of passing Practices A262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (See Supplementary Requirement S6). Note that Practices A262 requires the test to be performed on sensitized specimens in the low carbon and stabilized types and on specimens representative of the as-shipped condition of the other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and purchaser.

^B Quenched in water or rapidly cooled by other methods.

^C A solution treating temperature above 1950 °F [1065 °C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the indicated grades. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table (See Supplementary Requirement S4).

^D Cooled in still air, or faster.

12.3 The grain size of Grade UNS S32615, as determined in accordance with Test Methods E112, shall be No. 3 or finer.

12.4 The grain size of N08810 and N08811, as determined in accordance with Test Methods E112, shall be 5 or coarser.

13. Mechanical Tests and Grain Size Determinations Required

13.1 *Tension Test*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (See 13.9.2).

13.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (See 13.9.1).

13.3 *Flange Test*—One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (See 13.9.1).

13.4 *Reverse-Bend Test*—One reverse-bend test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

13.5 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (See 13.9.2).

13.6 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

13.7 *Grain Size*—Grain size determinations on grades TP309H, TP309HCb, TP310H and TP310HCb shall be made on the same number of tubes as prescribed for the flattening test.

13.8 Heavily cold worked tubes (HCW) shall be capable of passing the weld decay test listed in Supplementary S7 with a weld metal to base metal loss ratio of 0.90 to 1.10. The test is not required unless S7 is specified in the purchase order.

13.9 Lot Definitions:

13.9.1 For flattening and flange requirements, the term lot applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot

TABLE 3 Tensile and Hardness Requirements^A

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness Number, max
TP201	S20100	95 [655]	38 [260]	35	B95
TP 201LN	S20153	95 [655]	45 [310]	45	B100
TP202	S20200	90 [620]	38 [260]	35	B95
TPXM-19	S20910	100 [690]	55 [380]	35	C25
TPXM-29	S24000	100 [690]	55 [380]	35	B100
TP304	S30400	75 [515]	30 [205]	35	B90
TP304L	S30403	70 [485]	25 [170]	35	B90
TP304H	S30409	75 [515]	30 [205]	35	B90
...	S30415	87 [600]	42 [290]	35	B96
TP304N	S30451	80 [550]	35 [240]	35	B90
TP304LN	S30453	75 [515]	30 [205]	35	B90
TP305	S30500	75 [515]	30 [205]	35	B90
...	S30601	78 [540]	37 [255]	30	B100
...	S32615	80 [550]	32 [220]	25	B100
...	S30615	90 [620]	40 [275]	35	B95
...	S30815	87 [600]	45 [310]	35	B95
TP309S	S30908	75 [515]	30 [205]	35	B90
TP309H	S30909	75 [515]	30 [205]	35	B90
TP309Cb	S30940	75 [515]	30 [205]	35	B90
TP309HCb	S30941	75 [515]	30 [205]	35	B90
TP310S	S31008	75 [515]	30 [205]	35	B90
TP310H	S31009	75 [515]	30 [205]	35	B90
TP310Cb	S31040	75 [515]	30 [205]	35	B90
TP310HCb	S31041	75 [515]	30 [205]	35	B90
...	S31050:				
...	t ≤ 0.25 in.	84 [580]	39 [270]	25	B95
...	t > 0.25 in.	78 [540]	37 [255]	25	B95
...	S31254:				
...	t ≤ 0.187 in. [5.00 mm]	98 [675]	45 [310]	35	B100
...	t > 0.187 in. [5.00 mm]	95 [655]	45 [300]	35	B100
...	S31266	109 [750]	61 [420]	35	B100
...	S31277	112 [770]	52 [360]	40	B100
TP316	S31600	75 [515]	30 [205]	35	B90
TP316L	S31603	70 [485]	25 [170]	35	B90
TP316H	S31609	75 [515]	30 [205]	35	B90
TP316N	S31651	80 [550]	35 [240]	35	B90
TP316LN	S31653	75 [515]	30 [205]	35	B90
...	S31655	92 [635]	45 [310]	35	B100
TP317	S31700	75 [515]	30 [205]	35	B90
TP317L	S31703	75 [515]	30 [205]	35	B90
...	S31725	75 [515]	30 [205]	35	B90
...	S31726	80 [550]	35 [240]	35	B90
...	S31727	80 [550]	36 [245]	35	B96
...	S32050	98 [675]	48 [330]	40	
...	S32053	93 [640]	43 [295]	40	B96
TP321	S32100	75 [515]	30 [205]	35	B90
TP321H	S32109	75 [515]	30 [205]	35	B90
...	S32654	109 [750]	62 [430]	35	B100
...	S33228	73 [500]	27 [185]	30	B90
...	S34565	115 [795]	60 [415]	35	B100
TP347	S34700	75 [515]	30 [205]	35	B90
TP347H	S34709	75 [515]	30 [205]	35	B90
TP348	S34800	75 [515]	30 [205]	35	B90
TP348H	S34809	75 [515]	30 [205]	35	B90
...	S35045	70 [485]	25 [170]	35	B90
TPXM-15	S38100	75 [515]	30 [205]	35	B90
...	S38815	78 [540]	37 [255]	30	B100
Alloy 20	N08020	80 [550]	35 [240]	30	B95
...	N08367				
...	t ≤ 0.187	100 [690]	45 [310]	30	B100
...	t > 0.187	95 [655]	45 [310]	30	B100
800	N08800	75 [515]	30 [205]	30	90
800H	N08810	65 [450]	25 [170]	30	90
...	N08811	65 [450]	25 [170]	30	90
...	N08904	71 [490]	31 [215]	35	B90
...	N08926	94 [650]	43 [295]	35	B100

^A Not applicable to tubes less than 1/8 in. [3.2 mm] in outside diameter or having wall thickness below 0.015 in. [0.4 mm], or both. The tensile properties of such small diameter or thin wall tubes shall be a matter of agreement between the manufacturer and the purchaser.

shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 4.

13.9.2 For tension and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, annealed in the same furnace at the same temperature, time at heat, and furnace speed.

14. Permissible Variations in Dimensions

14.1 Dimensional tolerances other than wall thickness tolerances shall be in accordance with Specification A1016/A1016M. Wall thickness tolerances shall be ±10 % of nominal wall for all tubing sizes.

14.2 The wall thickness of the weld shall not exceed the wall thickness measured 90° from the weld by more than 6 % of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater.

14.2.1 Requirements of 14.2 are not applicable when any of the following apply:

14.2.1.1 When the specified wall thickness exceeds 12 % of the specified outside diameter;

14.2.1.2 When the specified wall thickness exceeds 0.165 in. [4.2 mm];

14.2.1.3 When the specified OD exceeds 3 in. [76.2 mm]; or

14.2.1.4 When the specified minimum yield strength given in Table 3 for the specified grade is 35 ksi [240 MPa] or greater.

15. Workmanship, Finish, and Appearance

15.1 Finished tubes shall have smooth ends free of burrs and shall not deviate from straightness by more than 0.030 in. [0.8 mm] in 3 ft [900 mm] of length.

16. Surface Condition

16.1 The tubes, after final heat treatment, shall be chemically descaled or pickled free of scale. When bright annealing is used, pickling or chemical descaling is not necessary.

TABLE 4 Number of Tubes in a Lot Heat Treated by the Continuous Process

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

17. Forming Operations

17.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. All tubes, when properly manipulated, shall be able to stand expanding and beading without showing cracks and flaws, and also shall stand all forging, welding, and bending operations necessary for application without developing defects.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A1016/A1016M, the marking for Grades TP304H, TP309H,

TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, TP348H, N08810, and N08811 shall also include the heat number and the heat-treatment lot identification.

19. Keywords

19.1 austenitic stainless steel; boiler tubes; condenser tube; heat exchanger tube; high temperature applications; N08800; N08810; N08811; steel tube; superheater tubes; temperature service applications, high; welded steel tube and heavily cold worked (HCW) tubes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition. Details of these supplemental requirements shall be agreed upon by the manufacturer and the purchaser.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1550 to 1650 °F [845 to 900 °C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and manufacturer.

S2. Minimum Wall Tubes

S2.1 When specified by the purchaser, tubes shall be furnished on a minimum wall basis. Such tubes shall satisfy the minimum wall thickness requirements of Specification A1016/A1016M rather than the nominal wall requirements of this specification. In addition to the marking required by Section 18, the tubing shall be marked S2.

S3. Pneumatic Test

S3.1 The tubing shall be examined by a pneumatic test (either air under water or pneumatic leak test) in accordance with Specification A1016/A1016M.

S4. Stabilizing Heat Treatment

S4.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S5. DELETED

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

NOTE S6.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S4 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S7. Weld Decay Test

S7.1 This test is not applicable to alloys with a nickel content $\geq 19.0\%$ or a molybdenum content $\geq 4.00\%$, or both.

NOTE S7.1—The weld decay test is sensitive for the presence of delta ferrite in the weld material. Increasing amounts of delta ferrite will result in a higher ratio as defined in S7.10. Alloys with the high nickel or molybdenum content of S7.1 may not form delta ferrite and therefore may not be sensitive to this test.

S7.2 When specified by the purchase order, one sample from each lot of tubing (See 13.9.2) shall be subjected to testing in a boiling mixture of 50 % reagent grade hydrochloric acid and 50 % water.

S7.3 Approximately 2-in. long samples shall be prepared from a production length of tubing. Shorter, 1-in. samples may be used for small diameter ($\frac{1}{2}$ -in. and below) tubing. Split the sample longitudinally to allow for easy micrometer measurements. The sample may be one piece which contains the weld and at least 90° of base-metal to one side of the weld.

Alternately, the sample may be two separate pieces with one containing the weld and a similar size section from the balance of the tube opposite the weld consisting of 100 % base metal. Remove all burrs and sharp edges by lightly grinding. Remove dust and grease by cleaning with soap and water or other suitable solvents. Then, place sample(s) in the flask. It is not recommended to test more than four samples together, or to mix alloy types.

S7.4 Prepare the hydrochloric acid solution by slowly adding reagent grade (approximately 37 %) hydrochloric acid to an equal volume of distilled water. (**Warning**—Protect eyes and use rubber gloves when handling acid. Mixing shall be done under a hood and testing shall be run under a hood.)

S7.5 The test container shall be a 1-L Erlenmeyer flask equipped with ground-glass joints and an Ahlin condenser. The volume of the solution shall be approximately 700 mL.

S7.6 Measure the thickness of the tube at five locations along the weld area and at five locations along the base-metal section. In both cases, take measurements at approximately equal longitudinal intervals along the section lengths. Make these measurements with a sharp pointed micrometer accurate to at least 0.001 in. The micrometer must be suitable for measuring the small features in the surface after testing. Typical pin micrometers have tapered anvils with a tip radius of less than 0.015 in.

S7.7 Immerse the samples into the solution. Add boiling chips and bring to a boil. Allow the chips to remain boiling throughout the test. The time of testing shall be that which is required to remove 40 to 60 % of the original base-metal thickness (usually 2 h or less). If more than 60 % of the base-metal thickness remains, the sample may be removed after 24 h.

S7.8 At the end of the test period, remove the samples from the solution, rinse with distilled water, and dry.

S7.9 After exposure to the test solution, repeat the tube-thickness measurement as in S7.6. If the thinning is not uniform across the width of the weld, then two sets of weld-metal measurement are required. One set of measurements is to be taken along the centerline of the weld. The second set of measurements is to be taken in the thinnest area of the weld.

S7.10 Calculate the corrosion ratio, R , for both sections of the weld as follows in Eq 1:

$$R = \frac{W_o - W}{B_o - B} \quad (1)$$

where:

W_o = average weld-metal thickness before the test,
 W = average weld-metal thickness after the test,
 B_o = average base-metal thickness before the test, and
 B = average base-metal thickness after the test.

S7.11 Acceptance Criteria:

S7.11.1 The ratio of the thinnest section of the weld and adjacent heat affected zone versus the base metal shall be determined. The following ratios or alternatives are commonly specified:

S7.11.1.1 A corrosion ratio of 1.25 or less. If not specified by the purchase order, this is the default criteria.

S7.11.1.2 A corrosion ratio of 1.00 or less.

S7.11.1.3 Alternative ratios may be agreed between the purchaser and supplier.

S8. Special Applications

S8.1 For special applications, such as hydraulic expansion of tubes into tube sheets, there shall be no dimensional indication of the weld. Tubes ordered to this requirement shall bear the additional marking of NB.

S9. Additional Testing of Welded Tubing for ASME Requirements

S9.1. When this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100 % joint efficiency for longitudinal weld, provided the following additional requirements are met:

S9.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E273 or E213 with the rejection criteria referenced in Specification A1016/A1016M.

S9.1.2 If Practice E273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests permitted by Specification A1016/A1016M.

S9.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S9.1.4 In addition to the marking prescribed in Specification A1016/A1016M, "S9" shall be added after the grade designation.

NOTE S9.1—When specified, the special testing in this supplement is intended for special ASME applications. It is not mandatory for all ASME applications.

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED FERRITIC ALLOY-STEEL BOILER AND SUPERHEATER TUBES



SA-250/SA-250M

(21)

(Identical with ASTM Specification A250/A250M-05(2014) except that Supplementary Requirement S1 is mandatory when 100% weld joint efficiency is required.)

Standard Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes

1. Scope

1.1 This specification covers several grades, designated T1, T1a, T1b, T2, T11, T12 and T22, of minimum-wall-thickness, electric-resistance-welded, carbon-molybdenum and chromium-molybdenum alloy-steel, boiler and superheater tubes.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.320 in. [0.9 to 8.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided for non-destructive examination for certain ASME applications.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5.1 Within the text, the SI units are shown in brackets.

1.5.2 The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (electric-resistance-welded tubes),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter or minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirement (7.3.6),

3.1.7 Test report required (see Certification Section of Specification A1016/A1016M),

3.1.8 Specification designation, and

3.1.9 Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Product furnished under this specification shall conform to the applicable requirements of Specification A1016/A1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A1016/A1016M constitutes nonconformance with this specification. In case of conflicts with the requirements of this specification and Specification A1016/A1016M, this specification shall prevail.

5. Materials and Manufacture

5.1 The steel shall be killed.

5.2 The tubes shall be made by electric-resistance welding.

5.3 Heat Treatment

5.3.1 After welding, or when cold finished, after the final cold-drawing pass, all tubes shall be heat treated and, except as provided in 5.3.2, furnished in the full annealed, isothermal annealed, normalized, or normalized and tempered condition at

TABLE 1 Chemical Requirements

Element	Composition, %						
	Grade T1	Grade T1a	Grade T1b	Grade T2	Grade T11	Grade T12	Grade T22
Carbon	0.10–0.20	0.15–0.25	0.14 max	0.10–0.20	0.05–0.15	0.05–0.15	0.15 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80	0.30–0.61	0.30–0.60	0.30–0.61	0.30–0.60
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.030	0.025
Sulfur, max	0.025	0.025	0.025	0.020	0.020	0.020	0.020
Silicon	0.10–0.50	0.10–0.50	0.10–0.50	0.10–0.30	0.50–1.00	0.50 max	0.50 max
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.87–1.13
Chromium	...	...	...	0.50–0.81	1.00–1.50	0.80–1.25	1.90–2.60

the option of the manufacturer. If furnished in the normalized and tempered condition, the minimum tempering temperature shall be 1200 °F [650 °C], except T22 shall be tempered at 1250 °F [676 °C] minimum.

5.3.2 When grades T1, T1a, T1b, and T2 are cold finished, the tubes may, at the option of the manufacturer, be heat treated after the final cold-drawing pass at a temperature of 1200 °F or higher, provided one of the heat treatments specified in 5.3.1 was applied after welding.

6. Chemical Composition

6.1 The steel shall conform to the requirements given in Table 1.

6.2 Product Analysis

6.2.1 An analysis of either one length of flat-rolled stock or one tube shall be made on each heat. The chemical composition thus determined shall conform to the requirements given in Table 1.

6.2.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (See 8.1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

7. Mechanical Requirements

7.1 Tensile Requirements

7.1.1 The material shall conform to the requirements as to tensile properties given in Table 2.

7.1.2 Table 3 gives the computed minimum elongation values for each 1/32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values given in Table 3, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. [50 mm] %, and
 t = actual thickness of specimen, in.[mm].

7.2 *Hardness Requirements*—The tubes shall have a hardness not exceeding the values given in Table 4.

7.3 Mechanical Tests Required

7.3.1 *Tension Test*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (See 8.2).

7.3.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (See 8.1).

7.3.3 *Flange Test*—One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (See 8.1).

7.3.4 *Reverse Flattening Test*—One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

7.3.5 *Hardness Test*—Brinell and Rockwell hardness tests shall be made on specimens from two tubes from each lot (See 8.2).

7.3.6 *Hydrostatic or Nondestructive Electric Tests*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which is to be used.

8. Sampling

8.1 For flattening and flange requirements, the term *lot* applies to all tubes prior to cutting of the same specified outside diameter and specified wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a

TABLE 2 Tensile Requirements

Grade	T1	T1a	T1b	T2	T11	T12	T22
Tensile strength, min, ksi [MPa]	55 [380]	60 [415]	53 [365]	60 [415]	60 [415]	60 [415]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	32 [220]	28 [195]	30 [205]	30 [205]	32 [220]	30 [205]
Elongation in 2 in. or 50 mm, min, %	30	30	30	30	30	30	30
For longitudinal strip tests a deduction shall be made for each 1/32-in. [0.8-mm] decrease in wall thickness below 5/16 in. [8 mm] from the basic minimum elongation of the following percentage points	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A

^A See Table 3 for the computed minimum values.

TABLE 3 Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min,% ⁴
in.	mm	Grades T1, T1a, T1b, T2, T11, T12, and T22
5/16 (0.312)	8	30
3/32 (0.281)	7.2	29
1/4 (0.250)	6.4	27
7/32 (0.219)	5.6	26
3/16 (0.188)	4.8	24
5/32 (0.156)	4	22
1/8 (0.125)	3.2	21
3/32 (0.094)	2.4	20
1/16 (0.062)	1.6	18

⁴ Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4 Hardness Requirements

Grade	Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and over in wall thickness), HBW	Rockwell Hardness Number (Tubes less than 0.200 in. [5.1 mm] in wall thickness), HRB
T1	146	80
T1a	153	81
T1b	137	77
T2	163	85
T11	163	85
T12	163	85
T22	163	85

continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes given in Table 5.

8.2 For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same specified outside diameter and specified wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9. Forming Operations

9.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

TABLE 5 Number of Tubes in a Lot Heat Treated by the Continuous Process

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

10. Product Marking

10.1 In addition to the marking prescribed in Specification A1016/A1016M, the marking shall include the words “Electric Resistance-Welded Steel.”

11. Keywords

11.1 boiler tube; resistance welded steel tube; steel tube, alloy; superheater tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for 100 % Joint Efficiency in Certain ASME Applications

S1.1 Where this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100 % joint efficiency for the longitudinal weld, provided the following additional requirements are met:

S1.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E273 or E213E273E213 with the rejection criteria referenced in Specification A1016/A1016M.

S1.1.2 If Practice E273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A1016/A1016M.

S1.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.1.4 In addition to the marking prescribed in Specification A1016/A1016M, “S1” shall be added after the grade designation.

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SPECIFICATION FOR STAINLESS CHROMIUM STEEL-CLAD PLATE



SA-263



(21)

(Identical with ASTM Specification A263-12(2019).)

Standard Specification for Stainless Chromium Steel-Clad Plate

1. Scope

1.1 This specification covers plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of stainless chromium steel. The material is generally intended for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 ASTM Standards:

- A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

2.2 Other Standards:

ASME Code Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 This material is considered as single-clad or double-clad stainless chromium-steel plate, depending on whether one or both sides are covered.

3.1.2 *alloy cladding*—the stainless chromium steel component of the composite plate.

3.1.3 *base metal (backing steel)*—component to which the alloy cladding is applied, usually the greater percentage of the composite plate.

3.1.4 *integrally and continuously bonded*—a condition in which the alloy cladding and base metal are brought together to form a metallurgical bond at essentially the entire interface of the two metals by means other than those processes that do not produce a homogeneous composite plate.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of pieces).

4.1.2 Cladding alloy specification (UNS or ASTM Specification A240/A240M) and whether cladding is for corrosion allowance only.

4.1.3 Base metal specification.

4.1.4 Bond integrity Class (1, 3, or 5; see Section 13).

4.1.5 Dimensions including the minimum or nominal thicknesses of the cladding alloy and the backing steel, or of the total composite and if more or less restrictive thickness tolerances apply.

4.1.6 Product analysis, if required (see Section 10). Specify whether applicable to the cladding alloy, backing steel, or both.

4.1.7 Mechanical properties including shear test if required (see Sections 7, 8, and 9).

4.1.8 Finish (see Section 12).

4.1.9 Restrictions, if required, on repair by welding (see Section 14).

4.1.10 Additions to the specification or special requirements such as any applicable construction code rules.

4.1.11 Notification when the cladding alloy is to be used for inclusion in the design strength calculations for an applicable construction code.

NOTE 1—Construction codes may dictate certain fabrication requirements when the cladding is used in the design calculations that may be different than if the cladding is used for corrosion resistance only. This may be particularly important when the alloy cladding involves the use of welded components in the explosion bonded clad manufacturing process. It is incumbent on the purchaser to make the clad manufacturer aware of any such restrictions or applications at time of order.

4.2 In addition to the basic requirements of this specification and the backing steel specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

4.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

5. Materials and Manufacture

5.1 Process:

5.1.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using, but not limited to electroslag remelting or vacuum-arc remelting processes.

5.1.2 The alloy-cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

5.1.3 For explosively bonded products, the alloy cladding metal may be comprised of two or more separate alloy plates or sheets completely welded together to form a single fabricated component.

5.2 *Heat Treatment*—Unless otherwise specified or agreed upon between the purchaser and the manufacturer, all plates shall be furnished in the normalized, tempered, normalized and tempered, or quenched and tempered condition as permitted by the backing steel specification. Stress relieving of the composite plate by heating subcritically is permitted, provided the temperature is 75°F (40°C) or more below the minimum tempering temperature (when tempered).

6. Chemical Composition

6.1 The composite plate shall conform to any desired combination of alloy-cladding metal and base metal as described in 6.2 and 6.3 and as agreed upon between the purchaser and the manufacturer.

6.2 *Alloy Cladding Metal*—The alloy-cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective chromium steel in Specification A240/A240M.

6.3 *Base Metal*—The base metal shall be carbon steel or low-alloy steel conforming to the ASTM specifications for steels for pressure vessels or other as agreed by the purchaser and the manufacturer. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

7. Mechanical Properties

7.1 Tensile Requirements:

7.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions.

(1) The nominal composite gage is less than or equal to 1½ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

The tensile properties thus determined shall be not less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

7.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

(1) The composite gage is greater than 1½ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).

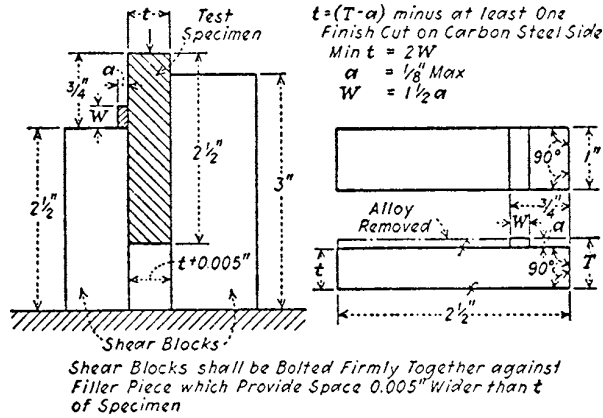
(3) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

7.1.3 If the cladding is for corrosion allowance only, the cladding need not be included in the tensile test. The tensile properties thus determined shall meet the base steel requirements.

7.2 Tests for strength of the bond, when required, must be specified by the purchaser and shall consist of one of the following.

7.2.1 *Shear Strength*—When required by the purchaser, the minimum shear strength of the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated in Fig. 1. The minimum cladding thickness for shear testing shall be 0.075 in. (1.9 mm) exclusive as ordered. Testing for shear strength for clad plates with minimum cladding thickness of 0.075 in. (1.9 mm) or less shall be permitted upon agreement between the purchaser and the manufacturer.

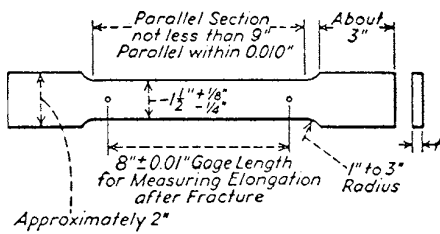
7.2.2 *Bond Strength*—As an alternative to the shear strength test provided in 7.2.1, or when agreed upon by the purchaser and the manufacturer, or both, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in the manner of the tension tests indicated in Fig. 2 and shall be bent through an



Metric Equivalents

in.	mm	in.	mm
0.005	0.127	1	25.4
1/8	3.18	2 1/2	64.5
3/4	19.1	3	76.2

FIG. 1 Test Specimen and Method of Making Shear Test of Clad Plate



Metric Equivalents

in.	mm.	in.	mm
0.01	0.254	1 1/2	38.1
1/8	3.17	2	50.8
1/4	6.35	3	76.2
1	25.4	8	203.2

NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 2 Standard Rectangular Tension Test Specimen with 8-in. Gage Length

angle of 180° to the bend diameters provided for in either Specification A6/A6M or Specification A20/A20M, Appendix X4 or equivalent, as applicable. At least two of the three tests shall show not more than 50 % separation on both edges of the bent portion. Greater separation shall be cause for rejection.

7.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with the Test Methods and Definitions of A370.

8. Number of Tests and Retests

8.1 One or more tension tests, as required by the specifications for the base metal and, when specified, one shear test or three bond bend tests shall be made representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate, including any SPWHT if required.

8.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

9. Test Specimens

9.1 The tension test specimens from plate shall conform to the requirements prescribed in the specifications for the base metal.

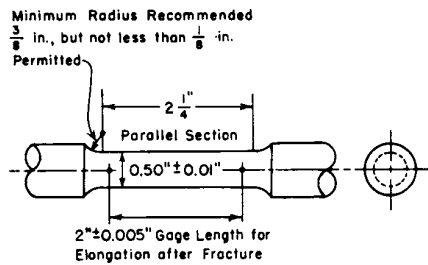
9.2 Bend test specimens for the alternative bond strength tests shall be taken at right angles to longitudinal axis of the plate.

9.3 When required by the purchaser, the shear test specimen should be taken near a corner of the plate, parallel to its longitudinal axis, or other location that is representative of the final product.

9.4 For plates 1 1/2 in. (38 mm) and under in thickness tension test specimens shall be full thickness of the material except as specified in 7.1.2 and 7.1.3.

9.5 For plates over 1 1/2 in. (38 mm) in thickness, tension tests shall be of the form shown in Fig. 3 and shall be of all base steel conforming to the requirements of the specification for the base steel.

9.6 The bend test specimen used for bond strength determination shall be 1 1/2 in. (38 mm) wide by not more than 3/4 in. (19 mm) in thickness and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both



Metric Equivalents

in.	mm	in.	mm
0.003	0.076	3/8	9.53
0.005	0.127	0.50	12.7
0.01	0.254	2	50.8
1/8	3.18	2 1/4	64.5

NOTE 1—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

FIG. 3 Standard Round Tension Test Specimen with 2-in. Gage Length

edges parallel. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad metal need not be reduced below $\frac{1}{8}$ in. (3.1 mm). The sides of the bend test specimen used for bond strength determination may have the corners rounded to a radius not over $\frac{1}{16}$ in. (1.6 mm) for plates, 2 in. (50 mm) and under in thickness, and not over $\frac{1}{8}$ in. (3.1 mm) for plates over 2 in. (50 mm) in thickness.

10. Product Analysis

10.1 Product analysis may be required for the cladding alloy on the finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

10.2 If product analysis is specified by the purchaser for the cladding alloy, it shall be made from drillings or millings taken from the final piece or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plate material, plus 40 % of the cladding thickness from the bonded side, not to exceed $\frac{1}{16}$ in. (1.6 mm). The material shall be chemically cleaned and sufficient millings shall be taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50 % of the cladding shall be removed and the sample exposed on this surface.

10.3 Methods and practices relating to chemical analysis required by this specification shall be in accordance with the Test Methods, Practices, and Terminology of A751.

10.4 Results of the product analysis shall conform to the requirements of Section 7 of Specification A480/A480M.

10.5 Results of the product analysis for the backing steel when required shall conform to the requirements of Section 7 of Specification A20/A20M.

11. Permissible Variations

11.1 Permissible variations except for thickness shall be in accordance with Specification A20/A20M.

11.2 Minimum thickness of the alloy cladding metal and of the backing steel, or of the total composite plate shall be as required by purchase order documents when ordered to minimum thicknesses.

11.3 Permissible variation in thickness when ordered to nominal thicknesses shall be 0.01 in. (0.3 mm) under each for backing steel or total composite, and 0.03 in. (0.8 mm) under for the alloy cladding.

11.4 Permissible variations for excess thickness of the total composite shall be the greater of 0.125 in. (3 mm) or 10 % of the total composite thickness ordered and may occur in either backing steel, cladding, or both, provided the minimum for each is met.

11.5 More restrictive or less restrictive permissible variations may be agreed upon by the purchaser and the manufacturer.

12. Workmanship, Finish, and Appearance

12.1 The material shall be free of injurious defects, shall have a workmanlike appearance, and shall conform to the designated finish.

12.2 Plate alloy surfaces shall be blasted (descaled by means such as sand or stainless grit, shot or wire, or equivalent), pickled, blast-cleaned and pickled, or 100 % conditioned.

13. Bond Quality

13.1 The cladding metal shall be integrally and continuously bonded to the base metal.

13.2 Inspection:

13.2.1 Clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness shall be visually inspected for bond integrity prior to shipment.

13.2.2 Clad plates $\frac{3}{8}$ in. (10 mm) and thicker total minimum composite thickness, and when specified by the purchaser, clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness, shall be ultrasonically inspected for bond integrity prior to shipment in accordance with the Procedures and Methods of Specification A578/A578M.

13.2.3 Areas of non-bond detected visually shall be explored ultrasonically to determine the extent of the condition in accordance with 13.2.2. For purposes of defining non-bond, the cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel. Areas within 1 in. (25 mm) of a cut edge on the plate that contain indications exceeding 50 % of the back reflection at the bond interface shall be considered to be unbonded.

13.2.4 Extent of ultrasonic examination shall be at the discretion of the manufacturer and sufficient enough to provide the quality level required by the purchaser. Plates may be ordered with 100 % coverage (Supplementary Requirements S12).

13.3 Quality Levels:

13.3.1 *Class 1*—No single unbonded area exceeding 1 in. (25 mm) in its longest dimension with total unbonded area not to exceed 1 % of the total clad surface area.

13.3.2 *Class 3*—No single unbonded area exceeding 3 in. (75 mm) in its longest dimension with total unbonded area not to exceed 3 % of the total clad surface area.

13.3.3 *Class 5*—No single unbonded area exceeding 9 in.² (58 cm²) with total unbonded area not to exceed 5 % of the total clad surface area.

13.3.4 The class to be supplied should be listed on the purchase order. When none has been specified, plates shall be furnished as Class 5 at the option of the manufacturer.

14. Welding

14.1 All welding which is a part of the delivered product, including any made in the fabrication of the cladding alloy component, shall be performed with a procedure and welders or welding operators that are qualified in accordance with Section IX of the ASME Code.

14.2 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

14.2.1 When specified in the purchase order, prior approval shall be obtained from the purchaser.

14.2.2 The defective area shall be removed and the area prepared for repair shall be examined by a magnetic particle method or a liquid penetrant method to ensure all defective area has been removed. Method of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

14.2.3 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

14.2.4 The repaired area shall be examined by a liquid penetrant method.

14.2.5 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

14.3 All repairs in Alloy Type 410 and any repairs to Type 410S penetrating into the backing steel shall be stress relieved to eliminate residual stresses unless otherwise agreed upon.

15. General Requirements for Delivery

15.1 Material furnished under this specification shall conform to the applicable requirements of Specification A20/A20M.

16. Certification

16.1 The chemical analysis of the base metal and the alloy cladding shall be certified to the purchaser by the clad plate manufacturer.

16.2 The results of the tests in Section 7 and any other tests required by the purchase order shall be reported to the purchaser.

16.3 Compliance with the clad quality level of 13.3 shall be certified. Reports shall include the results of ultrasonic inspection when Supplementary Requirement S12 is specified.

16.4 Compliance with any applicable construction code shall be certified and the appropriate documentation provided when appropriate in the case of explosively bonded clad produced using welded alloy cladding components (see 4.1.10 and 4.1.11).

17. Product Marking

17.1 Except as specified in 17.2, plates shall be marked in accordance with the requirements of Specification A20/A20M for the backing steel and the type number of the alloy cladding metal and this specification number.

17.2 For double-clad material or for material under $\frac{1}{4}$ in. (6.35 mm) in thickness, the marking shall be legibly stenciled instead of stamped.

18. Keywords

18.1 alloy cladding; backing steel; bond strength; carbon steel; clad steel plate; low-alloy steel; pressure vessel; shear strength; stainless chromium steel

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S2. Product Analysis

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S5. Charpy V-Notch Impact Test

S12. Ultrasonic Examination in accordance with Specification A578/A578M

SPECIFICATION FOR STAINLESS CHROMIUM-NICKEL STEEL-CLAD PLATE



SA-264



(21)

(Identical with ASTM Specification A264-12(2019).)

Standard Specification for Stainless Chromium-Nickel Steel-Clad Plate

1. Scope

1.1 This specification covers plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of stainless chromium-nickel steel. The material is generally intended for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 ASTM Standards:

- A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

2.2 Other Standards:

ASME Code Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 This material is considered as single-clad or double-clad corrosion-resisting chromium-nickel steel plate, depending on whether one or both sides are covered.

3.1.2 *alloy cladding*—the stainless chromium-nickel steel component of the composite plate.

3.1.3 *base metal (backing steel)*—component to which the alloy cladding is applied, usually the greater percentage of the composite plate and usually consisting of carbon or low-alloy steel.

3.1.4 *integrally and continuously bonded*—the process by which the alloy cladding and base metal are brought together to form a metallurgical bond at essentially the entire interface of the two metals by means other than those processes that do not produce a homogeneous composite plate.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of pieces).

4.1.2 Cladding alloy specification, (UNS or ASTM Specification A240/A240M and whether cladding is for corrosion allowance only),

4.1.3 Base metal specification.

4.1.4 Bond integrity Class (1, 3, or 5).

4.1.5 Dimensions including the minimum or nominal thickness of the cladding alloy, and the backing steel, or of the total composite plate and if more or less restrictive thickness tolerances apply.

4.1.6 Product analysis, if required (see Section 10). Specify whether applicable to the cladding alloy, backing steel or both.

- 4.1.7 Mechanical properties, including shear test if required.
- 4.1.8 Finish (see Section 12).
- 4.1.9 Restrictions, if required, on repair by welding (see Section 14).
- 4.1.10 Additions to the specification or special requirements such as any applicable construction code rules.
- 4.1.11 Corrosion testing if applicable.
- 4.1.12 Notification when the cladding alloy is to be used for inclusion in the design strength calculations for an applicable construction code.

NOTE 1—Construction codes may dictate certain fabrication requirements when the cladding is used in the design calculations that may be different than if the cladding is used for corrosion resistance only. This may be particularly important when the alloy cladding involves the use of welded components in the explosion bonded clad manufacturing process. It is incumbent on the purchaser to make the clad manufacturer aware of any such restrictions or applications at time of order.

4.2 In addition to the basic requirements of this specification and the backing steel specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

4.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4.4 Special tests.

5. Materials and Manufacture

5.1 Process:

5.1.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using, but not limited to electroslag remelting or vacuum-arc remelting processes.

5.1.2 The alloy-cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

5.1.3 For explosively bonded products, the alloy cladding metal may be comprised of two or more separate alloy plates or sheets completely welded together to form a single fabricated component.

5.2 Heat Treatment:

5.2.1 Unless otherwise specified or agreed upon between the purchaser and the manufacturer, all austenitic stainless steel clad plates shall be given a heat treatment consisting of heating to the proper temperature for the solution of the chromium carbides in the cladding followed by individual air cooling. For base metals of air-hardening low-alloy steels the above heat treatment shall be followed by a tempering treatment. In the case of clad plate manufactured without hot rolling, the base metal and alloy cladding components may be heat treated separately as appropriate prior to bonding.

5.2.2 Duplex stainless steel clad plates shall be provided in a heat treated condition as agreed upon between the purchaser and the manufacturer.

5.2.3 When plates are to be cold formed, or when otherwise required by the base metal specification, the purchaser may specify that such plates, following solution annealing, be heat treated for grain refinement of the base metal by normalizing and either air cooled or water quenched as appropriate.

6. Chemical Composition

6.1 The composite plate may conform to any desired combination of alloy-cladding metal and base metal as described in 6.2 and 6.3 and as agreed upon between the purchaser and the manufacturer.

6.2 *Alloy Cladding Metal*—The alloy-cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective chromium-nickel or duplex steel in Specification A240/A240M.

6.3 *Base Metal*—The base metal shall be carbon steel or low-alloy steel conforming to the ASTM specifications for steel for pressure vessels, or other, as agreed by the purchaser and the manufacturer. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

7. Mechanical Properties

7.1 Tensile Requirements:

7.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions.

(1) The composite gage is less than or equal to 1½ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa)

(3) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

(4) The tensile properties thus determined shall be not less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

7.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

(1) The composite gage is greater than 1½ in. (38 mm).

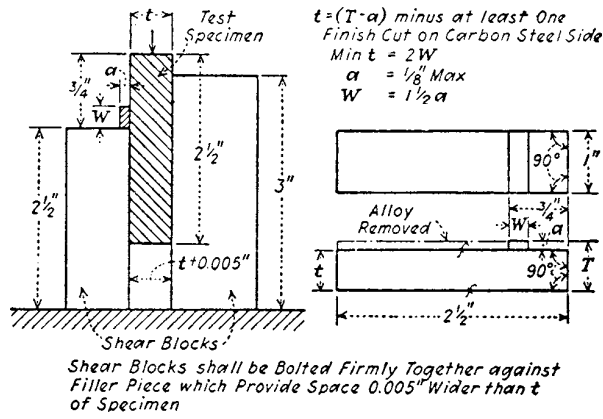
(2) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

7.1.3 If the cladding is for corrosion allowance only, the cladding need not be included in the tensile test. The tensile properties thus determined shall meet the base steel requirements.

7.2 Tests for strength of the bond, when required, must be specified by the purchaser and shall consist of one of the following.

7.2.1 *Shear Strength*—When required by the purchaser, the minimum shear strength of the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated in Fig. 1. The minimum



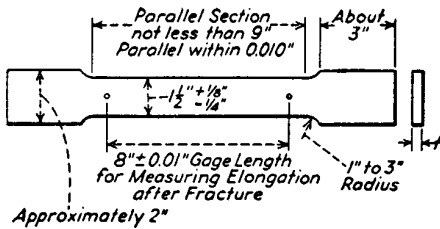
Metric Equivalents

in.	mm	in.	mm
0.005	0.127	1	25.4
1/8	3.18	2 1/2	64.5
3/4	19.1	3	76.2

FIG. 1 Test Specimen and Method of Making Shear Test of Clad Plate

cladding thickness for shear testing shall be 0.075 in. (1.9 mm), exclusive as ordered. Testing for shear strength for clad plates with minimum cladding thickness of 0.075 in. (1.9 mm) or less shall be permitted upon agreement between the purchaser and the manufacturer.

7.2.2 *Bond Strength*—As an alternative to the shear strength test provided in 7.2.1, or when agreed upon by the purchaser and the manufacturer, or both, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in the manner of the tension tests indicated in Fig. 2 and shall be bent through an angle of 180° to the bend diameters provided for in either



Metric Equivalents

in.	mm	in.	mm
0.01	0.254	1 1/2	38.1
1/8	3.17	2	50.8
1/4	6.35	3	76.2
1	25.4	8	203.2

NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 2 Standard Rectangular Tension Test Specimen with 8-in. Gauge Length

Specification A6/A6M or Specification A20/A20M, Appendix X4 or equivalent, as applicable. At least two of the three tests shall show not more than 50 % separation on both edges of the bent portion. Greater separation shall be cause for rejection.

7.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with the Test Methods and Definitions of A370.

8. Number of Tests and Retests

8.1 One or more tension tests, as required by the specifications for the base metal and when specified, one shear test or three bond bend tests shall be made, representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate, including any SPWHT if required.

8.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

9. Test Specimens

9.1 The tension test specimens from plate shall conform to the requirements prescribed in the specifications for the base metal.

9.2 Bend test specimens for the alternative bond strength tests, shall be taken at right angles to its longitudinal axis.

9.3 When required by the purchaser, the shear test specimen should be taken near a top or bottom corner of the plate as rolled, parallel to its longitudinal axis, or other location that is representative of the final product.

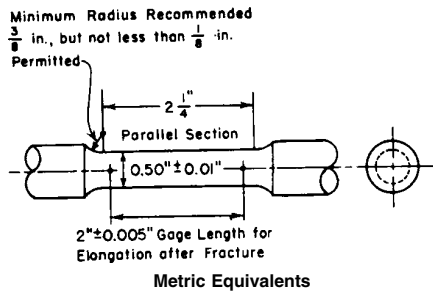
9.4 For plates 1 1/2 in. (38 mm) and under in thickness, tension test specimens shall be the full thickness of the material, except as specified in 7.1.2 and 7.1.3.

9.5 For plates over 1 1/2 in. (38 mm) in thickness, tension tests shall be of the form shown in Fig. 3 and shall be of all base steel conforming to the requirements of the specification for the base steel.

9.6 The bend test specimen used for bond strength determination shall be 1 1/2 in. (38 mm) wide by not more than 3/4 in. (19 mm) in thickness and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both edges parallel. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad metal need not be reduced below 1/8 in. (3.1 mm). The sides of the bend test specimen used for bond strength determination may have the corners rounded to a radius not over 1/16 in. (1.6 mm) for plates, 2 in. (50 mm) and under in thickness, and not over 1/8 in. (3.1 mm) for plates over 2 in. (50 mm) in thickness.

10. Product Analysis

10.1 Product analysis may be required for the cladding alloy on finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining



in.	mm	in.	mm
0.003	0.076	$\frac{3}{8}$	9.53
0.005	0.127	0.50	12.7
0.01	0.254	2	50.8
$\frac{1}{8}$	3.18	2 $\frac{1}{4}$	64.5

NOTE 1—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall be a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

FIG. 3 Standard Round Tension Test Specimen with 2-in. Gage Length

millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

10.2 If product analysis is specified by the purchaser for the cladding alloy, it shall be made on a sample taken from the finished product or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plus 40 % of the cladding thickness from the bonded side, not to exceed $\frac{1}{16}$ in. (1.6 mm). The material shall be cleaned and sufficient millings taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50 % of the cladding shall be removed and the sample exposed on this surface.

10.3 The results of the product analysis shall conform to the requirements of Section 7 of Specification A480/A480M.

10.4 Methods and practices relating to chemical analysis required by this specification shall be in accordance with the Test Methods, Practices, and Definitions of A751.

10.5 Results of the product analysis for the backing steel when required shall conform to the requirements of Section 7 of Specification A20/A20M.

11. Permissible Variations

11.1 Permissible variations except for thickness shall be in accordance with Specification A20/A20M.

11.2 Minimum thickness of the alloy cladding metal and of the backing steel, or of the total composite plate shall be as required by purchase order documents when ordered to minimum thicknesses.

11.3 Permissible variation in thickness when ordered to nominal thicknesses shall be 0.01 in. (0.3 mm) under each for backing steel or total composite, and 0.03 in. (0.8 mm) under for the alloy cladding.

11.4 Permissible variations for excess thickness of the total composite shall be the greater of 0.125 in. (3 mm) or 10 % of the total composite thickness ordered and may occur in either backing steel, cladding, or both, provided the minimum for each is met.

11.5 More restrictive or less restrictive permissible variations may be agreed upon by the purchaser and the manufacturer.

12. Workmanship, Finish, and Appearance

12.1 The material shall be free of injurious defects, shall have a workmanlike appearance, and shall conform to the designated finish.

12.2 Plate alloy surfaces shall be blasted (descaled by means of sand or stainless grit, shot, or wire), pickled, blast-cleaned and pickled, or 100 % conditioned.

13. Bond Quality

13.1 The cladding metal shall be integrally and continuously bonded to the base metal.

13.2 Inspection:

13.2.1 Clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness shall be visually inspected for bond integrity prior to shipment.

13.2.2 Clad plates $\frac{3}{8}$ in. (10 mm) and thicker total minimum composite thickness, and when specified by the purchaser, clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness, shall be ultrasonically inspected for bond integrity prior to shipment in accordance with the Procedures and Methods of Specification A578/A578M.

13.2.3 Areas of non-bond detected visually shall be explored ultrasonically to determine the extent of the condition in accordance with 13.2.2. For purposes of defining non-bond, the cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel. Areas within 1 in. (25 mm) of a cut edge on the plate that contain indications exceeding 50 % of the back reflection at the bond interface shall be considered to be unbonded.

13.2.4 Extent of ultrasonic examination shall be at the discretion of the manufacturer and sufficient enough to provide the quality level required by the purchaser. Plates may be ordered with 100 % coverage (Supplementary Requirement S12).

13.3 Quality Levels:

13.3.1 *Class 1*—No single unbonded area exceeding 1 in. (25 mm) in its longest dimension with total unbonded area not to exceed 1 % of the total clad surface area.

13.3.2 *Class 3*—No single unbonded area exceeding 3 in. (75 mm) in its longest dimension with total unbonded area not to exceed 3 % of the total clad surface area.

13.3.3 *Class 5*—No single unbonded area exceeding 9 in.² (58 cm²) with total unbonded area not to exceed 5 % of the total clad surface area.

13.3.4 The class to be supplied should be listed on the purchase order. When none has been specified, plates shall be furnished as Class 5 at the option of the manufacturer.

14. Welding

14.1 All welding which is part of the delivered product, including any made in the fabrication of the cladding alloy component, shall be performed with a procedure and welders or welding operators that are qualified in accordance with Section IX of the ASME Code.

14.2 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

14.2.1 When specified in the purchase order, prior approval shall be obtained from the purchaser.

14.2.2 The defective area shall be removed and the area prepared for repair shall be examined by a liquid penetrant method to ensure that all of the defective area has been removed. Method of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

14.2.3 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

14.2.4 The repaired area shall be examined by a liquid penetrant method.

14.2.5 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

15. General Requirements for Delivery

15.1 Material furnished under this specification shall conform to the applicable requirements of Specification A20/A20M.

16. Certification

16.1 The chemical analysis of the base metal and the alloy cladding shall be certified to the purchaser by the clad plate manufacturer.

16.2 The results of the tests in Section 7 and any other tests required by the purchase order shall be reported to the purchaser.

16.3 Compliance with the clad quality level of 13.3 shall be certified. Reports shall include the results of ultrasonic inspection when Supplementary Requirement S12 is specified.

16.4 Compliance with any applicable construction code shall be certified and the appropriate documentation provided when appropriate in the case of explosively bonded clad produced using welded alloy cladding components (see 4.1.10 and 4.1.12).

17. Product Marking

17.1 Except as specified in 17.2, plates shall be marked in accordance with the requirements of Specification A20/A20M for the backing steel and the type number of the alloy cladding metal and this specification number.

17.2 For double-clad material or for material under ¼ in. (6.35 mm) in thickness, the marking specified in 17.1 shall be legibly stenciled instead of stamped.

18. Keywords

18.1 alloy cladding; backing steel; bond strength; carbon steel; clad steel plate; low-alloy steel; pressure vessel; shear strength; stainless chromium-nickel steel

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S2. Product Analysis

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S5. Charpy V-Notch Impact Test

S12. Ultrasonic Examination in accordance with Specification A578/A578M

SPECIFICATION FOR NICKEL AND NICKEL-BASE ALLOY-CLAD STEEL PLATE



SA-265



(21)

(Identical with ASTM Specification A265-12(2019).)

Standard Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate

1. Scope

1.1 This specification covers plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of nickel or nickel-base alloy. The material is generally intended for pressure vessel use but may be used in other structural applications where corrosion resistance of the alloy is of prime importance.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 ASTM Standards:

- A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B127 Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
- B162 Specification for Nickel Plate, Sheet, and Strip
- B168 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel-Chromium-Cobalt-

Molybdenum Alloy (UNS N06617), and Nickel-Iron-Chromium-Tungsten Alloy (UNS N06674) Plate, Sheet, and Strip

- B333 Specification for Nickel-Molybdenum Alloy Plate, Sheet, and Strip
 - B409 Specification for Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
 - B424 Specification for Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825, UNS N08221, and UNS N06845) Plate, Sheet, and Strip
 - B443 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip
 - B463 Specification for UNS N08020 Alloy Plate, Sheet, and Strip
 - B575 Specification for Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip
 - B582 Specification for Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet, and Strip
 - B625 Specification for UNS N08925, UNS N08031, UNS N08932, UNS N08926, UNS N08354, and UNS R20033 Plate, Sheet, and Strip
- 2.2 *Other Standards:*
ASME Code Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 This material is considered as single-clad or double-clad nickel or nickel-base alloy clad steel plate, depending on whether one or both sides are covered.

3.1.2 The term plate as used in this specification applies to material $\frac{3}{16}$ in. (2.73 mm) and over in thickness, and over 10 in. (254 mm) in width.

3.1.3 *alloy cladding*—the nickel or nickel-base alloy component of the composite plate.

3.1.4 *base metal (backing steel)*—component to which the alloy cladding is applied, usually the greater percentage of the composite plate and usually consisting of carbon or low-alloy steel.

3.1.5 *integrally and continuously bonded*—the process by which the alloy cladding and base metal are brought together to form a metallurgical bond at essentially the entire interface of the two metals by means other than those processes that do not produce a homogeneous composite plate.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to the following:

- 4.1.1 Quantity (weight or number of pieces).
- 4.1.2 Heat treatment, if required (see Section 5).
- 4.1.3 Dimensions, including the thickness of the cladding alloy and the backing steel, or of the total composite plate and if more or less restrictive thickness tolerances apply.
- 4.1.4 Cladding alloy specification (see Section 6).
- 4.1.5 Base metal specification (see Section 6).
- 4.1.6 Product analysis, if required. Specify whether applicable to the cladding alloy, backing steel, or both (see Section 10).
- 4.1.7 Mechanical Properties (see Sections 7, 13, and 14).
- 4.1.8 Restrictions, if required, on repair by welding (see Section 14).
- 4.1.9 Additions to the specification or special requirements such as applicable construction code rules.
- 4.1.10 Corrosions tests, if required.
- 4.1.11 Notification when the cladding alloy is to be used for inclusion in the design strength calculations for an applicable construction code.

NOTE 1—Construction codes may dictate certain fabrication requirements when the cladding is used in the design calculations that may be different than if the cladding is used for corrosion resistance only. This may be particularly important when the alloy cladding involves the use of welded components in the explosion bonded clad manufacturing process. It is incumbent on the purchaser to make the clad manufacturer aware of any such restrictions or applications at time of order.

4.2 In addition to the basic requirements of this specification and the backing steel specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

- 4.2.1 Nondestructive examination,
- 4.2.2 Impact testing, and
- 4.2.3 Simulated Post-Weld Heat Treatment of Mechanical Test Coupons (SPWHT).

4.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

- 4.4 Special tests.

5. Materials and Manufacture

5.1 Process:

5.1.1 The steel shall be made by the open-hearth, electric-furnace (with separate degassing and refining optional), or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using, but not limited to electroslag remelting or vacuum arc remelting processes.

5.1.2 The cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

5.1.3 For explosively bonded products, the alloy cladding metal may be comprised of two or more separate alloy plates or sheets completely welded together to form a single fabricated component.

5.2 *Heat Treatment*—Unless a specific heat treatment is required by the cladding material or base steel specification, or unless otherwise agreed upon by the purchaser and manufacturer, the clad plate shall be furnished in a condition that is appropriate for the cladding alloy, base metal, or both.

6. Chemical Composition

6.1 The composite plate may conform to any desired combination cladding metal and base metal as described in 6.2 and 6.3, and as agreed upon between the purchaser and the manufacturer.

6.2 *Cladding Metal*—The nickel or nickel-base alloy cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective metal in Specifications B127, B162, B168, B333, B409, B424, B443, B463, B575, B582, and B625, or other nickel-base alloy as agreed upon by the purchaser and manufacturer.

6.3 *Base Metal*—The base metal shall be carbon steel or low-alloy steel conforming to the ASTM specifications for steels for either pressure vessels or general structural applications, or other, as agreed upon by the purchaser and manufacturer. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

7. Mechanical Properties

7.1 Tensile Requirements:

7.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions.

(1) The nominal composite gage is less than or equal to 1½ in (38 mm).

TABLE 1 Weights for Component Materials

	Density		Weight per Square Foot for Material 1 in. (25.4 mm) in Thickness, lb
	lb/in. ³	g/cm ³	
Steel	0.283	7.83	40.80
Nickel	0.321	8.88	46.22
Nickel-copper alloy	0.319	8.83	45.94
Nickel-chromium-iron alloy	0.307	8.49	44.21

(2) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

(4) The tensile properties thus determined shall not be less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

7.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

(1) The composite gage is greater than 1½ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

7.1.3 If the cladding is for corrosion allowance only, the cladding need not be included in the tensile test. The tensile properties thus determined shall meet the base steel requirements.

7.2 Test for strength of the bond, when required, must be specified by the purchaser and shall consist of one of the following.

7.2.1 *Shear Strength*—When required by the purchaser, the minimum shear strength of the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated in Fig. 1. The minimum cladding thickness for shear testing shall be 0.075 in. (1.9 mm) exclusive as ordered. Testing for shear strength for clad plates with minimum cladding thickness of 0.075 in. (1.9 mm) or less shall be permitted upon agreement between the purchaser and the manufacturer.

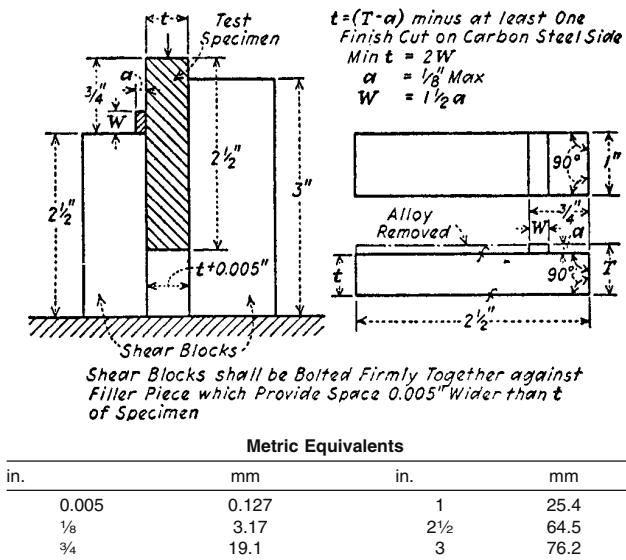


FIG. 1 Test Specimen and Method of Making Shear Test of Clad Plate

7.2.2 *Bond Strength*—As an alternative to the shear strength test provided in 7.2.1 or when agreed upon by the purchaser and the manufacturer, or both, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in the manner of the tension tests indicated in Fig. 2 and shall be bent through an angle of 180° to the bend diameters provided for in either Specification A6/A6M or Specification A20/A20M (Appendix X4, or equivalent), as applicable. At least two of the three tests shall show not more than 50 % separation on both edges of the bent portion. Greater separation shall be cause for rejection.

7.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with the Test Methods and Definitions of A370.

8. Number of Tests and Retests

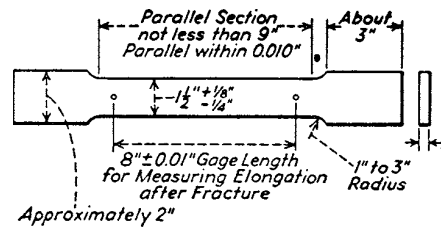
8.1 One or more tension tests, as required by the specifications for the base metal and when specified, one shear test or three bond bend tests shall be made, representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate, including any SPWHT if required.

8.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

9. Test Specimens

9.1 The tension test specimens shall conform to the requirements prescribed in the specifications for the base metal.

9.2 Bend test specimens for the alternative bond strength tests shall be taken at right angles to its longitudinal axis.



Metric Equivalents			
in.	mm	in.	mm
0.01	0.254	1½	38.1
1/8	3.17	2	50.8
1/4	6.35	3	76.2
1	25.4	8	203.2

NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension t is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 2 Standard Rectangular Test Specimens with 8-in. Gage Length

9.3 When required by the purchaser, the shear test specimen shall be taken near a top or bottom corner of the plate as rolled, parallel to its longitudinal axis, or other location that is representative of the final product.

9.4 For plates 1½ in. (38 mm) and under in thickness, tension test specimens shall be the full thickness of the material, except as specified in 7.1.2 and 7.1.3.

9.5 For plates over 1½ in. (38 mm) in thickness, tension tests shall be of the form shown in Fig. 3 and shall be of all base steel conforming to the requirements of the specification for the base steel.

9.6 The bend test specimen used for bond strength determination shall be 1½ in. (38 mm) by not more than ¾ in. (19 mm) in thickness and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both edges parallel. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad material need not be reduced below ⅛ in. (3.1 mm). The sides of the bend test specimen used for bond strength determination may have the corners rounded to a radius not over ¼ in. (1.6 mm) for plates, 2 in. (50 mm) and under in thickness, and not over ⅛ in. (3.1 mm) for plates over 2 in. (50 mm) in thickness.

10. Product Analysis

10.1 Product analysis may be required for the cladding alloy on finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is

sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

10.2 If product analysis is specified by the purchaser for the cladding alloy, it shall be made on a sample taken from the finished product or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plus 40 % of the cladding thickness from the bonded side, not to exceed ¼ in. (1.6 mm). The material shall be cleaned and sufficient millings taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50 % of the cladding shall be removed and the sample exposed on this surface.

10.3 The results of the product analysis shall conform to the requirements of standards referenced in Section 2.

10.4 Methods and practices relating to chemical analysis required by this specification shall be in accordance with the Test Methods, Practices, and Terminology of A751.

10.5 Results of the product analysis for the backing steel when required shall conform to the requirements of Section 7 of Specification A20/A20M or A6/A6M, as applicable.

11. Permissible Variations

11.1 Permissible variations except for thickness shall be in accordance with Specification A20/A20M or A6/A6M as applicable based on the backing specification.

11.2 Minimum thickness of the alloy cladding metal and of the backing steel, or of the total composite plate shall be as required by purchase order documents when ordered to minimum thickness.

11.3 Permissible variation in thickness when ordered to nominal thicknesses shall be 0.01 in. (0.3 mm) under each for backing steel or total composite, and 0.03 in. (0.8 mm) under for the alloy cladding.

11.4 Permissible variations for excess thickness of the total composite shall be the greater of 0.125 in. (3 mm) or 10 % of the total composite thickness ordered and may occur in either backing steel, cladding, or both, provided the minimum for each is met.

11.5 More restrictive or less restrictive permissible variations may be agreed upon by the purchaser and the manufacturer.

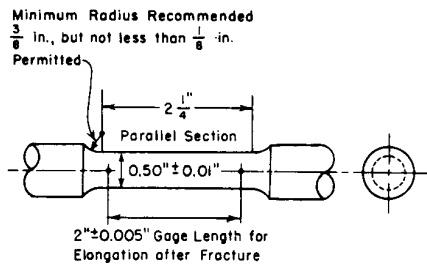
12. Workmanship Finish, and Appearance

12.1 The material shall be free of injurious defects and shall have a workmanlike appearance.

12.2 Unless otherwise specified, the clad surface may be supplied as-rolled, blasted (descaled by means of sand, grit, shot or wire followed by pickling), or 100 % conditioned.

13. Bond Quality

13.1 The cladding metal shall be integrally and continuously bonded to the base metal.



Metric Equivalents			
in.	mm	in.	mm
0.003	0.076	⅜	9.53
0.005	0.127	0.50	12.7
0.01	0.254	2	50.8
⅛	3.18	2¼	64.5

NOTE 1—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

FIG. 3 Standard Round Tension Tests Specimen with 2-in. Gage Length

13.2 Inspection:

13.2.1 Clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness shall be visually inspected for bond integrity prior to shipment.

13.2.2 Clad plates $\frac{3}{8}$ in. (10 mm) and thicker total minimum composite thickness, and when specified by the purchaser, clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness, shall be ultrasonically inspected for bond integrity prior to shipment in accordance with the Procedures and Methods of Specification A578/A578M.

13.2.3 Areas of non-bond detected visually shall be explored ultrasonically to determine the extent of the condition in accordance with 13.2.2. For purposes of defining non-bond, the cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel. Areas within 1 in. (25 mm) of a cut edge on the plate that contain indications exceeding 50 % of the back reflection at the bond interface shall be considered to be unbonded.

13.2.4 Extent of ultrasonic examination shall be at the discretion of the manufacturer and sufficient enough to provide the quality level required by the purchaser. Plates may be ordered with 100 % coverage (see Supplementary Requirement S12).

13.3 Quality Levels:

13.3.1 *Class 1*—No single unbonded area exceeding 1 in. (25 mm) in its longest dimension with total unbonded area not to exceed 1 % of the total clad surface area.

13.3.2 *Class 3*—No single unbonded area exceeding 3 in. (75 mm) in its longest dimension with total unbonded area not to exceed 3 % of the total clad surface area.

13.3.3 *Class 5*—No single unbonded area exceeding 9 in.² (58 cm²) with total unbonded area not to exceed 5 % of the total clad surface area.

13.3.4 The class to be supplied shall be listed on the purchase order. When none has been specified, plates shall be furnished as Class 5 at the option of the manufacturer.

14. Welding

14.1 All welding which is a part of the delivered product, including any made in the fabrication of the cladding alloy component, shall be performed with a procedure and welders or welding operators that are qualified in accordance with Section IX of the ASME Code.

14.2 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

14.2.1 When specified in the purchase order, prior approval shall be obtained from the purchaser.

14.2.2 The defective area shall be removed and the area prepared for repair shall be examined by a liquid penetrant method to ensure all defective area has been removed. Method

of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

14.2.3 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

14.2.4 The repaired area shall be examined by a liquid penetrant method in accordance with 14.2.2.

14.2.5 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

15. General Requirements for Delivery

15.1 Material furnished under this specification shall conform to the applicable requirements of Specification A6/A6M or A20/A20M as appropriate for the backing metal.

15.2 In the event of conflicts between this specification and the general delivery requirement specification for the backing steel, this specification shall apply.

16. Certification

16.1 The chemical analysis of the base metal and the alloy cladding shall be certified to the purchaser by the clad plate manufacturer.

16.2 The results of the tests in Section 7 and any other tests required by the purchase order shall be reported to the purchaser.

16.3 Compliance with the clad quality level of 13.3 shall be certified. Reports shall include the results of ultrasonic inspection when Supplementary Requirement S12 is specified.

16.4 Compliance with any applicable construction code shall be certified and the appropriate documentation provided when appropriate in the case of explosively bonded clad produced using welded alloy cladding components (see 4.1.9 and 4.1.11).

17. Product Marking

17.1 Except as specified in 17.2, plates shall be marked in accordance with the requirements of Specification A6/A6M or A20/A20M for the backing steel as applicable, the cladding alloy designation, and this specification number.

17.2 For double-clad material or for material under $\frac{3}{8}$ in. (6.35 mm) nominal in thickness or for clad plates provided with conditioned surfaces, the marking specified in 17.1 shall be legibly stenciled instead of stamped when the material is shipped with the alloy surface up.

18. Keywords

18.1 alloy cladding; bond strength; carbon steel; clad steel plate; low-alloy steel; nickel; nickel-base alloy

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S2. Product Analysis

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S5. Charpy V-Notch Impact Test

S12. Ultrasonic Examination in accordance with Specification A578/A578M

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SPECIFICATION FOR CARBON STEEL FORGINGS FOR PRESSURE VESSEL COMPONENTS



SA-266/SA-266M



(Identical with ASTM Specification A266/A266M-13.)

Standard Specification for Carbon Steel Forgings for Pressure Vessel Components

1. Scope

1.1 This specification covers four grades of carbon steel forgings for boilers, pressure vessels, and associated equipment.

NOTE 1—Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 2	Class 2
Grade 3	Class 3
Grade 4	Class 4

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 Unless the order specifies the applicable “M” specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

- A275/A275M Practice for Magnetic Particle Examination of Steel Forgings
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A788/A788M Specification for Steel Forgings, General Requirements

A1058 Test Methods for Mechanical Testing of Steel Products—Metric

E112 Test Methods for Determining Average Grain Size

E165/E165M Practice for Liquid Penetrant Examination for General Industry

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

2.2 *Other Standard:*

ASME Boiler and Pressure Vessel Code, Section IX

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A788/A788M, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging.

3.2 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

3.4 For hubbed flat heads and tube sheets ordered for ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S12 of Specification A788/A788M shall be specified in addition to Supplementary Requirement S8 of this specification.

4. Materials and Manufacture

4.1 The steel shall be made in accordance with the Melting Process Section of Specification A788/A788M. A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

4.2 The material shall be forged as close as practical to the specified shape and size.

4.3 The finished product shall be a hot-worked forging as defined by Specification A788/A788M.

5. Machining

5.1 Surfaces shall be machined as designated by the purchaser. Unmachined surfaces shall be sufficiently free of scale to permit inspection.

5.2 Machining may be performed either prior to or after heat treatment at the option of the manufacturer unless specified in accordance with Supplementary Requirement S1.

6. Heat Treatment

6.1 After forging and before reheating for heat treatment, the forgings shall be cooled in such a manner as to prevent injury and to accomplish transformation.

6.2 All forgings shall be annealed, normalized, or normalized and tempered, but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. When tempering is performed, it shall be at a subcritical temperature, but no less than 1100°F [595°C].

6.3 A multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize, and again liquid quenched. On completion of the austenitizing/quenching cycles, tempering at a temperature between 1100°F [595°C] and the lower critical temperature shall follow.

NOTE 2—Although liquid quenching from the austenitizing temperatures is more effective in enhancing impact properties, air cooling from the austenitizing temperatures is also beneficial and may be used instead of the normalizing procedure in 6.2.

7. Chemical Composition

7.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 1 except that the additional features of Supplementary Requirements S11 and S12 shall also apply as individually specified in the ordering information.

7.2 *Product Analysis*—The purchaser may use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat.

8. Mechanical Properties

8.1 *General Requirements*—Except when otherwise specified in accordance with Supplementary Requirement S2, the material shall conform to the requirements for mechanical

properties prescribed in Table 2 when tested in accordance with the latest issue of Test Methods and Definitions A370 or Test Methods A1058 when the M suffix standard has been specified. The largest obtainable tension test specimen as specified in Test Methods and Definitions A370 or Test Methods A1058, as applicable, shall be used.

8.1.1 Except when otherwise specified in accordance with Supplementary Requirement S2, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging. For upset-disc forgings, the longitudinal axis of the test specimen shall be in the tangential direction.

8.1.1.1 The longitudinal axis of the specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks or midway between the center and surface of solid forgings. For hollow forgings, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed as defined in 8.1.3, the tension test specimens shall be taken from a location that represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane.

8.1.2 Except as specified herein, tests for acceptance shall be made after heat treatment has been completed. When the ends of the cylindrical forgings are closed in by reforging, the cylindrical forgings may be annealed, normalized, or normalized and tempered and tested prior to reforging. After reforging, the entire forging shall be reheat-treated in the same manner and at the same temperature range as employed when the forging was heat-treated prior to certification testing.

8.1.3 When mutually agreed upon between manufacturer and purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same type of hot working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than T by T by $3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 3—In using separately forged test blocks, attention is drawn to the effect of mass differences between the production forgings and the test blocks.

TABLE 1 Chemical Requirements

	Composition, %		
	Grades 1 and 2	Grade 3	Grade 4
Carbon, max	0.30	0.35	0.30
Manganese	0.40–1.05	0.80–1.35	0.80–1.35
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35

TABLE 2 Tensile Requirements

	Grade 1	Grades 2 and 4	Grade 3
Tensile strength, min, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	75–100 [515–690]
Yield strength (0.2 % offset), min, ksi [MPa]	30 [205]	36 [250]	37.5 [260]
Elongation in 2 in. [62.5 mm], min, %	23 [21]	20 [18]	19 [17]
Reduction of area, min, %	38	33	30

8.2 *Specific Requirements*—The number and location of tests are based on forging length, weight, and heat treatment, and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 *Annealed, Normalized, or Normalized and Tempered Steel Forgings:*

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 *Quenched and Tempered Forgings:*

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 lb [2250 kg] to 10 000 lb [4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 For quenched and tempered forgings and forged bars that exceed 12 ft [3.7 m] in length, one tension test shall be taken from each end of each forging.

8.2.2.4 For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension test specimens shall be taken from each forging. These shall be offset 180° from each other except that if the length of the forging, excluding test prolongations, exceeds 12 ft [3.7 m], then one specimen shall be taken from each end of the forging.

9. Repair Welding

9.1 Repair welding of forgings is permissible only at the option of the purchaser. If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10. Certification

10.1 In addition to the mandatory certification requirements of Specification A788/A788M, the heat treatment cycle data shall be included.

11. Product Marking

11.1 Each forging shall be identified in accordance with the Marking Section of Specification A788/A788M. In addition, the forging shall be marked following the grade designation by the letter “A” for annealed, “N” for normalized, “NT” for normalized and tempered, and “S” for liquid quenched and tempered, as applicable.

12. Keywords

12.1 pressure vessel service; steel forgings—carbon

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be as specified by the purchaser.

S2. Alternative Tension Test Orientation

S2.1 In lieu of the requirements of Section 8, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall

conform with requirements of Table 2, with the exception of the ductility limits that shall be as follows:

Grade	1	2 and 4	3
Elongation in 2 in. [62.5 mm], min, %	20 [18]	19 [17]	18 [16]
Reduction of area, min, %	30	25	25

S3. Hydrostatic Test

S3.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. The method shall be in accordance with Practice A275/A275M. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 After forgings have been heat treated by liquid quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Test Method E165/E165M as an alternative to magnetic particle examination.

S6. Macroetch Test

S6.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted in accordance with Method E381. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S7. Product Analysis

S7.1 A product analysis in accordance with Section 7 shall be made from one randomly selected forging representing each size and shape of forging on the order. If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S8. Specimen Location on Forged Hubs

S8.1 Forged hubs to be butt-welded to shells shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. A tension specimen (subsize if necessary) shall be taken in this direction and as close to the finished hub outside diameter as practical.

S9. Hardness

S9.1 The purchaser may check the Brinell hardness of the forging at any location on the surface of the forging, and the hardness shall be within the following limits:

Grade	Brinell Hardness Range HBW
1	121 to 170
2 and 4	137 to 197
3	156 to 207

S10. Grain Size

S10.1 The austenitic grain size of the steel shall be 1 to 5 as determined using Test Methods E112.

S11. Restriction on Residual Elements (Applicable to Heat Analysis)

S11.1 Nickel, chromium, and molybdenum shall be determined and shall not exceed the following limits:

Nickel	0.25 % max
Chromium	0.20 % max
Molybdenum	0.08 % max

S12. Restriction on Carbon (Applicable to Grade I)

S12.1 The carbon content shall be 0.30 % max.

S13. Impact Tests

S13.1 Charpy impact tests shall be made. The number and location of the tests, minimum properties, and test temperatures shall be specified.

S13.2 The specimens shall be machined and tested in accordance with Test Methods and Definitions A370.

S13.3 Retests may be conducted in accordance with Section 10 of Specification A788/A788M.

S14. Individual Forging

S14.1 Forgings, whether identical or not, shall be produced individually. They shall not be forged in multiples and separated prior to or after heat treatment.

S14.2 The shape and size of individual forgings shall be agreed upon between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

S15. Carbon Equivalency

S15.1 The heat analysis including the residual element restrictions of S1 in Specification A788/A788M shall be limited such that the carbon equivalent shall not exceed 0.45 for Grade 1 or 0.50 for Grade 2 or 4 when calculated in accordance with the following formula:

$$CE = \% C + \frac{\% Mn}{6} + \frac{\% Cr + \% Mo + \% V}{5} + \frac{\% Ni + \% Cu}{15}$$

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SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC AND MARTENSITIC STAINLESS STEEL TUBING FOR GENERAL SERVICE



SA-268/SA-268M



(Identical with ASTM Specification A268/A268M-10.)

Standard Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service

1. Scope

1.1 This specification covers a number of grades of nominal-wall-thickness, stainless steel tubing for general corrosion-resisting and high-temperature service. Most of these grades are commonly known as the “straight-chromium” types and are characterized by being ferromagnetic. Two of these grades, TP410 and UNS S 41500 (Table 1), are amenable to hardening by heat treatment, and the high-chromium, ferritic alloys are sensitive to notch-brittleness on slow cooling to ordinary temperatures. These features should be recognized in the use of these materials. Grade TP439 is used primarily for hot-water tank service and does not require post-weld heat treatment to prevent attack of the heat affected zone.

1.2 An optional supplementary requirement is provided, and when desired, shall be so stated in the order.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

3. Terminology

3.1 *Lot Definitions:*

3.1.1 For flange and flaring requirements, the term lot applies to all tubes, prior to cutting, of the same nominal size and wall thickness that are produced from the same heat of steel. If final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. If the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as given in Table 2.

3.1.2 For tensile and hardness test requirements, the term lot applies to all tubes, prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. If final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. If the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless or welded tubes),

4.1.3 Grade (Table 1),

4.1.4 Size (outside diameter and nominal wall thickness),

TABLE 1 Chemical Requirements

Grade	TP405	TP410	TP429	TP430	TP443	TP446-1	TP446-2 ⁴	...	TP409
UNS Designation	S40500	S41000	S42900	S43000	S44300	S44600	S44600	S40800	S40900
Element	Composition, %								
C, max	0.08	0.15	0.12	0.12	0.20	0.20	0.12	0.08	0.08
Mn, max	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.00	1.00
P, max	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.045	0.045
S, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.045	0.030
Si, max	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ni	0.50 max	...	...	...	0.75 max	0.75 max	0.50 max	0.80 max	0.50 max
Cr	11.5–14.5	11.5–13.5	14.0–16.0	16.0–18.0	18.0–23.0	23.0–27.0	23.0–27.0	11.5–13.0	10.5–11.7
Mo	...	...	...	...	...	...	...	...	...
Al	0.10–0.30	...	...	...	...	...	...	...	...
Cu	...	...	...	...	0.90–1.25	...	...	...	...
N	...	...	...	...	...	0.25	0.25	...	...
Ti	...	...	...	...	...	...	...	12 × C min; 1.10 max	6 × C min; 0.75 max

TABLE 1 Continued

Grade	TP439	...	...	TP430 Ti	TP XM-27	TP XM-33 ^A	18Cr-2Mo	29-4	29-4-2	26-3-3	25-4-4	...	...	...	...	...	TP468
UNS Designation	S43035	S43932	S41500 ^B	S43036	S44627	S44626	S44400	S44700	S44800	S44660	S44635	S44735	S32803	S40977	S43940	S42035	S46800
Element	Composition, %																
C, max	0.07	0.030	0.05	0.10	0.01 ^A	0.06	0.025	0.010	0.010	0.030	0.025	0.030	0.015 ^C	0.03	0.03	0.08	0.030
Mn, max	1.00	1.00	0.5–1.0	1.00	0.40	0.75	1.00	0.30	0.30	1.00	1.00	1.00	0.5	1.50	1.00	1.00	1.00
P, max	0.040	0.040	0.03	0.040	0.02	0.040	0.040	0.025	0.025	0.040	0.040	0.040	0.020	0.040	0.040	0.045	0.040
S, max	0.030	0.030	0.03	0.030	0.02	0.020	0.030	0.020	0.020	0.030	0.030	0.030	0.005	0.015	0.015	0.030	0.030
Si, max	1.00	1.00	0.60	1.00	0.40	0.75	1.00	0.20	0.20	1.00	0.75	1.00	0.50	1.00	1.00	1.00	1.00
Ni	0.50 max	0.50	3.5–5.5	0.75 max	0.5 ^D max	0.50 max	1.00 max	0.15 max	2.0–2.5	1.0–3.50	3.5–4.5	1.00 max	3.0–4.0	0.30–1.00	...	1.0–2.5	0.50
Cr	17.00–19.00	17.0–19.0	11.5–14.0	16.00–19.50	25.0–27.5	25.0–27.0	17.5–19.5	28.0–30.0	28.0–30.0	25.0–28.0	24.5–26.0	28.00–30.00	28.0–29.00	0.50–12.50	7.50–18.50	13.5–15.50	8.00–20.00
Mo	...	...	0.5–1.0	...	0.75–1.50	0.75–1.50	1.75–2.50	3.5–4.2	3.5–4.2	3.0–4.0	3.5–4.5	3.60–4.20	1.8–2.5	...	...	0.2–1.2	...
Al, max	0.15	0.15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cu, max	...	...	...	...	0.2	0.20	...	0.15	0.15	...	...	...	...	...	...	...	...
N, max	0.04	0.030 (Ti + Cb) {0.20 + 4 (C + N)} min.; 0.75 max	...	...	0.015	0.040	0.035	0.020 ^E	0.020 ^E	0.040	0.035	0.045	0.020	0.030	...	...	0.030
Ti	0.20 + 4 (C + N) min; 1.10 max	...	...	5 × C min; 0.75 max	...	7 × (C + N) but no less than 0.20 min; 1.00 max	(Ti + Cb) 0.20 + 4 (C + N) min; 0.80 max	...	...	(Ti + Cb) = 0.20–1.00 and 6 × (C + N) min	(Ti + Cb) = 0.20 + 4 (C + N) min to 0.80 max	(Ti + Cb) = 0.20–1.00 and 6 × (C + N) min	...	...	0.10–0.60	0.30–0.50	0.07–0.30
Cb	...	...	...	...	0.05–0.20	...	...	...	...	...	...	...	0.15–0.50 ^F	...	(3 × %C + 0.30) min	...	0.10–0.60 (Ti + Cb) = 0.20 + 4(C+N) min; 0.80 max

^A For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015 % is necessary. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).

^B Plate version of CA6NM.

^C Carbon plus nitrogen = 0.30 max.

^D Nickel plus copper.

^E Carbon plus nitrogen = 0.025 % max.

^F Cb/(C + N) = 12 min.

- 4.1.5 Length (specific or random),
 4.1.6 Optional requirements (hydrostatic or nondestructive electric test, Section 16),
 4.1.7 Test report required (Certification Section of Specification A1016/A1016M),
 4.1.8 Specification designation,
 4.1.9 Intergranular corrosion test, and
 4.1.10 Special requirements.

TABLE 2 Number of Tubes in a Lot Heat Treated by the Continuous Process

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of Specification A1016/A1016M unless otherwise provided herein.

6. Manufacture

6.1 The tubes shall be made by the seamless or welded process with no filler metal added.

7. Heat Treatment

7.1 As a final heat treatment, tubes shall be reheated to a temperature of 1200 °F [650 °C] or higher and cooled (as appropriate for the grade) to meet the requirements of this specification.

7.2 The martensitic grade UNS S 41500 shall be reheated to a temperature of 950 °F [510 °C] or higher and cooled as appropriate to meet the requirements of this specification.

8. Chemical Composition

8.1 The steel shall conform to the chemical requirements prescribed in Table 1.

9. Product Analysis

9.1 An analysis of either one billet or one length of flatrolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 The product analysis tolerance of the Chemical Requirements Table of A480/A480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

9.3 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining

material in the heat or lot shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

10. Tensile Requirements

10.1 The material shall conform to the tensile properties prescribed in Tables 3 and 4.

11. Hardness Requirements

11.1 The tubes shall have a hardness number not to exceed those prescribed in Table 5.

TABLE 3 Tensile Requirements

Grade and UNS Designation	Tensile strength,	Yield strength,	Elongation ^A
	min, ksi [MPa]	min, ksi [MPa]	in 2 in. or 50 mm, min, %
TP405	60 [415]	30 [205]	20
S40500	55 [380]	30 [205]	20
S40800	60 [415]	30 [205]	20
TP410	60 [415]	30 [205]	20
S41000	60 [415]	30 [205]	20
TP429, TP430, and TP430 Ti	60 [415]	35 [240]	20
S429000, S 43000, and S 43036	70 [485]	40 [275]	20
TP443	70 [485]	40 [275]	18
S44300	65 [450]	40 [275]	20
TP446-1	65 [450]	40 [275]	20
S44600	55 [380]	25 [170]	20
TP446-2	60 [415]	30 [205]	20
S44600	60 [415]	30 [205]	20
TP409	115 [795]	90 [620]	15
S40900	60 [415]	30 [205]	20
TP439	60 [415]	30 [205]	20
S43035	60 [415]	30 [205]	20
S43932	60 [415]	30 [205]	20
S41500	115 [795]	90 [620]	15
TPXM-27	65 [450]	40 [275]	20
S44627	68 [470]	45 [310]	20
TPXM-33	60 [415]	40 [275]	20
S44626	60 [415]	40 [275]	20
18Cr-2Mo	60 [415]	40 [275]	20
S44400	80 [550]	60 [415]	20
29-4 and 29-4-2	80 [550]	60 [415]	20
S44700 and S44800	85 [585]	65 [450]	20
26-3-3	85 [585]	65 [450]	20
S44660	90 [620]	75 [515]	20
25-4-4	90 [620]	75 [515]	20
S44635	75 [515]	60 [415]	18
S44735	87 [600]	72 [500]	16
28-2-3.5	65 [450]	41 [280]	18
S32803	62 [430]	36 [250]	18
S40977	80 [550]	55 [380]	16
S43940	60 [415]	30 [205]	22
S42035	60 [415]	30 [205]	22
TP468	60 [415]	30 [205]	22
S46800	60 [415]	30 [205]	22

^A For tubing smaller than ½ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 2 shall apply. Mechanical property requirements do not apply to tubing smaller than ⅙ in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].

^B For longitudinal strip tests a deduction of 0.90 % for TP446-1 and S44735 and 1.00 % for all other grades shall be made from the basic minimum elongation for each ⅙ in. [0.8 mm] decrease in wall thickness below ⅙ in. [8 mm]. The following table gives the computed minimum values:

TABLE 4 Minimum Elongation Values

Wall Thickness		Elongation ^A in 2 in. or 50 mm, min, %		
in.	mm	TP446-1 and S44735	S41500	All Other Grades
3/16 [0.312]	8	18	15	20
3/32 [0.281]	7.2	17	14	19
1/4 [0.250]	6.4	16	14	18
7/32 [0.219]	5.6	15	13	17
3/16 [0.188]	4.8	14	12	16
5/32 [0.156]	4	13	11	15
1/8 [0.125]	3.2	13	11	14
3/32 [0.094]	2.4	12	10	13
1/16 [0.062]	1.6	11	9	12
0.062–0.035, excl	1.6–0.9	10	8	12
0.035–0.022, excl	0.9–0.6	10	8	11
0.022–0.015, incl	0.6–0.4	10	8	11

^ACalculated elongation requirements shall be rounded to the nearest whole number.

Note—The above table gives the computed minimum values for each 1/32 in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
TP446-1 and S44735	$E = 28.8t + 9.00$ [$E = 1.13t + 9.00$]
S41500	$E = 24t + 7.5$
All other grades	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]

where:

E = elongation in 2 in. or 50 mm, %.

t = actual thickness of specimen, in. [mm].

TABLE 5 Hardness Requirements.

Grade	UNS Designation	Brinell Hardness, max	Rockwell Hardness, B Scale, max
TP405	S40500	207	95
...	S40800	207	95
TP410	S41000	207	95
TP429, TP430, and TP430 TI	S42900, S 43000, and S 43036	190	90
TP443	S44300	207	95
TP446-1 and TP446-2	S44600	207	95
TP409	S40900	207	95
TP439	S43035 ^A	190	90
...	S43932	190	90
...	S41500	295 ^B	32
TPXM-33 and TPXM-27	S44626 and S44627	241	100
18CR-2Mo	S44400	217	95
29-4 and 29-4-2	S44700 and S44800	207	100
26-3-3	S44660	265	25 ^B
25-4-4	S44635	270	27 ^B
...	S44735	...	100
28-2-3.5	S32803	240	100
...	S40977	180	88
...	S43940	180	88
...	S42035	180	88

^A Editorially corrected October 2000.

^B Rockwell hardness, C scale.

12. Permissible Variations in Dimensions

12.1 Variations in outside diameter, wall thickness, and length from those specified shall not exceed the amounts prescribed in Table 6.

12.2 The permissible variations in outside diameter given in Table 6 are not sufficient to provide for ovality in thin-walled tubes, as defined in the Table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 6; however, the mean diameter at that cross section must still be within the given permissible variation.

12.3 When the specified wall is 2 % or less of the specified outside diameter, the method of measurement is in accordance with the agreement between the purchaser and the manufacturer (see Note 1).

NOTE 1—Very thin wall tubing may not be stiff enough for the outside diameter to be accurately measured with a point contact test method, such as with the use of a micrometer or caliper. When very thin walls are specified, “go”–“no go” ring gages are commonly used to measure diameters of 1 1/2 in. [38.1 mm] or less. A0.002-in. [0.05-mm] additional tolerance is usually added on the “go” ring gage to allow clearance for sliding. On larger diameters, measurement is commonly performed with a pi tape. Other test methods such as optical test methods may also be considered.

13. Surface Condition

13.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

14. Mechanical Tests Required

14.1 *Tension Tests*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

14.2 *Flaring Test (for Seamless Tubes)*—One test shall be made on specimens from one end of one tube from each lot of finished tubes. The minimum expansion of the inside diameter shall be 10 %. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness 3/8 in. [9.52 mm] and over, the flattening test may be performed instead of the flaring test unless the flaring test is specified in the purchase order.

14.3 *Flange Test (for Welded Tubes)*—One test shall be made on specimens from one end of one tube from each lot of finished tubes. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness 3/8 in. [9.52 mm] and over, the flattening test may be performed instead of the flange test unless the flange test is specified in the purchase order.

14.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

14.5 When more than one heat is involved, the tension, flaring, flanging, and hardness test requirements shall apply to each heat.

14.6 *Reverse Flattening Test*—For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

15. Intergranular Corrosion Test

15.1 If intergranular corrosion testing is specified in the purchase order, the test shall be made in accordance with

TABLE 6 Permissible Variations in Dimensions

Group	Size, Outside Diameter, in. [mm]	Permissible Variations in Outside Diameter, in. [mm]	Permissible Variations in Wall Thickness, ^A %	Permissible Variations in Cut Length, in. ^B [mm]		Thin-Walled Tubes ^C
				Over	Under	
1	Up to ½ [12.7], excl	±0.005 [0.13]	±15	⅛ [3]	0	...
2	½ to 1½ [12.7 to 38.1], excl	±0.005 [0.13]	±10	⅛ [3]	0	less than 0.065 in. [1.6 mm] nominal
3	1½ to 3½ [38.1 to 88.9], excl	±0.010 [0.25]	±10	⅜ [5]	0	less than 0.095 in. [2.4 mm] nominal
4	3½ to 5½ [88.9 to 139.7], excl	±0.015 [0.38]	±10	⅜ [5]	0	less than 0.150 in. [3.8 mm] nominal
5	5½ to 8 [139.7 to 203.2], incl	±0.030 [0.76]	±10	⅜ [5]	0	less than 0.150 in. [3.8 mm] nominal

^AWhen tubes as ordered require wall thicknesses ¼ in. [19 mm] or over, or an inside diameter 60 % or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5 % over or under will be permitted.

For tubes less than ½ in. [12.7 mm] in inside diameter which cannot be successfully drawn over a mandrel, the wall thickness may vary ±15 % from that specified.

^BThese tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over tolerances shall be increased by ⅛ in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft, or ½ in. [13 mm], whichever is lesser.

^COvality provisions of 12.2 apply.

Practices A763, using samples prepared as agreed upon between the seller and the purchaser.

16. Hydrostatic or Nondestructive Electric Test

16.1 Each tube, seamless or welded, shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

17. Product Marking

17.1 In addition to the marking described in Specification A1016/A1016M, the marking shall indicate whether the tubing is seamless or welded.

18. Keywords

18.1 ferritic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Pneumatic Test

S1.1 The tubing shall be examined by a pneumatic test (either air under water or pneumatic leak test) in accordance with Specification A1016/A1016M.

S2. Additional Testing of Welded Tubing for 100 % Joint Efficiency in Certain ASME Applications (see Note S2.1)

NOTE S2.1—When specified, the special testing in this supplement is intended for special ASME applications. It is not mandatory for all ASME applications.

S2.1 Where this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100 % joint efficiency for the longitudinal weld, provided the following additional requirements are met:

S2.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E273 or E213 with the rejection criteria referenced in Specification A1016/A1016M.

S2.1.2 If Practice E273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A1016/A1016M.

S2.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S2.1.4 In addition to the marking prescribed in Specification A1016/A1016M, “S2” shall be added after the grade designation.

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SPECIFICATION FOR STAINLESS STEEL BARS AND SHAPES



SA-276



(Identical with ASTM Specification A276-97.)

SPECIFICATION FOR STAINLESS STEEL BARS AND SHAPES



SA-276



(Identical with ASTM Specification A 276-97.)

1. Scope

1.1 This specification covers hot-finished or cold-finished bars except bars for reworking (Note 1). It includes rounds, squares, and hexagons, and hot-rolled or extruded shapes, such as angles, tees, and channels in the more commonly used types of stainless steels. The free-machining types (Note 2), for general corrosion resistance and high-temperature service, are covered in a separate specification.

NOTE 1 —For bars for reworking, see Specification A 314.

NOTE 2 —For free-machining stainless bars designed especially for optimum machinability, see Specification A 582/A 582M.

NOTE 3 —There are standards covering high nickel, chromium, austenitic corrosion, and heat resisting alloy materials. These standards are under the jurisdiction of ASTM Subcommittee B02.07 and may be found in Annual Book of ASTM Standards, Vol. 02.04.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

- A 314 Specification for Stainless Steel Billets and Bars for Forging
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
- A 582/A 582M Specification for Free-Machining Stainless Steel Bars
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 Other Document:

- SAE J1086 Recommended Practice for Numbering Metals and Alloys

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include but are not limited to the following:

3.1.1 Quantity (weight or number of pieces);

3.1.2 Name of material: stainless steel;

3.1.3 Form (bars, angles, etc.);

3.1.4 Condition (Section 5.1);

3.1.5 Finish (Section 4 of Specification A 484/A 484M);

3.1.6 Surface preparation of shapes (Section 4 of Specification A 484/A 484M);

3.1.7 Applicable dimensions including size, thickness, width, and length;

3.1.8 Cross section (round, square, etc.);

3.1.9 Type or UNS designation (Table 1);

3.1.10 ASTM designation and date of issue; and

3.1.11 Whether bars are to be rolled as bars or cut from strip or plate.

3.1.12 Test for magnetic permeability when specified by customer purchase order when ordering Types 201 and 205.

3.1.13 Special requirements.

NOTE 4 —A typical ordering description is as follows: 5,000 lb (2268 kg) Stainless Steel Bars, Annealed and Centerless Ground, 1½ in. (38.10 mm) Round, 10 to 12 ft (3.05 to 3.66 m) in length, Type 304, ASTM Specification A 276 dated _____, End use: machined valve parts.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specification A 484/A 484M shall apply. Failure to comply with the

general requirements of Specification A 484/A 484M constitutes nonconformance to this specification.

5. Manufacture

5.1 Condition:

5.1.1 Bars shall be furnished in one of the following conditions listed in the Mechanical Requirements table:

5.1.1.1 *Condition A* — Annealed.

5.1.1.2 *Condition H* — Hardened and tempered at a relatively low temperature.

5.1.1.3 *Condition T* — Hardened and tempered at a relatively high temperature.

5.1.1.4 *Condition S* — Strain Hardened—Relatively light cold work.

5.1.1.5 *Condition B* — Relatively severe cold work.

6. Chemical Composition

6.1 The steel shall conform to the requirements for chemical composition specified in Table 1.

6.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties Requirements

7.1 The material shall conform to the mechanical test requirements specified in Table 2.

7.2 The martensitic grades shall be capable of meeting the hardness requirements after heat treating as specified in Table 3.

7.3 Hardness measurements, when required, shall be made at a location midway between the surface and the center of the cross section.

8. Magnetic Permeability

8.1 When required by the purchase order, the magnetic permeability of Types 201 and 205 in the annealed condition shall not exceed 1.2 as tested by a Severn-type indicator.

9. Certification

9.1 Upon request of the purchaser in the contract or order, the producer's certification that the material was manufactured and tested in accordance with this specification, together with a certified report of the test results shall be furnished at the time of the shipment.

10. Keywords

10.1 austenitic stainless steel; austenitic-ferritic duplex stainless steel; ferritic stainless steel; martensitic stainless steel; stainless steel bars; stainless steel shapes.

TABLE 1
CHEMICAL REQUIREMENTS^A

UNS Designation ^B	Type	Composition, %									
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Other Elements
Austenitic Grades											
S20100	201	0.15	5.50–7.50	0.060	0.030	1.00	16.00–18.00	3.50–5.50	...	0.25	...
S20161	...	0.15	4.00–6.00	0.040	0.040	3.00–4.00	15.00–18.00	4.00–6.00	...	0.08–0.20	...
S20200	202	0.15	7.50–10.00	0.060	0.030	1.00	17.00–19.00	4.00–6.00	...	0.25	...
S20500	205	0.12–25	14.00–15.50	0.060	0.030	1.00	16.50–18.00	1.00–1.70	...	0.32–0.40	...
S20910	XM–19	0.06	4.00–6.00	0.040	0.030	1.00	20.50–23.50	11.50–13.50	1.50–3.00	0.20–0.40	Cb 0.10–0.30, V 0.10–0.30
S21800	...	0.10	7.00–9.00	0.060	0.030	3.50–4.50	16.00–18.00	8.00–9.00	...	0.08–0.18	...
S21900	XM–10	0.08	8.00–10.00	0.060	0.030	1.00	19.00–21.50	5.50–7.50	...	0.15–0.40	...
S21904	XM–11	0.04	8.00–10.00	0.060	0.030	1.00	19.00–21.50	5.50–7.50	...	0.15–0.40	...
S24000	XM–29	0.08	11.50–14.50	0.060	0.030	1.00	17.00–19.00	2.25–3.75	...	0.20–0.40	...
S24100	XM–28	0.15	11.00–14.00	0.060	0.030	1.00	16.50–19.00	0.50–2.50	...	0.20–0.45	...
S24565	...	0.030	5.0–7.0	0.030	0.010	1.00	23.00–25.00	16.0–18.0	4.0–5.0	0.4–0.6	Cb 0.10
S28200	...	0.15	17.00–19.00	0.045	0.030	1.00	17.00–19.00	...	0.75–1.25	0.40–0.60	Cu 0.75–1.25
S30200	302	0.15	2.00	0.045	0.030	1.00	17.00–19.00	8.00–10.00	...	0.10	...
S30215	302B	0.15	2.00	0.045	0.030	2.00–3.00	17.00–19.00	8.00–10.00	...	...	...
S30400	304	0.08	2.00	0.045	0.030	1.00	18.00–20.00	8.00–10.50	...	0.10	...
S30403	304L ^C	0.030	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	...	0.10	...
S30451	304N	0.08	2.00	0.045	0.030	1.00	18.00–20.00	8.00–10.50	...	0.10–0.16	...
S30452	XM–21	0.08	2.00	0.045	0.030	1.00	18.00–20.00	8.00–10.50	...	0.16–0.30	...
S30453	304LN	0.03	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	...	0.10–0.16	...
S30454	...	0.03	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	...	0.16–0.30	...
S30500	305	0.12	2.00	0.045	0.030	1.00	17.00–19.00	10.50–13.00	...	...	...
S30800	308	0.08	2.00	0.045	0.030	1.00	19.00–21.00	10.00–12.00	...	...	...
S30815	...	0.10	0.80	0.040	0.030	1.40–2.00	20.00–22.00	10.00–12.00	...	0.14–0.20	Ce 0.03–0.08
S30900	309	0.20	2.00	0.045	0.030	1.00	22.00–24.00	12.00–15.00	...	...	...
S30908	309S	0.08	2.00	0.045	0.030	1.00	22.00–24.00	12.00–15.00	...	...	...
S30940	309Cb	0.08	2.00	0.045	0.030	1.00	22.00–24.00	12.00–16.00	...	0.10	Cb+Ta 10×C–1.10
S31000	310	0.25	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...
S31040	310Cb	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	0.10	Cb+Ta 10×C–1.10
S31254	...	0.020	1.00	0.030	0.010	0.80	19.50–20.50	17.50–18.50	6.00–6.50	0.18–0.22	Cu 0.50–1.00
S31400	314	0.25	2.00	0.045	0.030	1.50–3.00	23.00–26.00	19.00–22.00	...	...	...
S31600	316	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	...
S31603	316L ^C	0.030	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	...
S31635	316Ti	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	Ti 5×(C+N)–0.70
S31640	316Cb	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	Cb+Ta 10×C–1.10

TABLE 1
CHEMICAL REQUIREMENTS⁴ (CONT'D)

UNS Designation ^B	Type	Composition, %									
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Other Elements
Austenitic-Ferritic Grades											
S31651	316N	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10–0.16	...
S31653	316LN	0.030	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10–0.16	Cu 0.16–0.30
S31654	...	0.03	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	...	...
S31700	317	0.08	2.00	0.045	0.030	1.00	18.00–20.00	11.00–15.00	3.00–4.00	0.10	...
S31725	...	0.03	2.00	0.045	0.030	1.00	18.00–20.00	13.50–17.50	4.0–5.0	0.10	Cu 0.75
S31726	...	0.03	2.00	0.045	0.030	1.00	17.00–20.00	13.50–17.50	4.0–5.0	0.10–0.20	Cu 0.75
S32100	321	0.08	2.00	0.045	0.030	1.00	17.00–19.00	9.00–12.00	...	...	Ti 5×(C+N)–0.70 ^D
S32550	...	0.04	1.50	0.040	0.030	1.00	24.0–27.0	4.50–6.50	2.9–3.9	0.10–0.25	Cu 1.50–2.50
S34700	347	0.08	2.00	0.045	0.030	1.00	17.00–19.00	9.00–13.00	...	...	Cb+Ta 10×C min
S34800	348	0.08	2.00	0.045	0.030	1.00	17.00–19.00	9.00–13.00	...	...	Cb+Ta 10×C min, Ta 0.10 Co 0.20
S31100	XM-26	0.06	1.00	0.040	0.030	1.00	25.00–27.00	6.00–7.00	...	...	Ti 0.25
S31803	...	0.030	2.00	0.030	0.020	1.00	21.00–23.00	4.50–6.50	2.50–3.50	0.08–0.20	...
S32304	...	0.030	2.50	0.040	0.030	1.00	21.50–24.50	3.00–5.50	0.05–0.60	0.05–0.20	Cu 0.05–0.60
S32760 ^E	...	0.030	1.00	0.030	0.010	1.00	24.00–26.00	6.00–8.00	3.00–4.00	0.20–0.30	Cu 0.05–1.00 W 0.50–1.00
Ferritic Grades											
S40500	405	0.08	1.00	0.040	0.030	1.00	11.50–14.50	...	...	...	Al 0.10–0.30
S42900	429	0.12	1.00	0.040	0.030	1.00	14.00–16.00	...	...	...	...
S43000	430	0.12	1.00	0.040	0.030	1.00	16.00–18.00	...	...	...	...
S44400	...	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	Ti+Cb 0.20+4× (C+N)–0.80
S44600	446	0.20	1.50	0.040	0.030	1.00	23.00–27.00	...	...	0.25	...
S44627	XM-27 ^F	0.010 ^G	0.40	0.020	0.020	0.40	25.00–27.50	0.50 max.	0.75–1.50	0.015 ^G	Cu 0.20 Cb 0.05–0.20
S44700	...	0.010	0.30	0.025	0.020	0.20	28.00–30.00	0.15 max.	3.50–4.20	0.020	C+N 0.025 Cu 0.15
S44800	...	0.010	0.30	0.025	0.020	0.20	28.00–30.00	2.00–2.50	3.50–4.20	0.020	C+N 0.25 Cu 0.15

TABLE 1
CHEMICAL REQUIREMENTS^A (CONT'D)

UNS Designation ^B	Type	Composition, %									
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Other Elements
Martensitic Grades											
S40300	403	0.15	1.00	0.040	0.030	0.50	11.50–13.00	...	...	...	...
S41000	410	0.15	1.00	0.040	0.030	1.00	11.50–13.50	...	...	...	...
S41040	XM-30	0.18	1.00	0.040	0.030	1.00	11.50–13.50	...	...	...	Cb 0.05–0.30
S41400	414	0.15	1.00	0.040	0.030	1.00	11.50–13.50	1.25–2.50	...	...	...
S41500	^H	0.05	0.50–1.00	0.030	0.030	0.60	11.50–14.00	3.50–5.50	0.50–1.00	...	...
S42000	420	over 0.15	1.00	0.040	0.030	1.00	12.00–14.00	...	...	...	...
S42010	...	0.15–0.30	1.00	0.040	0.030	1.00	13.50–15.00	0.35–0.85	0.40–0.85	...	...
S43100	431	0.20	1.00	0.040	0.030	1.00	15.00–17.00	1.25–2.50	...	...	...
S44002	440A	0.60–0.75	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75	...	...
S44003	440B	0.75–0.95	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75	...	...
S44004	440C	0.95–1.20	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75	...	...
S50400	9	0.15	0.30–0.60	0.030	0.030	0.75–1.00	8.00–10.00	...	0.90–1.10	...	...

NOTES

^A Maximum, unless range or minimum is indicated.

^B Designations established in accordance with Practice E 527 and SAE J1086.

^C For some applications, the substitution of Type 304L for Type 304, or Type 316L for Type 316 may be undesirable because of design, fabrication, or service requirements. In such cases, the purchaser should so indicate on the order.

^D Nitrogen content is to be reported for this grade.

^E % Cr + 3.3 × % Mo + 16 × % N ≥ 40.

^F Nickel plus copper shall be 0.50 % max.

^G Product analysis tolerance over the maximum limit for carbon and nitrogen shall be 0.002 %.

^H Wrought version of CA 6NM.

TABLE 2
MECHANICAL REQUIREMENTS

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A Min.		Elongation in 2 in. (50 mm), ^B or 4D Min. ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D	
				ksi	MPa	ksi	MPa			Max.	
Austenitic Grades											
201, 202	A	hot-finished or cold-finished	all	75	515	40	275	40	45	...	
S20161	A	hot-finished or cold-finished	all	125	860	50	345	40	40	255	
205	A	hot-finished or cold-finished	all	100	690	60	414	40	50	...	
XM-19	A	hot-finished or cold-finished	all	100	690	55	380	35	55	...	
	As hot-rolled	hot-finished or cold-finished	up to 2 (50.8), incl.	135	930	105	725	20	50	...	
S21800	A	hot-finished or cold-finished	over 2 to 3 (50.8 to 76.2), incl.	115	795	75	515	25	50	...	
			over 3 to 8 (76.2 to 203.2), incl.	100	690	60	415	30	50	...	
			all	95	655	50	345	35	55	241	
XM-10, XM-11	A	hot-finished or cold-finished	all	90	620	50	345	45	60	...	
XM-29	A	hot-finished or cold-finished	all	100	690	55	380	30	50	...	
XM-28	A	hot-finished or cold-finished	all	100	690	55	380	30	50	...	
S24565	A	hot-finished or cold-finished	all	115	795	60	415	35	40	...	
S28200	A	hot-finished or cold-finished	all	110	760	60	410	35	55	...	
302, 302B, 304, 304LN, 305, 308, 309, 309S, 309Cb, 310, 310S, 310Cb, 314, 316, 316LN, 316Cb, 316Ti, 317, 321, 347, 348 304L, 316L	A	hot-finished cold-finished	all	75 ^E	515	30 ^E	205	40 ^G	50	...	
			up to 1/2 (12.70) incl.	90	620	45	310	30	40	...	
			over 1/2 (12.70)	75 ^E	515	30 ^E	205	30	40	...	
	A	hot-finished cold-finished	all	70	485	25	170	40 ^G	50	...	
			up to 1/2 (12.70) incl.	90	620	45	310	30	40	...	
			over 1/2 (12.70)	70	485	25	170	30	40	...	

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TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A Min.		Elongation in 2 in. (50 mm) ^B or 4D Min. ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D Max.
				ksi	MPa	ksi	MPa			
Austenitic Grades (Cont'd)										
304N, 316N	A	hot-finished or cold-finished	all	80	550	35	240	30	...	...
202, 302, 304, 304N, 316, 316N	B	cold-finished	up to $\frac{3}{4}$ (19.05) incl.	125	860	100	690	12	35	...
			over $\frac{3}{4}$ (19.05) to 1 (25.40)	115	795	80	550	15	35	...
			over 1 (25.40) to $1\frac{1}{4}$ (31.75)	105	725	65	450	20	35	...
			over $1\frac{1}{4}$ (31.75) to $1\frac{1}{2}$ (38.10)	100	690	50	345	24	45	...
304, 304N, 316, 316N	S	cold-finished	over $1\frac{1}{2}$ (38.10) to $1\frac{3}{4}$ (44.45)	95	655	45	310	28	45	...
			up to 2 (50.8) incl.	95	650	75	515	25	40	...
			over 2 to $2\frac{1}{2}$ (50.8 to 63.5) incl.	90	620	65	450	30	40	...
XM-21, S30454, S31654	A	hot-finished or cold-finished	over $2\frac{1}{2}$ to 3 (63.5 to 76.2) incl.	80	550	55	380	30	40	...
			all	90	620	50	345	30	50	...
XM-21, S30454, S31654	B	cold finished	up to 1 (25.40) incl.	145	1000	125	860	15	45	...
			over 1 (25.40) to $1\frac{1}{4}$ (31.75)	135	930	115	795	16	45	...
			over $1\frac{1}{4}$ (31.75) to $1\frac{1}{2}$ (38.10)	135	895	105	725	17	45	...
			over $1\frac{1}{2}$ (38.10) to $1\frac{3}{4}$ (44.45)	125	860	100	690	18	45	...
S30815	A	hot-finished or cold-finished	all	87	600	45	310	40	50	...
S31254	A	hot-finished or cold-finished	all	95	650	44	300	35	50	...
S31725	A	hot-finished or cold-finished	all	75	515	30	205	40	...	...
S31726	A	hot-finished or cold-finished	all	80	550	35	240	40	...	...

TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A Min.		Elongation in 2 in. (50 mm), ^B or 4D Min. ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D Max.
				ksi	MPa	ksi	MPa			
Austenitic-Ferritic Grades										
XM-26	A	hot-finished or cold-finished	all	90	620	65	450	20	55	...
S31803	A	hot-finished or cold-finished	all	90	620	65	448	25	...	290
S32304	A	hot-finished or cold-finished	all	87	600	58	400	25	...	290
S32550	A	hot-finished or cold-finished	all	110	760	80	550	15	...	302
S32760	A	hot-finished or cold-finished	all	109	750	80	550	25	...	290
S32760	S	cold-finished	all	125	860	105	720	16	...	335
Ferritic Grades										
405 ^F	A	hot-finished	all	...	...	...	...	...	...	207
		cold-finished	all	...	...	...	...	...	...	217
429	A	hot-finished	all	70	480	40	275	20	45	...
		cold-finished	all	70	480	40	275	16	45	...
430	A	hot-finished or cold-finished	all	60	415	30	207	20	45	...
S44400	A	hot-finished	all	60	415	45	310	20	45	217
		cold-finished	all	60	415	45	310	16	45	217
446, XM-27	A	hot-finished	all	65	450	40	275	20	45	219
		cold-finished	all	65	450	40	275	16	45	219
S44700	A	hot-finished	all	70	480	55	380	20	40	...
		cold-finished	all	75	520	60	415	15	30	...
S44800	A	hot-finished	all	70	480	55	380	20	40	...
		cold-finished	all	75	520	60	415	15	30	...

TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A Min.		Elongation in 2 in. (50 mm), ^B or 4D Min. ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D Max.
				ksi	MPa	ksi	MPa			
Martensitic Grades										
403, 410	A	hot-finished	all	70	480	40	275	20	45	...
		cold-finished	all	70	480	40	275	16	45	...
403, 410	T	hot-finished	all	100	690	80	550	15	45	...
		cold-finished	all	100	690	80	550	12	40	...
XM-30	T	hot-finished	all	125	860	100	690	13	45	302
		cold-finished	all	125	860	100	690	12	35	...
403, 410	H	hot-finished	all	120	830	90	620	12	40	...
		cold-finished	all (rounds only)	120	830	90	620	12	40	...
XM-30	A	hot-finished	all	70	480	40	275	13	45	235
		cold-finished	all	70	480	40	275	12	35	...
414	A	hot-finished or cold-finished	all	...	...	...	...	...	...	298
414	T	hot-finished or cold-finished	all	115	790	90	620	15	45	...
S41500	T	hot-finished or cold-finished	all	115	795	90	620	15	45	295
420	A	hot-finished	all	...	...	...	...	...	...	241
		cold-finished	all	...	...	...	...	...	...	255
S42010	A	hot-finished or cold-finished	all	...	...	...	...	...	...	235
	...	cold-finished	all	...	...	...	...	...	...	255
431	A	hot-finished or cold-finished	all	...	...	...	...	...	...	285
		cold-finished	all	...	...	...	...	...	...	...
440A, 440B, and 440C	A	hot-finished	all	...	...	...	...	...	...	269
		cold-finished	all	...	...	...	...	...	...	285
9 (S50400)	A	hot-finished or cold-finished	all	60	415	30	207	30	45	179
	T	hot-finished or cold-finished	all	100	690	80	550	14	35	241

NOTES

^A Yield strength shall be determined by the 0.2% offset in accordance with Test Methods and Definitions A 370. An alternative method of determining yield strength may be used based on total extension under load of 0.5%.

^B For some specific products, it may not be practicable to use a 2 in. or 50 mm gage length. The use of sub-size test specimens, when necessary, is permissible in accordance with Test Methods and Definitions A 370.

^C Reduction of area does not apply on flat bars $\frac{3}{16}$ in. (4.76 mm) and under in thickness as this determination is not generally made in this product size.

^D Or equivalent Rockwell hardness.

^E For extruded shapes of all Cr-Ni grades of Condition A, the yield strength shall be 25 ksi (170 MPa) min., and tensile strength shall be 70 ksi (480 MPa) min.

^F Material shall be capable of being heat treated to a maximum Brinell hardness of 250 when oil quenched from 1750°F (953°C).

^G For shapes having section thickness of $\frac{1}{2}$ in. (12.5 mm) or less, 30% min., elongation is acceptable.

TABLE 3 RESPONSE TO HEAT TREATMENT

Type ^A	Heat Treatment Temperature ^B °F (°C), Min.	Quenchant	Hardness HRC, Min.
403	1750 (955)	Air	35
410	1750 (955)	Air	35
414	1750 (955)	Oil	42
420	1825 (995)	Air	50
S42010	1850 (1010)	Oil	48
431	1875 (1020)	Oil	40
440A	1875 (1020)	Air	55
440B	1875 (1020)	Oil	56
440C	1875 (1020)	Air	58

NOTES

^A Samples for testing shall be in the form of a section not exceeding $\frac{3}{8}$ in. (9.50 mm) in thickness.

^B Temperature tolerance is $\pm 25^{\circ}\text{F}$ (14°C).

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**SPECIFICATION FOR GRAY IRON CASTINGS FOR
PRESSURE CONTAINING PARTS FOR TEMPERATURES
UP TO 650°F (350°C)**



SA-278/SA-278M

(21)

(Identical with ASTM Specification A278/A278M-01(2015) except for an editorial change to 5.1.1 and a change to 16.1 making certification mandatory.)

Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)

1. Scope

1.1 This specification covers gray iron for castings suitable for pressure-containing parts for use at temperatures up to 650°F (350°C).

1.2 *Classes of Iron:*

1.2.1 Castings of all classes are suitable for use up to 450°F (230°C). For temperatures above 450°F and up to 650°F, only Class 40, 45, 50, 55, and 60 castings are suitable.

1.2.2 Castings of all classes are suitable for use up to 230°C. For temperatures above 230°C and up to 350°C, only Class 275, 300, 325, 350, 380, and 415 castings are suitable.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A644 Terminology Relating to Iron Castings

E8 Test Methods for Tension Testing of Metallic Materials

3. Terminology

3.1 Definitions of many terms common to gray iron castings may be found in Terminology A644.

4. Classification

4.1 Classification by tensile strength.

4.1.1 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in ksi, in English units. Class 25 has a minimum specified tensile strength of 25 ksi.

4.1.2 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in MPa, in Metric units. Class 150 has a minimum specified tensile strength of 150 MPa.

5. Ordering Information

5.1 Orders for material in this specification should include the following information:

5.1.1 ASTM designation and year date,

5.1.2 Class of iron required and service temperature,

5.1.3 Quantity,

5.1.4 *Heat Treatment:*

5.1.4.1 Whether or not heat treatment is required for Class 40, 45, 50, 55, and 60 castings to be used at temperatures at 450°F or less (see 6.2),

5.1.4.2 Whether or not heat treatment is required for Class 275, 300, 325, 350, 380, and 415 castings to be used at temperatures at 230°C or less (see 6.2),

5.1.5 The size of separately cast test bar to be poured (see Section 9 and Table 1),

5.1.6 The size of test specimen to be machined from test bars C or S, and

5.1.7 Special requirements.

6. Materials and Manufacture

6.1 Castings intended for use above 450°F (230°C) shall be stress-relieved by placing them in a suitable furnace at a temperature not exceeding 400°F (200°C) and heating them uniformly to the temperatures and for the times specified in Table 2. The heating and cooling rates shall be uniform and shall not be more than 400°F/h (250°C/h) for castings of 1-in. (25-mm) maximum section. For heavier sections the maximum heating and cooling rates in degrees Fahrenheit per hour shall be 400 divided by the maximum section thickness.

6.2 *Heat Treatment and Cooling Rate:*

6.2.1 Castings of Class Nos. 45, 50, 55, and 60, which are to be used at temperatures below 450°F, may be heat treated in

TABLE 1 Diameters and Lengths of Cast Test Bars

Test Bar	As-Cast Diameter, in. (mm)		Length, in. (mm)		
	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)	
A	0.88 (23)	0.85 (22)	0.96 (25)	5.0 (125)	6.0 (150)
B	1.20 (33)	1.14 (32)	1.32 (36)	7.0 (150)	9.0 (230)
C	2.00 (54)	1.90 (53)	2.10 (58)	6.0 (175)	10.0 (255)
S ^A					

^A All dimensions of Test Bar S shall be agreed upon by the manufacturer and the purchaser.

TABLE 2 Stress Relieving Requirements

Class	Metal Temperature, °F (°C)	Holding Time, h ^A
40, 45, 50, 55, 60 (275, 300, 325, 350, 380, 415)	1050 to 1200 (565 to 650)	2 (2 min) ^B 12 (12 max) ^B

^A In no case shall the holding time be less than 1 h/in. of maximum metal section, or in excess of 12 h max, dependent upon which governs.

^B In no case shall the holding time be less than 1 h for every 25-mm metal section, or in excess of 12 h max, depending upon which governs.

accordance with 6.1 or they shall be cooled in the mold to 500°F at an average rate of not more than 100°F/h for castings up to 1 in. in section. For heavier sections the maximum cooling rate in degrees Fahrenheit per hour shall be 100 divided by the maximum section thickness.

6.2.2 Castings of Class Nos. 275, 300, 325, 350, 380, and 415, which are to be used at temperatures below 230°C, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 250°C at an average rate of not more than 50°C/h for castings up to 25-mm in section. For heavier sections the maximum cooling rate in degrees Celsius per hour shall be 1250 divided by the maximum section thickness.

7. Chemical Composition

7.1 Carbon Equivalent:

7.1.1 Class 40, 45, 50, 55, and 60 castings intended for service above 450°F (230°C) shall have a maximum carbon equivalent of 3.8 % as calculated from the equation $CE = \%C + 0.3 (\%Si + \%P)$. The maximum phosphorus and sulfur contents shall be 0.25 % and 0.12 %, respectively.

7.1.2 Class 275, 300, 325, 350, 380, and 415 castings intended for service above 230°C shall have a maximum carbon equivalent of 3.8 % as calculated from the equation $CE = \%C + 0.3 (\%Si + \%P)$. The maximum phosphorus and sulfur contents shall be 0.25 % and 0.12 %, respectively.

7.2 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately 1/32 in. thick cut from test coupons. Drillings shall not be used because of attendant loss of graphite.

8. Tensile Requirements

8.1 Iron used in supplying castings to this specification shall conform to the tensile requirements prescribed in Table 3 and Table 4.

9. Test Bars

9.1 Separately cast test bars having the dimensions shown in Table 1 shall be poured from the same lot as the castings

TABLE 3 Tensile Requirements

Class	Tensile Strength, min, ksi
No. 20	20
No. 25	25
No. 30	30
No. 35	35
No. 40	40
No. 45	45
No. 50	50
No. 55	55
No. 60	60

TABLE 4 Tensile Requirements (SI)

Class	Tensile Strength, min, MPa
No. 150	150
No. 175	175
No. 200	200
No. 225	225
No. 250	250
No. 275	275
No. 300	300
No. 325	325
No. 350	350
No. 380	380
No. 415	415

represented. The size of the test bar to be poured shall be selected by the purchaser using Table 5. In the event no choice is made, the selection will be made by the manufacturer.

9.2 Separately cast test bars shall be heat treated in the same furnace together with the castings represented.

9.3 At the option of the manufacturer, test coupons may be removed from the casting at a location agreed upon between the manufacturer and purchaser.

9.4 Castings weighing in excess of 2000 lb may be represented either by separately cast test bars (9.1) or by integrally cast test bars having a cooling rate closely approximating that of the controlling section of the casting.

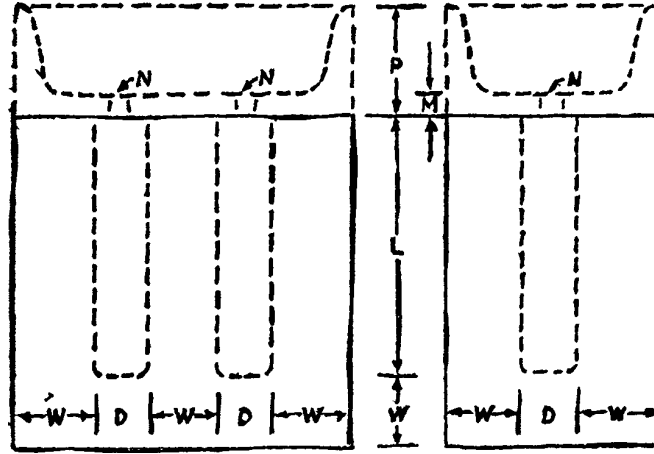
9.5 For castings weighing in excess of 10 000 lb or having a controlling section greater than 2 in., test bars may be removed from the casting or integral projections having a cross section no less than the controlling section. The minimum tensile strength requirement for tension tests performed on either of these test bars shall be 80 % of the specified class.

10. Molding and Pouring Test Bars

10.1 The test bars shall be cast in dried siliceous sand molds maintained at approximately room temperature. A suitable design for a mold is shown in Fig. 1.

TABLE 5 Separately Cast Test Bars for Use When a Specific Correlation Has Not Been Established Between the Test Bar and the Casting

Thickness of the Wall of the Controlling Section of the Casting, in. (mm)	Test Bar
Under 0.25 (6)	S
0.25 to 0.50 (6 to 12)	A
0.51 to 1.00 (13 to 25)	B
1.01 to 2 (26 to 50)	C
Over 2 (50)	S



Number of test bars in a single mold—2 suggested.
 L—see Table 1.
 D—see Table 1.
 W—not less than diameter, D .

P —2 in. (50-mm) suggested
 N — $\frac{5}{16}$ in. (8-mm) in diameter, suggested
 M —1.5 N , suggested

FIG. 1 Suitable Design and Dimensions for Mold for Separately Cast Cylindrical Test Bars for Gray Iron

11. Workmanship, Finish, and Appearance

11.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. If the pattern is supplied by the purchaser without drawings, the dimensions of the casting shall be as predicted by the pattern.

11.2 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order.

12. Sampling

12.1 A lot shall consist of one of the following:

12.1.1 All the metal poured from a single heating in a batch type melting furnace,

12.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or single casting, or

12.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

12.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

13. Tension Test Specimens

13.1 Tension test specimens A and B in Fig. 2 shall be machined from test bars A and B in Table 1, respectively.

13.2 The purchaser shall specify whether test specimen B or C is to be machined from test bar C. If no choice is made, the manufacturer shall make the selection.

13.3 The size of the test specimen to be machined from test bar S shall be as agreed upon between the manufacturer and purchaser.

14. Number of Tests and Retests

14.1 One tension test shall be performed on each lot in accordance with Test Method E8 and conform to the tensile requirements specified.

14.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected.

14.3 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

15. Repair

15.1 Any repairs performed on castings produced to this specification shall be agreed upon between the manufacturer and purchaser.

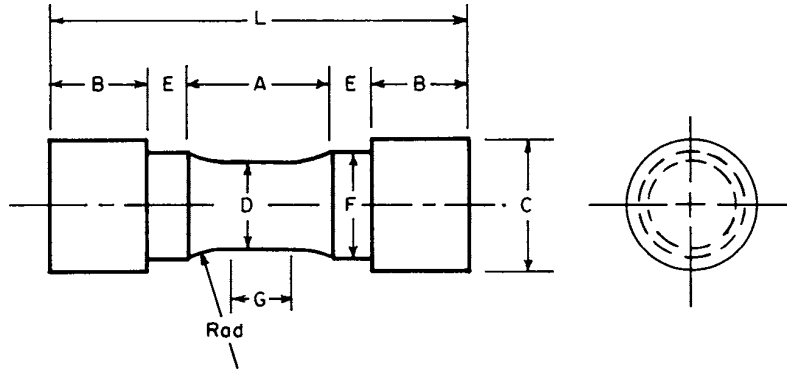
16. Certification

16.1 When requested by the purchaser, the manufacturer shall furnish his certification stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification including the year date. The certification shall also include the results of all tests performed.

16.2 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Inspection

17.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the



Dimensions, in. (mm)	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
<i>G</i> — Length of parallel, min	0.50 (13)	0.75 (20)	1.25 (32)
<i>D</i> — Diameter	0.500 ± 0.010 (13 ± 0.25)	0.750 ± 0.015 (20 ± 0.4)	1.25 ± 0.025 (32 ± 0.5)
<i>R</i> — Radius of fillet, min	1 (25)	1 (25)	2 (50)
<i>A</i> — Length of reduced section, min	1¼ (32)	1½ (38)	2¼ (57)
<i>L</i> — Overall length, min	3¾ (95)	4 (100)	6¾ (160)
<i>C</i> — Diameter of end section, approximate	7/8 (22)	1¼ (32)	17/8 (47)
<i>E</i> — Length of shoulder, min	¼ (6)	¼ (6)	5/16 (8)
<i>F</i> — Diameter of shoulder	5/8 ± 1/64 (16 ± 0.5) _A	15/16 ± 1/64 (25 ± 0.5) _A	17/16 ± 1/64 (36 ± 0.5) _A
<i>B</i> — Length of end section			

^A Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 2 Tension-Test Specimens

manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

18. Rejection and Rehearing

18.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

19. Product Marking

19.1 Castings shall have the name of the manufacturer, or his recognized trademark, and the class of iron to which it conforms, cast or indelibly stamped on a surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

20. Keywords

20.1 elevated temperature service; gray iron castings; pressure containing parts

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SPECIFICATION FOR LOW AND INTERMEDIATE TENSILE STRENGTH CARBON STEEL PLATES



SA-283/SA-283M



(21)

(Identical with ASTM Specification A283/A283M-03(2007).)

SPECIFICATION FOR LOW AND INTERMEDIATE TENSILE STRENGTH CARBON STEEL PLATES



SA-283/SA-283M



[Identical with ASTM Specification A 283/A 283M-03(2007).]

1. Scope

1.1 This specification covers four grades (A, B, C, and D) of carbon steel plates of structural quality for general application.

1.2 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exactly equivalents, therefore each system is to be used independently of the other, without combining values in any way.

1.4 For plate produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 6/A 6M apply.

1.5 This specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures do not contain any mandatory requirements.

2. Referenced Document

2.1 *ASTM Standard:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

3. General Requirements for Delivery

3.1 Plates furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the specific date ordered, unless a conflict exists in which case this specification shall prevail.

3.2 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operation involved in the processing of a coil into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1 — For plates produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 6/A 6M.

4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

5. Chemical Requirements

5.1 The heat analysis shall conform to the requirements prescribed in Table 1.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

6. Tensile Requirements

6.1 Material as represented by the test specimens shall conform to the requirements as to tensile properties prescribed in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Heat Analysis, %			
	Grade A	Grade B	Grade C	Grade D
Carbon, max	0.14	0.17	0.24	0.27
Manganese, max	0.90	0.90	0.90	0.90
Phosphorus, max	0.035	0.035	0.035	0.035
Sulfur, max	0.04	0.04	0.04	0.04
Silicon				
Plates 1½ in. [40 mm] and under, max	0.40	0.40	0.40	0.40
Plates over 1½ in. [40 mm]	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Copper, min % when copper is specified	0.20	0.20	0.20	0.20

TABLE 2
TENSILE REQUIREMENTS^A

	Grade A	Grade B	Grade C	Grade D
Tensile strength, ksi [MPa]	45–60 [310–415]	50–65 [345–450]	55–75 [380–515]	60–80 [415–550]
Yield point, min, ksi [MPa]	24 [165]	27 [185]	30 [205]	33 [230]
Elongation in 8 in. [200 mm], min, % ^B	27	25	22	20
Elongation in 2 in. [50 mm], min, % ^B	30	28	25	23

^A See Specimen Orientation under the Tension Tests section of Specification A6/A 6M.

^B For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirement shall not apply unless specified in the order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

- S2. Product Analysis,**
- S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,**
- S5. Charpy V-Notch Impact Test,**
- S6. Drop Weight Test,**
- S8. Ultrasonic Examination, and**
- S15. Reduction of Area**
- S97. Limitation on Rimmed or Capped Steel**
 - S97.1** The steel shall be other than rimmed or capped.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, LOW- AND INTERMEDIATE-TENSILE STRENGTH



SA-285/SA-285M



(Identical with ASTM Specification A285/A285M-17.)

Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength

1. Scope

1.1 This specification covers carbon steel plates of low- and intermediate-tensile strengths which may be killed or semi-killed at the producer's option. These plates are intended for fusion-welded pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
A	45–65 [310–450]
B	50–70 [345–485]
C	55–75 [380–515]

1.3 The maximum thickness of plates is limited by the capacity of the composition to meet the specified mechanical property requirements.

NOTE 1—For killed carbon steels only, refer to the following ASTM specifications:

A299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon

A515/A515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

A516/A516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each

system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A515/A515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

A516/A516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the

TABLE 1 Chemical Requirements

Elements	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max ^A	0.17	0.22	0.28
Manganese, max:			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorus, max ^A	0.025	0.025	0.025
Sulfur, max ^A	0.025	0.025	0.025

^A Applies to both heat and product analyses.

TABLE 2 Tensile Requirements

	Grade A		Grade B		Grade C	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength	45–65	[310–450]	50–70	[345–485]	55–75	[380–515]
Yield strength, min ^A	24	[165]	27	[185]	30	[205]
Elongation in 8 in. or [200 mm], min, % ^B		27		25		23
Elongation in 2 in. or [50 mm], min, % ^B		30		28		27

^A Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

^B See Specification A20/A20M for elongation adjustment.

listed Supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plate. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 2—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition as given in Table 1.

6. Mechanical Properties

6.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7. Keywords

7.1 carbon steel plate; low-and-intermediate strength steel plate for pressure vessels; steel plate for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
 S4. Additional Tension Test,
 S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S11. Ultrasonic Examination in accordance with Specification A577/A577M, and
 S12. Ultrasonic Examination in accordance with Specification A578/A578M.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional supplementary requirements suitable for this specification:

S57. Copper-Bearing

S57.1 The copper content, by heat analysis shall be 0.20–0.35 % and by product analysis 0.18–0.37 %.

S58. Restricted Copper

S58.1 The maximum incidental copper content by heat analysis shall not exceed 0.25 %.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, MANGANESE-SILICON



SA-299/SA-299M



(Identical with ASTM Specification A299/A299M-17.)

Standard Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon

1. Scope

1.1 This specification covers manganese-silicon carbon steel plates for use in welded boilers and other pressure vessels.

1.2 Plates under this specification are produced in two grades. The specified minimum yield strength decreases for thicknesses over 1 in. [25 mm].

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A20/A20M, which outlines the testing and retesting methods and procedures, permitted variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

TABLE 1 Chemical Requirements

Elements	Composition, %
Carbon, max: ^A	
1 in. [25 mm] and under	
Grade A	0.26
Grade B	0.28
Over 1 in. [25 mm]	
Grade A	0.28
Grade B	0.30
Manganese:	
1 in. [25 mm] and under	
Heat analysis	0.90 to 1.40
Product analysis	0.84 to 1.52
Over 1 in. [25 mm]	
Heat analysis	0.90 to 1.50
Product analysis	0.84 to 1.62
Phosphorus, max ^A	0.025
Sulfur, max ^A	0.025
Silicon:	
Heat analysis	0.15 to 0.40
Product analysis	0.13 to 0.45

^A Applies to both heat and product analyses.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

TABLE 2 Tensile Requirements

	Grade A	Grade B
Tensile strength, ksi [MPa]	75–95 [515–655]	80–100 [550–690]
Yield strength, min, ^A ksi [MPa]:		
1 in. [25 mm] and under	42 [290]	47 [325]
Over 1 in. [25 mm]	40 [275]	45 [310]
Elongation in 8 in. [200 mm], min, % ^B	16	16
Elongation in 2 in. [50 mm], min, % ^B	19	19

^A Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

^B See the Elongation Requirement Adjustments subsection in the Tension Tests section of Specification A20/A20M.

6. Chemical Composition

6.1 The steel shall conform to the requirements given in Table 1.

7. Mechanical Properties

7.1 *Tension Test Requirements*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,
 S2. Product Analysis,
 S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
 S4. Additional Tension Test,
 S5. Charpy V-Notch Impact Test,
 S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,
 S8. Ultrasonic Examination in accordance with Specification A435/A435M,
 S9. Magnetic Particle Examination,
 S11. Ultrasonic Examination in accordance with Specification A577/A577M,
 S12. Ultrasonic Examination in accordance with Specification A578/A578M.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MANGANESE-MOLYBDENUM AND MANGANESE-MOLYBDENUM-NICKEL



SA-302/SA-302M



(Identical with ASTM Specification A302/A302M-17.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese- Molybdenum and Manganese-Molybdenum-Nickel

1. Scope

1.1 This specification covers manganese-molybdenum and manganese-molybdenum-nickel alloy steel plates intended particularly for welded boilers and other pressure vessels.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]	Type
A	75–95 [515–655]	manganese-molybdenum
B	80–100 [550–690]	manganese-molybdenum
C	80–100 [550–690]	manganese-molybdenum-nickel
D	80–100 [550–690]	manganese-molybdenum-nickel

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

- A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
- A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

TABLE 1 Chemical Requirements

NOTE 1—Where “...” appears, there is no requirement.

Elements	Composition, %			
	Grade A	Grade B	Grade C	Grade D
Carbon, max: ^A				
Up to 1 in. [25 mm], incl, in thickness	0.20	0.20	0.20	0.20
Over 1 to 2 in. [50 mm], incl	0.23	0.23	0.23	0.23
Over 2 in. [50 mm] in thickness	0.25	0.25	0.25	0.25
Manganese:				
Heat analysis	0.95–1.30	1.15–1.50	1.15–1.50	1.15–1.50
Product analysis	0.87–1.41	1.07–1.62	1.07–1.62	1.07–1.62
Phosphorus, max ^A	0.025	0.025	0.025	0.025
Sulfur, max ^A	0.025	0.025	0.025	0.025
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:				
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60	0.45–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64	0.41–0.64
Nickel:				
Heat analysis	...	...	0.40–0.70	0.70–1.00
Product analysis	...	...	0.37–0.73	0.67–1.03

^A Applies to both heat and product analyses.

TABLE 2 Tensile Requirements

	Grade A	Grade B	Grade C	Grade D
Tensile strength, ksi [MPa]	75–95 [515–655]	80–100 [550–690]	80–100 [550–690]	80–100 [550–690]
Yield strength, min, ksi [MPa]	45 [310]	50 [345]	50 [345]	50 [345]
Elongation in 8 in. [200 mm], min, % ^A	15	15	17	17
Elongation in 2 in. [50 mm], min, % ^A	19	18	20	20

^A See Specification A20/A20M for elongation adjustment.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized, normalized and tempered, or stress relieved.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized or normalized and tempered.

5.3 When normalizing plates 4 in. [100 mm] or over in thickness, the cooling rate may be accelerated by air blasting or liquid quenching followed by tempering in the temperature range from 1100 to 1300°F [595 to 705°C] to obtain mechanical properties comparable to those developed by normalizing plates in the lesser thicknesses.

5.4 If approved by the purchaser, for plates less than 4 in. [100 mm] in thickness, cooling rates faster than those obtained by cooling in air are permissible for improvement of toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test Requirements*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7.1.1 For accelerated cooled plates with a nominal thickness of ¾ in. [20 mm] or less, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

8. Keywords

8.1 alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

- S1. Vacuum Treatment,
- S2. Product Analysis,
- S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
 - S4.1 Additional Tension Test,
 - S5. Charpy V-Notch Impact Test,
 - S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),
 - S7. High-Temperature Tension Test,
- S8. Ultrasonic Examination in accordance with Specification A435/A435M,
- S9. Magnetic Particle Examination,
- S11. Ultrasonic Examination in accordance with Specification A577/A577M,
- S12. Ultrasonic Examination in accordance with Specification A578/A578M, and
- S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR CARBON STEEL BOLTS AND STUDS, 60 000 PSI TENSILE STRENGTH



SA-307

(Identical with ASTM Specification A307-10 except for the deletion of “private label distributor” and “as appropriate” in para. 13.1.1.)

Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

1. Scope

1.1 This specification covers the chemical and mechanical requirements of three grades of carbon steel bolts and studs in sizes ¼ in. through 4 in. The fasteners are designated by “Grade” denoting tensile strength and intended use, as follows:

Grade	Description
Grade A	Bolts and studs having a minimum tensile strength of 60 ksi and intended for general applications,
Grade B	Bolts and studs having a tensile strength of 60 to 100 ksi and intended for flanged joints in piping systems with cast iron flanges, and
Grade C	Replaced by Specification F1554 Gr.36

1.1.1 The term *studs* includes stud stock, sometimes referred to as *threaded rod*.

1.2 This specification does not cover requirements for machine screws, thread cutting/forming screws, mechanical expansion anchors or similar externally threaded fasteners.

1.3 Suitable nuts are covered in Specification A563. Unless otherwise specified, the grade and style of nut for each grade of fastener, of all surface finishes, shall be as follows:

Fastener Grade and Size	Nut Grade and Style ^A
A ¼ to 1½ in.	A, hex
A over 1½ to 4 in.	A, heavy hex
B, ¼ to 4 in.	A, heavy hex

^A Nuts of other grades and styles having specified proof load stresses (Specification A563, Table 3) greater than the specified grade and style of nut are also suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 Supplementary Requirement S1 of an optional nature is provided, which describes additional restrictions to be applied when bolts are to be welded. It shall apply only when specified in the inquiry, order, and contract.

1.6 Terms used in this specification are defined in Terminology F1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:

A563 Specification for Carbon and Alloy Steel Nuts
 A706/A706M Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
 A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
 B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
 D3951 Practice for Commercial Packaging
 F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
 F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
 F1554 Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
 F1789 Terminology for F16 Mechanical Fasteners
 F2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 ASME Standards:

B 1.1 Unified Screw Threads
 B 18.2.1 Square and Hex Bolts and Screws
 B 18.24 Part Identifying Number (PIN) Code System

2.3 SAE Standard:

J429 Mechanical and Material Requirements For Externally Threaded Fasteners

3. Ordering Information

3.1 Orders for externally threaded fasteners (including nuts and accessories) under this specification shall include the following:

- 3.1.1 ASTM designation and year of issue,
- 3.1.2 Name of product, bolts or studs; and bolt head style, that is, hex or heavy hex,
- 3.1.3 Grade, that is, A, or B. If no grade is specified, Grade A is furnished.
- 3.1.4 Quantities (number of pieces by size including nuts),
- 3.1.5 Fastener size and length,
- 3.1.6 Washers—Quantity and size (separate from bolts),
- 3.1.7 Zinc Coating—Specify the zinc-coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.5).
- 3.1.8 Other Finishes—Specify other protective finish, if required.
- 3.1.9 Specify if inspection at point of manufacture is required,
- 3.1.10 Specify if certified test report is required (see 8.2), and
- 3.1.11 Specify additional testing (8.3) or special requirements.
- 3.1.12 For establishment of a part identifying system, see ASME B18.24.

4. Materials and Manufacture

4.1 Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Bolts shall be produced by hot or cold forging of the heads or machining from bar stock.

4.3 Heat Treatment:

4.3.1 Cold headed fasteners with head configurations other than hex having a minimum head height less than or equal to .5 D (D is nominal diameter) shall be stress relief annealed at a minimum temperature of 875°F.

4.3.2 Stress relieving of hex head fasteners and those with minimum head heights greater than .5 D shall be at the manufacturer's option.

4.4 Bolt and stud threads shall be rolled or cut.

4.5 Zinc Coatings, Hot-Dip and Mechanically Deposited:

4.5.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, for example hot dip, mechanically deposited, or no preference.

4.5.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Specification F2329.

4.5.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 55 of Specification B695.

4.5.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification F2329, or a mechanically deposited zinc coating in accordance with Specification B695, Class 55. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

5. Chemical Composition

5.1 Grade A and B bolts and studs shall have a heat analysis conforming to the requirements specified in Table 1 based on the steel producer's heat analysis.

5.2 The purchaser shall have the option of conducting product analyses on finished bolts in each lot, which shall conform to the product analysis specified in Table 1.

5.3 In case of conflict or for referee purposes, the product analysis shall take precedence.

5.4 Bolts and studs are customarily furnished from stock, in which case individual heats of steel cannot be identified.

5.5 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grade B bolts and studs.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A751.

6. Mechanical Properties

6.1 Grades A and B bolts and studs shall conform to the hardness specified in Table 2.

6.2 Grade A and B bolts and studs 1½ in. in diameter or less, other than those excepted in 6.4, shall be tested full size and shall conform to the requirements for tensile strength specified in Table 3.

6.3 Grade A and B bolts and studs larger than 1½ in. in diameter, other than those excepted in 6.4, shall preferably be tested full size and when equipment of sufficient capacity is available and shall conform to the requirements for tensile strength specified in Table 3. When equipment of sufficient capacity for full-size bolt testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 4.

TABLE 1 Chemical Requirements for Grades A and B Bolts and Studs

	Heat Analysis	Product Analysis
Carbon, max	0.29	0.33
Manganese, max	1.20	1.25
Phosphorus, max	0.04	0.041
Sulfur, max		
Grade A	0.15	^A
Grade B	0.05	0.051

^A Resulfurized steel is not subject to rejection based on product analysis for sulfur.

TABLE 2 Hardness Requirements for Bolts and Studs

Grade	Length, in.	Hardness ^A			
		Brinell		Rockwell B	
		min	max	min	max
A	Less than 3 × dia ^B	121	241	69	100
	3 × dia and longer	...	241	...	100
B	Less than 3 × dia ^B	121	212	69	95
	3 × dia and longer	...	212	...	95

^A As measured anywhere on the surface or through the cross section.

^B Also bolts with drilled or undersize heads. These sizes and bolts with modified heads shall meet the minimum and maximum hardness as hardness is the only requirement.

TABLE 3 Tensile Requirements for Full-Size Bolts and Studs

Bolt Size, in.	Threads per inch	Stress Area, ^A in. ²	Tensile Strength, lbf ^B		
			Grade A, min ^C	Grade B	
				min ^D	max ^D
1/4	20	0.0318	1 900	1 900	3 180
5/16	18	0.0524	3 100	3 100	5 240
3/8	16	0.0775	4 650	4 650	7 750
7/16	14	0.1063	6 350	6 350	10 630
1/2	13	0.1419	8 500	8 500	14 190
9/16	12	0.182	11 000	11 000	18 200
5/8	11	0.226	13 550	13 550	22 600
3/4	10	0.334	20 050	20 050	33 400
7/8	9	0.462	27 700	27 700	46 200
1	8	0.606	36 350	36 350	60 600
1 1/8	7	0.763	45 800	45 800	76 300
1 1/4	7	0.969	58 150	58 150	96 900
1 3/8	6	1.155	69 300	69 300	115 500
1 1/2	6	1.405	84 300	84 300	140 500
1 3/4	5	1.90	114 000	114 000	190 000
2	4 1/2	2.50	150 000	150 000	250 000
2 1/4	4 1/2	3.25	195 000	195 000	325 000
2 1/2	4	4.00	240 000	240 000	400 000
2 3/4	4	4.93	295 800	295 800	493 000
3	4	5.97	358 200	358 200	597 000
3 1/4	4	7.10	426 000	426 000	710 000
3 1/2	4	8.33	499 800	499 800	833 000
3 3/4	4	9.66	579 600	579 600	966 000
4	4	11.08	664 800	664 800	1 108 000

^A Area calculated from the equation:

$$A_s = 0.7854 [D - (0.9743/n)]^2$$

where:

A_s = stress area,
 D = nominal diameter of bolt, and
 n = threads per inch.

^B 1 lbf = 4.448 N.

^C Based on 60 ksi (414 MPa).

^D Based on 60–100 ksi (414–690 MPa).

6.4 Grades A and B bolts and studs less than three diameters in length or bolts with drilled or undersize heads are not subject to tensile tests.

6.5 In the event that bolts are tested by both full size and by machine test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

TABLE 4 Tensile Requirements for Machined Specimens

	Grade A	Grade B
Tensile strength, ksi	60 min	60–100
Yield point, min ksi	...	...
Elongation in 2 in., min, %	18	18

6.6 For bolts and studs on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 Unless otherwise specified, threads shall be the Coarse Thread Series as specified in the latest issue of ASME B1.1, and shall have a Class 2A tolerance.

7.2 Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest issue of ASME B18.2.1. Unless otherwise specified, Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of ASME B18.2.1.

7.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating the maximum limit of pitch and major diameter shall not exceed the Class 2A maximum limit by more than the following amounts:

Diameter, in.	Oversize Limit, in. (mm) ^A
1/4	0.016
5/16, 3/8	0.017
7/16, 1/2	0.018
5/8 to 3/4, incl	0.020
7/8	0.022
1.0 to 1 1/4, incl	0.024
1 1/8, 1 1/2	0.027
1 3/4 to 4.0, incl	0.050

^A These values are the same as the overtapping required for zinc-coated nuts in Specification A563.

7.4 The gaging limit for bolts and studs shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated threading ring gage of that same size (Class X tolerance, gage tolerance plus) shall be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency and quality described in Table 5.

8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of

TABLE 5 Sample Sizes and Acceptance Numbers for Inspection of Hot-Dip or Mechanically Deposited Zinc-Coated Threads

Lot Size	Sample Size ^A	Acceptance Number
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

^A Inspect all bolts in the lot if the lot size is less than the sample size.

individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

- 8.3.1 One type of item,
- 8.3.2 One nominal size, and
- 8.3.3 One nominal length of bolts and studs.

8.4 From each lot, the number of tests for each requirement shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and under	1
801 to 8 000	2
8 001 to 22 000	3
Over 22 000	5

8.5 If any machined test specimen shows defective machining it shall be discarded and another specimen substituted.

8.6 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be tested, in which case all of the additional samples shall meet the specification.

9. Test Methods

9.1 Grades A and B bolts and studs shall be tested in accordance with Test Methods F606.

9.2 Standard square and hex head bolts only shall be tested by the wedge tension method except as noted in 6.4. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body. Other headed bolts shall be tested by the axial tension method.

9.3 Speed of testing as determined with a free running crosshead shall be a maximum of 1 in./min for the tensile strength tests of bolts.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser it shall be specified in the inquiry, order, or contract.

10.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

11. Responsibility

11.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

12. Rejection and Rehearing

12.1 Disposition of nonconforming lots shall be in accordance with Guide F1470, specifically sections on disposition of nonconforming lots, suppliers option, and purchasers option.

13. Product Marking

13.1 Grades A and B Bolts and Studs:

13.1.1 Bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer. Additional marking required by the manufacturer for his own use shall be at the option of the manufacturer.

13.1.2 In addition to the requirements of 13.1, all bolt heads, one end of studs $\frac{3}{8}$ in. and larger, and whenever feasible studs less than $\frac{3}{8}$ in. shall be marked with a grade marking as follows:

Grade	Marking
A	307A
B	307B

13.1.3 All markings shall be located on the top of the bolt head or stud end and shall be raised or depressed at the option of the manufacturer.

14. Packaging and Package Marking

14.1 Packaging:

14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 Package Marking:

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

- 14.2.1.1 ASTM designation and grade,
- 14.2.1.2 Size,
- 14.2.1.3 Name and brand or trademark of the manufacturer,
- 14.2.1.4 Number of pieces,
- 14.2.1.5 Purchase order number,
- 14.2.1.6 Country of origin.

15. Keywords

- 15.1 bolts; carbon steel; steel; studs

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order or contract:

S1. Bolts Suitable for Welding

S1.1 The material described in this section is intended for welding. This supplemental section, by additional chemical composition restrictions and by a carbon equivalent formula, provides assurance of weldability by chemical composition control.

S1.2 Welding technique is of fundamental importance when bolts produced to this supplementary section are welded. It is presupposed that suitable welding procedures for the steel being welded and the intended service will be selected.

S1.3 All of the requirements of this supplemental section apply in addition to all of the chemical, mechanical, and other requirements of the base specification, Specification A307 for Grade B.

S1.4 Because of the embrittling effects of welding temperatures on cold-forged steel, this supplemental section is limited to hot-forged bolts, or, if not forged, then to bolts produced from hot-rolled bars without forging or threaded bars, bars studs, or stud bolts produced from hot-rolled bars without forging. Cold-forged bolts, or cold-drawn threaded bars, if they are given a thermal treatment by heating to a temperature of not less than 1500°F (815°C) and air-cooled are also suitable.

S1.5 Chemical Requirements:

S1.5.1 *Heat Chemical Analysis*—Material conforming to the following additional analysis limitations shall be used to manufacture the product described in this supplementary requirement.

Carbon	0.30 %, max
Manganese	1.00 %, max
Phosphorus	0.04 %, max
Sulfur	0.05 %, max
Silicon	0.50 %, max

S1.5.2 *Carbon Equivalent (Source—Specification A706/A706M)*—In addition to the heat chemical analysis requirements in S1.5.1, the heat analysis shall be such as to provide a carbon equivalent (CE) not exceeding 0.55 when calculated as follows:

$$CE = \% C + \frac{\% Mn}{6} + \frac{\% Cu}{40} + \frac{\% Ni}{20} + \frac{\% Cr}{10} - \frac{\% Mo}{50} - \frac{\% V}{10}$$

S1.6 *Analysis Reports*—If requested on the order or contract, the chemical composition of each heat of steel used and the calculated carbon equivalent for each heat shall be reported to the purchaser.

S1.7 *Product (Check) Verification Analysis*—Chemical analyses when made by the purchaser or a representative on bolts from each heat of steel, shall not exceed the values specified in S1.5.2 by more than the following amounts:

	%
Carbon	+0.03
Manganese	+0.06
Phosphorus	+0.008
Sulfur	+0.008
Silicon	+0.05

S2. Permanent Manufacturer's Identification

S2.1 Replaced by Specification F1554.

S3. Permanent Grade Identification

S3.1 Replaced by Specification F1554.

SPECIFICATION FOR COLD-DRAWN, STRESS-RELIEVED CARBON STEEL BARS SUBJECT TO MECHANICAL PROPERTY REQUIREMENTS



SA-311/SA-311M

(21)

(Identical with ASTM Specification A311/A311M-04(2015) except for deletion of 5.1.11, revision of Note A to Table 1 and an editorial change to 5.1.9. Certification has been made mandatory in 11.1.)

SPECIFICATION FOR COLD-DRAWN, STRESS-RELIEVED CARBON STEEL BARS SUBJECT TO MECHANICAL PROPERTY REQUIREMENTS



SA-311/SA-311M

[Identical to ASTM Specification A 311/A 311M-04(2015) except for deletion of 5.1.11, revision of Note A to Table 1 and an editorial change to 5.1.9. Certification has been made mandatory in 11.1.]

1. Scope

1.1 This specification covers two classes, nine grades, and four conditions of stress-relieved cold-drawn carbon steel bars produced to mechanical property requirements. One class, B, is cold drawn with higher than normal (heavy) drafts to provide higher strength levels, and four grades provide improved machinability.

1.2 Supplementary Requirements, S1 through S6, of an optional nature are provided.

1.3 The values stated in inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for
- A 108 Specification for Steel Bar, Carbon and Alloy, Cold-Finished
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- E 527 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 Definitions:

3.1.1 stress relieving — heating to a suitable temperature, holding long enough to reduce residual stresses, and

then cooling slowly enough to minimize the development of new residual stresses.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 heavy draft — Using higher than normal drafts (approximately 10% through 35% reduction), followed by stress relieving, produces higher tensile and yield strengths provided an appropriate composition is used; for example, medium carbon with normal or higher manganese content.

4. Classification

4.1 The bars are furnished in the following classes and grades, and in the conditions shown in 6.4.

4.1.1 Class A — Normal-draft cold-drawn and stress-relieved rounds, squares, hexagons, and flats in the following grades:

Grades	UNS Designations
1018	G10180
1035	G10350
1045	G10450
1050	G10500
1541	G15410
1117	G11170
1137	G11370
1141	G11410
1144	G11440

4.1.2 Class B — Heavy-draft cold-drawn and stress-relieved rounds and hexagons in the following grades:

Grades	UNS Designations
1045	G10450
1050	G10500
1541	G15410
1141	G11410
1144	G11440

5. Ordering Information

5.1 Orders for material under this specification should include the following information as required to adequately describe the desired material:

- 5.1.1 Quantity (weight [mass] or number of pieces),
- 5.1.2 Name of material (carbon steel bars, cold drawn, stress relieved),
- 5.1.3 Condition 8.3,
- 5.1.4 Cross-sectional shape,
- 5.1.5 Size,
- 5.1.6 Length,
- 5.1.7 Class and grade,
- 5.1.8 Report of heat analysis, tensile properties Section 11,
- 5.1.9 Specification designation A 311 or A 311M,
- 5.1.10 Application,
- 5.1.11 **DELETED**
- 5.1.12 Supplementary requirements, if any, and
- 5.1.13 Additional requirements, if any.

NOTE 1 — A typical ordering description is as follows: 10000 lb carbon steel bars, cold drawn, stress relieved turned and polished, round 2.0 in. (50.8 mm) Diameter, 10 to 12 ft (3048 to 3658 mm) long, Class B, Grade 1050, (UNS G10500), fine grain, test reports required, ASTM A 311/A 311M dated _____, hydraulic cylinder piston rods. [5000 kg carbon steel bars, cold drawn, stress relieved turned and polished round 50 mm diameter, 3050 to 3650 mm long, Class B, Grade 1050 (UNS G10500), fine grain, test reports required, ASTM A 311M dated _____, hydraulic cylinder piston rods.]

6. Materials and Manufacture

6.1 *Melting Practice* — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

6.2 Cold Working:

6.2.1 Class A bars shall be cold drawn using normal drafting practices.

6.2.2 Class B bars shall be cold drawn using heavy (higher than normal) drafting practices.

6.3 *Thermal Treatment* — After cold drawing, the bars shall be stress relieved at a temperature of not less than 550°F [288°C] to meet the mechanical requirements specified in Table 2.

6.4 *Condition* — The bars shall be furnished in the following cold finish conditions, as specified:

6.4.1 Cold drawn, stress relieved;

6.4.2 Cold drawn, stress relieved, turned, and polished;

6.4.3 Cold drawn, stress relieved, turned, ground, and polished; and

6.4.4 Cold drawn, stress relieved, ground, and polished.

NOTE 2 — When turned bars are specified, turning may be performed prior to cold-drawing.

7. Chemical Composition

7.1 *Composition* — The cast or heat analysis shall conform to the chemical composition requirements specified in Table 1 for the grade ordered.

8. Mechanical Properties

8.1 *Requirements* — The bars shall conform to the requirements listed in Table 2.

8.2 *Number of Tests* — At least one tension test shall be made on each lot. A lot shall consist of bars of the same size from the same heat which have been stress relieved in the same stationary furnace charge. For continuous type of treatment, a lot shall consist of 25 tons [25 Mg] or less of the same size of each heat, treated in the same cycle.

8.3 *Specimens* — Tension test specimens shall be taken longitudinally in accordance with and from the locations specified in Test Methods and Definitions A 370.

8.4 *Test Methods* — Tension tests shall be made in accordance with Test Methods and Definitions A 370. The yield strength shall be determined at 0.2% offset or at 0.005 in./in. [0.005 mm/mm] of gage length, total extension under load.

9. Workmanship, Finish, and Appearance

9.1 *Surface Finish* — Unless otherwise specified, the bars shall have a commercial bright smooth surface finish consistent with the cold finishing operations specified in 6.4.

9.2 Bars that are thermal treated after cold finishing may have a discolored or oxidized surface.

9.3 *Oiling* — The bars shall be given a surface coating of oil or other rust inhibitor to protect against rust during shipment.

9.4 Workmanship — The bars shall be free of pipe, cracks, and flakes. Within the limits of good manufacturing and inspection practices, the bars shall be free of injurious seams, laps, segregation, or other imperfections that, due to their nature, degree, or extent, will interfere with the use of the material in machining or fabrication of suitable parts.

10. General Requirements

10.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 29/A 29M and/or Specification A 108 unless otherwise stated.

11. Certification and Test Reports

11.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis and tension test results shall be furnished at the time of shipment. The report shall include the name of the manufacturer, ASTM designation and year date and revision letter, if any, class and grade, heat number, size, and grain size (if requested).

12. Keywords

12.1 carbon steel bars; cold finished steel bars; steel bars

TABLE 1
CHEMICAL REQUIREMENTS
(CAST OR HEAT ANALYSIS)^A

UNS Designation	Grade	Carbon, %	Manganese, %	Phosphorus, max %	Sulfur, %
G10180	1018	0.15–0.20	0.60–0.90	0.040	0.050 max
G10350	1035	0.32–0.38	0.60–0.90	0.040	0.050 max
G10450	1045	0.43–0.50	0.60–0.90	0.040	0.050 max
G10500	1050	0.48–0.55	0.60–0.90	0.040	0.050 max
G15410	1541	0.36–0.44	1.35–1.65	0.040	0.050 max
G11170	1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13
G11370	1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13
G11410	1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13
G11440	1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33

^A The intentional addition of Bi, Se, Te, and Pb is not permitted.

TABLE 2
MECHANICAL REQUIREMENTS

UNS No.	Grade Designation	Diameter, Thickness, or Distance Between Parallel Faces, in. [mm]	Tensile Strength, min., ksi [MPa]	Yield Strength, min., ksi [MPa]	Elongation in 2 in. [50 mm], min., %	Reduction of Area, min., %
Class A — Normal Draft Cold Drawn and Stress Relieved Annealed						
G10180	1018	Up to $\frac{7}{8}$ [20], incl	70 [485]	60 [415]	18	40
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	65 [450]	55 [380]	16	40
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	60 [415]	50 [345]	15	35
		Over 2 [50] to 3 [75], incl	55 [380]	45 [310]	15	35
G10350	1035	Up to $\frac{7}{8}$ [20], incl	85 [590]	75 [520]	13	35
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	80 [550]	70 [485]	12	35
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	75 [520]	65 [450]	12	35
		Over 2 [50] to 3 [75], incl	70 [485]	60 [415]	10	30
G10450	1045	Up to $\frac{7}{8}$ [20], incl	95 [655]	85 [585]	12	35
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	90 [620]	80 [550]	11	30
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	85 [585]	75 [520]	10	30
		Over 2 [50] to 3 [75], incl	80 [550]	70 [485]	10	30
G10500 and G15410	1050 and G1541	Up to $\frac{7}{8}$ [20], incl	100 [690]	90 [620]	11	35
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	95 [655]	85 [585]	11	30
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	90 [620]	80 [550]	10	30
		Over 2 [50] to 3 [75], incl	85 [585]	75 [520]	10	30
G11170	1117	Up to $\frac{7}{8}$ [20], incl	75 [520]	65 [450]	15	40
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	70 [485]	60 [415]	15	40
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	65 [450]	55 [380]	13	35
		Over 2 [50] to 3 [75], incl	60 [415]	50 [345]	12	30
G11370 and G11410	1137 and 1141	Up to $\frac{7}{8}$ [20], incl	95 [655]	90 [620]	11	35
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	90 [620]	85 [585]	11	30
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	85 [585]	80 [550]	10	30
		Over 2 [50] to 3 [70], incl	80 [550]	75 [520]	10	30
G11440	1144	Up to $\frac{7}{8}$ [20], incl	105 [725]	95 [655]	10	30
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	100 [690]	90 [620]	10	30
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	95 [655]	85 [585]	10	25
		Over 2 [50] to 3 [70], incl	90 [620]	80 [550]	10	20
		Over 3 [70] to $4\frac{1}{2}$ [115], incl	85 [585]	75 [520]	10	20
Class B — Heavy Draft Cold Drawn and Stress Relieved Annealed						
UNS No.	Grade Designation	In. [mm], Round or Hexagon ^A	Tensile Strength, min., ksi [MPa]	Yield Strength, min., ksi [MPa]	Elongation in 2 in. [50 mm], min., %	Reduction of Area, min., %
G10450	1045	Up to $\frac{7}{8}$ [20] incl	115 [795]	100 [690]	10	25
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	115 [795]	100 [690]	10	25
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	115 [795]	100 [690]	10	25
		Over 2 [50] to 3 [75], incl	115 [795]	100 [690]	9	25
		Over 3 [75] to 4 [102], incl	105 [725]	90 [620]	7	20
G10500 G15410 G11410 and G11440	1050 1541 1141 and 1144	Up to $\frac{7}{8}$ [20], incl	115 [795]	100 [690]	8	25
		Over $\frac{7}{8}$ [20] to $1\frac{1}{4}$ [30], incl	115 [795]	100 [690]	8	25
		Over $1\frac{1}{4}$ [30] to 2 [50], incl	115 [795]	100 [690]	8	25
		Over 2 [50] to 3 [75], incl	115 [795]	100 [690]	8	20
		Over 3 [75] to $4\frac{1}{2}$ [115], incl	115 [795]	100 [690]	7	20

^A Maximum size for hexagons is $1\frac{1}{2}$ in. [40 mm].

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Special Surface

S1.1 When inspection standards more restrictive than visual inspection are required, special surface may be specified.

S2. Restricted Cast or Heat Analysis

S2.1 When required, the purchaser may specify restrictive cast or heat analysis limits on one or more elements. The degree of restriction and the number of elements so restricted are both subject to agreement between the manufacturer and the purchaser.

S3. Restricted Decarburization

S3.1 The purchaser may specify a maximum affected depth of decarburization when required for special applications, subject to agreement between the manufacturer and the purchaser.

S4. Nonmetallic Inclusion Requirements (Microscopical)

S4.1 When nonmetallic inclusion requirements are specified, the samples for testing shall be taken on a longitudinal direction midway between the center and the surface of the material. The area of the sample to be examined

should be agreed upon between the purchaser and the manufacturer, and the test specimen should be hardened by heating and quenched before being polished to avoid pits. The rating of the inclusion count should also be agreed upon and be based upon examination at a magnification of 100 diameters. Resulfurized steels are not subject to inclusion ratings.

S5. Restricted Incidental Elements

S5.1 The purchaser may specify limiting maximum requirements for copper, nickel, chromium, or molybdenum subject to agreement between the manufacturer and the purchaser.

S6. Grain Size

S6.1 The steel shall conform to either the coarse austenitic grain size (except as stated in S6.2), or the fine austenitic grain size requirement of Specification A 29/A 29M.

S6.2 Certain elements, or combinations of elements, such as manganese, sulfur, and lead tend to produce grain refinement and it is technically inappropriate to ensure coarse grain size as measured by the McQuaid-Ehn test on high manganese, high sulfur, and leaded steels such as 1144, 1151, and 11L41.

SPECIFICATION FOR SEAMLESS, WELDED, AND HEAVILY COLD WORKED AUSTENITIC STAINLESS STEEL PIPES



SA-312/SA-312M

(21)

(Identical with ASTM Specification A312/A312M-18a except for the revision to para. 6.2 to add "H" grade heat treatment requirements.)

Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes

1. Scope

1.1 This specification covers seamless, straight-seam welded, and heavily cold worked welded austenitic stainless steel pipe intended for high-temperature and general corrosive service.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades TP304, TP304L, and TP347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ASME B31.3, for service at temperatures as low as -425°F [-250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as -325°F [-200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than -50°F [-45°C].

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309Cb, TP309S, TP310Cb, TP310S, TP316, TP321, TP347, and TP348, and are intended for service at temperatures where creep and stress rupture properties are important.

1.3 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, it is permitted to specify in the order one or more of these supplementary requirements.

1.4 Table X1.1 lists the standardized dimensions of welded and seamless stainless steel pipe as shown in ASME B36.19. These dimensions are also applicable to heavily cold worked pipe. Pipe having other dimensions is permitted to be ordered

and furnished provided such pipe complies with all other requirements of this specification.

1.5 Grades TP321 and TP321H have lower strength requirements for pipe manufactured by the seamless process in nominal wall thicknesses greater than $\frac{3}{8}$ in. [9.5 mm].

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

- A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
- A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe
- A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes
- E112 Test Methods for Determining Average Grain Size

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ASME Standards:*

B1.20.1 Pipe Threads, General Purpose

B36.10M Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

ASME Boiler and Pressure Vessel Code : Section VIII

2.3 *AWS Standard:*

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes

2.4 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Specification A999/A999M and Terminology A941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material to this specification shall conform to the requirements of the current edition of Specification A999/A999M.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Manufacture:*

6.1.1 The pipe shall be manufactured by one of the following processes:

6.1.2 *Seamless (SML) pipe* shall be made by a process that does not involve welding at any stage of production.

6.1.3 *Welded (WLD) pipe* shall be made using an automatic welding process with no addition of filler metal during the welding process.

6.1.4 *Heavily cold-worked (HCW) pipe* shall be made by applying cold working of not less than 35 % reduction in thickness of both wall and weld to a welded pipe prior to the final anneal. No filler shall be used in making the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW-51.

6.1.5 Welded pipe and HCW pipe of NPS 14 and smaller shall have a single longitudinal weld. Welded pipe and HCW pipe of a size larger than NPS 14 shall have a single longitudinal weld or shall be produced by forming and welding two longitudinal sections of flat stock when approved by the purchaser. All weld tests, examinations, inspections, or treatments shall be performed on each weld seam.

6.1.6 At the option of the manufacturer, pipe shall be either hot finished or cold finished.

6.1.7 The pipe shall be free of scale and contaminating exogenous iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to require that a passivating treatment be applied to the finished pipe.

6.2 *Heat Treatment*—All pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2. Other than for Grades S33228, S30815, S31272, and the H Grades, seamless pipe immediately following hot forming may be individually quenched by water or rapidly cooled by other means, provided that the temperature of the pipes after hot forming is not less than the minimum specified solution treatment temperature in Table 2. For H Grades, as well as Grades S33228, S30815, and S31272, the pipes shall be reheated to the specified solution treatment for the required time before quenching.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Permitted Variations in Wall Thickness

9.1 In addition to the implicit limitation of wall thickness for seamless pipe imposed by the limitation on weight in Specification A999/A999M, the wall thickness for seamless and welded pipe at any point shall be within the tolerances specified in Table 3, except that for welded pipe the weld area shall not be limited by the "Over" tolerance. The wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS and schedule number is shown in Table X1.1.

10. Tensile Requirements

10.1 The tensile properties of the material shall conform to the requirements prescribed in Table 4.

TABLE 1 Chemical Requirements

Grade	UNS Designation ^A	Composition, % ^B																	
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Niobium ^M	Tantalum, max	Nitrogen ^C	Vanadium	Copper	Cerium	Boron	Aluminum	Other
TP201	S20100	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	...	...	...	0.25	...	...	...	...	...	...
TP201LN	S20153	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	...	...	...	...	0.10–0.25	...	1.00	...	...	...	...
...	S20400	0.030	7.0–9.0	0.045	0.030	1.00	15.0–17.0	1.50–3.00	...	...	...	...	0.15–0.30	...	...	...	...	...	...
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	...	0.10–0.30	...	0.20–0.40	0.10–0.30	...	...	...	...	...
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	...	...	...	...	0.15–0.40	...	...	...	...	...	...
TPXM-11	S21904	0.04	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	...	...	...	...	0.15–0.40	...	...	...	...	...	...
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	...	...	...	...	0.20–0.40	...	...	...	...	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...	...	...	...	...	...	...
TP304L	S30403	0.035 ^D	2.00	0.045	0.030	1.00	18.0–20.0	8.0–13.0	...	...	...	...	...	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...	...	...	...	...	...	...
...	S30415	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	...	...	...	...	0.12–0.18	...	...	0.03–0.08	...	...	...
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	0.10–0.16	...	...	...	...	...	...
TP304LN	S30453	0.035	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	...	...	...	0.10–0.16	...	...	...	...	...	...
...	S30600	0.018	2.00	0.02	0.02	3.7–4.3	17.0–18.5	14.0–15.5	0.20	...	...	...	...	...	0.50 max	...	...	...	...
...	S30601	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	0.20	...	...	...	0.05	...	0.35	...	...	...	...
...	S30615	0.16–0.24	2.00	0.030	0.03	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	...	...	...	...	...	...	0.80–1.50	...
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	...	...	...	0.14–0.20	...	...	0.03–0.08	...	...	...
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	0.75	...	...	...	...	...	...	...	...	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...	...	...	...	...	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	...	10 × C min, 1.10 max	...	...	...	...	...	...	...	...

TABLE 1 Continued

Grade	UNS Designation ^A	Composition, % ^B																	
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Niobium ^M	Tantalum, max	Nitrogen ^C	Vanadium	Copper	Cerium	Boron	Aluminum	Other
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	...	10 × C min, 1.10 max	...	...	...	...	...	...	...	...
	S31002	0.015	2.00	0.020	0.015	0.15	24.0–26.0	19.0–22.0	0.10	...	...	...	0.10	...	...	...	...	...	...
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	...	...	...	...	...	...	...	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...	...	...	...	...	...	...	...
	S31035	0.04–0.10	0.60	0.025	0.015	0.40	21.5–23.5	23.5–26.5	...	...	0.40–0.60	...	0.20–0.30	...	2.5–3.5	...	0.002–0.008	...	W 3.0–4.0 Co 1.0–2.0
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	10 × C min, 1.10 max	...	...	...	...	...	...	...	...
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	10 × C min, 1.10 max	...	...	...	...	...	...	...	...
...	S31050	0.025	2.00	0.020	0.015	0.4	24.0–26.0	20.5–23.5	1.6–2.6	...	...	...	0.09–0.15	...	...	...	...	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	...	...	...	0.18–0.25	...	0.50–1.00	...	...	...	...
...	S31266	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	5.2–6.2	...	...	...	0.35–0.60	...	1.00–2.50	...	...	...	W 1.50–2.50
	S31272	0.08–0.12	1.5–2.00	0.030	0.015	0.25–0.75	14.0–16.0	14.0–16.0	1.00–1.40	0.30–0.60	...	...	...	...	...	0.004–0.008	...	...	...
	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	...	...	...	0.30–0.40	...	0.50–1.50	...	...	...	...
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...	...	...	...	...	...	...
TP316L	S31603	0.035 ^D	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...	...	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...	...	...	...	...	...	...
TP316Ti	S31635	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	5× (C+N) –0.70	...	...	0.10	...	...	...	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	0.10–0.16	...	...	...	...	...	...
TP316LN	S31653	0.035	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	0.10–0.16	...	...	...	...	...	...
...	S31655	0.030	2.00	0.045	0.015	1.00	19.5–21.5	8.0–9.5	0.50–1.50	...	...	...	0.14–0.25	...	1.00	...	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...	...	...	...	...	...	...	...

TABLE 1 Continued

Grade	UNS Designation ^A	Composition, % ^B																	
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Niobium ^M	Tantalum, max	Nitrogen ^C	Vanadium	Copper	Cerium	Boron	Aluminum	Other
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...	...	...	...	...	...	...	...
...	S31725	0.03	2.00	0.040 ^E	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	...	...	...	0.10	...	0.75	...	...	...	...
...	S31726	0.03	2.00	0.040 ^E	0.030	1.00	17.0–20.0	13.5–17.5	4.0–5.0	...	...	...	0.10–0.20	...	0.75	...	...	...	...
...	S31727	0.03	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	...	...	...	0.15–0.21	...	2.8–4.0	...	...	...	...
...	S31730	0.030	2.00	0.040	0.010	1.00	17.0–19.0	15.0–16.5	3.0–4.0	...	...	...	0.045	...	4.0–5.0	...	...	...	...
...	S32053	0.03	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	...	...	...	0.17–0.22	...	...	...	...	...	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	^F	...	...	0.10	...	...	...	...	...	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	4(C+N) min; 0.70 max	...	...	0.10	...	...	...	...	...	...
...	S32615	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	...	...	...	...	...	1.50–2.50	...	...	...	...
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	...	...	...	0.45–0.55	...	0.30–0.60	...	...	...	...
...	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	0.60–1.00	...	...	...	...	0.05–0.10	...	0.025	...
...	S34565	0.03	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	...	0.10	...	0.40–0.60	...	...	...	...	...	...
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	^G	...	...	...	...	...	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	^H	...	...	...	...	...	...	...	...
TP347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	0.20–0.50 ^I	...	0.06–0.10	...	...	...	...	...	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	^G	0.10	...	...	...	...	...	...	...
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	^H	0.10	...	...	...	...	...	...	...
...	S35045	0.06–0.10	1.50	...	0.015	1.00	25.0–29.0	32.0–37.0	...	0.15–0.60	...	...	...	...	0.75	...	...	0.15–0.60	...
...	S35315	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	...	...	...	...	0.12–0.18	...	...	0.03–0.08	...	...	...
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...	...	...	...	...	...	...	...
...	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	...	...	...	...	...	0.75–1.50	...	...	0.30	...

TABLE 1 Continued

Grade	UNS Designation ^A	Composition, % ^B																	
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Niobium ^M	Tantalum, max	Nitrogen ^C	Vanadium	Copper	Cerium	Boron	Aluminum	Other
Alloy 20	N08020	0.07	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	2.0–3.0	...	^L	^L	...	...	3.0–4.0	...	...	...
	N08028	0.030	2.50	0.030	0.030	1.0	26.0–28.0	30.0–34.0	3.0–4.0	...	...	...	...	...	0.60–1.4	...	...	...
	N08029	0.020	2.0	0.025	0.015	0.6	26.0–28.0	30.0–34.0	4.0–5.0	...	...	...	...	...	0.6–1.4	...	...	...
...	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	...	...	...	0.18–0.25	...	0.75	...	...	...
800	N08800	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	...	...	...	...	0.75	...	...	0.15–0.60	Fe ^J 39.5 min.
800H	N08810	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	0.15–0.60	...	...	...	...	0.75	...	...	0.15–0.60	Fe ^J 39.5 min.
	N08811	0.06–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	0.15–0.60 ^K	...	...	...	...	0.75	...	...	0.15–0.60 ^K	Fe ^J 39.5 min.
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	...	...	...	0.10	...	1.00–2.00	...	...	...
...	N08925	0.020	1.00	0.045	0.030	0.50	19.0–21.0	24.0–26.0	6.0–7.0	...	...	...	0.10–0.20	...	0.80–1.50	...	...	...
...	N08926	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	...	...	...	0.15–0.25	...	0.50–1.50	...	...	...

^A New designation established in accordance with Practice E527 and SAE J1086.

^B Maximum, unless otherwise indicated. Where ellipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.

^C The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

^D For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.20 mm] in average wall thickness (0.044 in. [1.10 mm] in minimum wall thickness).

^E For welded pipe, the phosphorus maximum shall be 0.045 %.

^F Ti 5 × (C+N) min, 0.70 max.

^G The niobium content shall be not less than ten times the carbon content and not more than 1.00 %.

^H The niobium content shall be not less than eight times the carbon content and not more than 1.0 %.

^I Grade S34751 shall have a niobium content of not less than 15 times the carbon content.

^J Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

^K Al + Ti shall be 0.85 % min; 1.20 % max.

^L Niobium (Nb) + Tantalum = 8 × Carbon min, 1.00 max.

^M The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

TABLE 2 Annealing Requirements

Grade or UNS Designation ^A	Heat Treating Temperature ^B	Cooling/Testing Requirements
All grades not individually listed below:	1900 °F [1040 °C]	<i>C</i>
TP321H, TP347H, TP348H		
Cold finished	2000 °F [1100 °C]	<i>D</i>
Hot finished	1925 °F [1050 °C]	<i>D</i>
TP304H, TP316H		
Cold finished	1900 °F [1040 °C]	<i>D</i>
Hot finished	1900 °F [1040 °C]	<i>D</i>
TP309H, TP309HCb, TP310H, TP310HCb	1900 °F [1040 °C]	<i>D</i>
S30600	2010–2140 °F [1100–1170 °C]	<i>D</i>
S30601	2010–2140 °F [1100–1170 °C]	<i>D</i>
S30815, S31272	1920 °F [1050 °C]	<i>D</i>
S31035	2160–2280 °F [1180–1250 °C]	<i>D</i>
S31254, S32654	2100 °F [1150 °C]	<i>D</i>
S31266	2100 °F [1150 °C]	<i>D</i>
S31277	2050 °F [1120 °C]	<i>D</i>
S31727, S32053	1975–2155 °F [1080–1180 °C]	<i>D</i>
S33228	2050–2160 °F [1120–1180 °C]	<i>D</i>
S34565	2050–2140 °F [1120–1170 °C]	<i>D</i>
S35315	2010 °F [1100 °C]	<i>D</i>
S38815	1950 °F [1065 °C]	<i>D</i>
N08367	2025 °F [1110 °C]	<i>D</i>
N08020	1700–1850 °F [925–1010 °C]	<i>D</i>
N08028	2000 °F [1100 °C]	<i>D</i>
N08029	2000 °F [1100 °C]	<i>D</i>
N08810	2050 °F [1120 °C]	<i>D</i>
N08811	2100 °F [1150 °C]	<i>D</i>
N08904	2000 °F [1100 °C]	<i>D</i>
N08925, N08926	2010–2100 °F [1100–1150 °C]	<i>D</i>

^A New designation established in accordance with Practice E527 and SAE J1086.

^B Minimum, unless otherwise stated.

^C Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of pipes, heat treated by either separate solution annealing or by direct quenching, of passing Practices A262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S7). Note that Practices A262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.

^D Quenched in water or rapidly cooled by other means.

11. Mechanical Tests, Grain Size Determinations, and Weld Decay Tests Required

11.1 *Mechanical Testing Lot Definition*—The term *lot* for mechanical tests shall be as follows:

11.1.1 Where the final heat treated condition is obtained, consistent with the requirements of 6.2, in a continuous furnace, by quenching after hot forming or in a batch-type furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, the term *lot* for mechanical tests shall apply to all pipes of the same specified outside diameter and specified wall thickness (or schedule) that are produced from the same heat of steel and subjected to the same finishing treatment within the same operating period.

TABLE 3 Permitted Variations in Wall Thickness

NPS Designator	Tolerance, % from Nominal	
	Over	Under
⅜ to 2½ incl., all t/D ratios	20.0	12.5
3 to 18 incl., t/D up to 5 % incl.	22.5	12.5
3 to 18 incl., t/D > 5 %	15.0	12.5
20 and larger, welded, all t/D ratios	17.5	12.5
20 and larger, seamless, t/D up to 5 % incl.	22.5	12.5
20 and larger, seamless, t/D > 5 %	15.0	12.5

where:

t = Nominal Wall Thickness

D = Ordered Outside Diameter

11.1.2 Where the final heat treated condition is obtained, consistent with the requirements of 6.2, in a batch-type furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, the term *lot* shall apply to the larger of: (a) each 200 ft [60 m] or fraction thereof and (b) those pipes heat treated in the same furnace batch charge for pipes of the same specified outside diameter and specified wall thickness (or schedule) that are produced from the same heat of steel and are subjected to the same finishing temperature within the same operating period.

11.2 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

11.3 *Flattening Test*—For material heat treated in a continuous furnace, by quenching after hot forming or in a batch-type furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, flattening tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 lengths of pipe. For material heat treated in a batch-type furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, flattening tests shall be made on 5 % of the pipe from each heat treated lot.

11.3.1 For welded pipe a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A370. For welded pipe with a specified wall thickness over ⅜ in., two side bend tests may be made instead of the face bend test. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

11.4 *Grain Size*—Grain size determinations, in accordance with Test Methods E112, shall be made on the grades listed in Table 5. Grain size determinations shall be made on each heat

TABLE 4 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP201	S20100	75 [515]	38 [260]
TP201LN	S20153	95 [655]	45 [310]
...	S20400	95 [635]	48 [330]
TPXM-19	S20910	100 [690]	55 [380]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21904	90 [620]	50 [345]
TPXM-29	S24000	100 [690]	55 [380]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP304H	S30409	75 [515]	30 [205]
...	S30415	87 [600]	42 [290]
TP304N	S30451	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
...	S30600	78 [540]	35 [240]
...	S30601	78 [540]	37 [255]
...	S30615	90 [620]	40 [275]
...	S30815	87 [600]	45 [310]
TP309S	S30908	75 [515]	30 [205]
TP309H	S30909	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309HCb	S30941	75 [515]	30 [205]
...	S31002	73 [500]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP310H	S31009	75 [515]	30 [205]
...	S31035	95 [655]	45 [310]
TP310Cb	S31040	75 [515]	30 [205]
TP310HCb	S31041	75 [515]	30 [205]
...	S31050:		
t ≤ 0.250 in. [6.35 mm]		84 [580]	39 [270]
t > 0.250 in. [6.35 mm]		78 [540]	37 [255]
...	S31254:		
t ≤ 0.187 in. [5.00 mm]		98 [675]	45 [310]
t > 0.187 in. [5.00 mm]		95 [655]	45 [310]
...	S31266	109 [750]	61 [420]
...	S31272	65 [450]	29 [200]
...	S31277	112 [770]	52 [360]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP316H	S31609	75 [515]	30 [205]
...	S31635	75 [515]	30 [205]
TP316N	S31651	80 [550]	35 [240]
TP316LN	S31653	75 [515]	30 [205]
...	S31655	92 [635]	45 [310]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
...	S31725	75 [515]	30 [205]
...	S31726	80 [550]	35 [240]
...	S31727	80 [550]	36 [245]
...	S31730	70 [480]	25 [175]
...	S32053	93 [640]	43 [295]
TP321	S32100:		
Welded		75 [515]	30 [205]
Seamless:			
t ≤ 0.375 in. [9.50 mm]		75 [515]	30 [205]
t > 0.375 in. [9.50 mm]		70 [485]	25 [170]
TP321H	S32109:		
Welded		75 [515]	30 [205]
Seamless:			
t ≤ 0.375 in. [9.50 mm]		75 [515]	30 [205]
t > 0.375 in. [9.50 mm]		70 [480]	25 [170]
...	S32615	80 [550]	32 [220]
...	S32654	109 [750]	62 [430]
...	S33228	73 [500]	27 [185]
...	S34565	115 [795]	60 [415]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP347LN	S34751	75 [515]	30 [205]

TABLE 4 Continued

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
...	S35045	70 [485]	25 [170]
...	S35315		
Welded		94 [650]	39 [270]
Seamless		87 [600]	38 [260]
TPXM-15	S38100	75 [515]	30 [205]
...	S38815	78 [540]	37 [255]
Alloy 20	N08020	80 [550]	35 [240]
...	N08028	73 [500]	31 [214]
...	N08029	73 [500]	31 [214]
...	N08367:		
t ≤ 0.187 in. [5.00 mm]		100 [690]	45 [310]
t > 0.187 in. [5.00 mm]		95 [655]	45 [310]
800	N08800 cold-worked annealed	75 [515]	30 [205]
...	hot finished annealed	65 [450]	25 [170]
800H	N08810	65 [450]	25 [170]
...	N08811	65 [450]	25 [170]
...	N08904	71 [490]	31 [215]
...	N08925	87 [600]	43 [295]
...	N08926	94 [650]	43 [295]
Elongation in 2 in. or 50 mm (or 4D), min, %		Longi- tudinal	Trans- verse
All Grades except S31050 and S32615		35	25
S32615, S31050		25	...
S31277, N08925, N08028, N08029		40	...
N08367, N08020, N08800, N08810, N08811		30	...

TABLE 5 Grain Size Requirements

Grade	UNS Designation	Grain Size
...	N08810	5 or coarser
...	N08811	5 or coarser
TP304H	S30409	7 or coarser
TP309H	S30909	6 or coarser
TP309HCb	S30940	6 or coarser
TP310H	S31009	6 or coarser
TP310HCb	S31041	6 or coarser
TP316H	S31609	7 or coarser
TP321H	S32109	7 or coarser
...	S32615	3 or finer
TP347H	S34709	7 or coarser
TP348H	S34809	7 or coarser

treatment lot, as defined in 11.1, for the same number of pipes as prescribed for the flattening test in 11.3. The grain size results shall conform to the requirements prescribed in Table 5.

11.5 HCW pipe shall be capable of passing the weld decay tests listed in Supplementary S9 with a weld metal to base metal loss ratio of 0.90 to 1.1. The test is not required to be performed unless S9 is specified in the purchase order.

12. Hydrostatic or Nondestructive Electric Test

12.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used

shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

12.2 The hydrostatic test shall be in accordance with Specification A999/A999M, unless specifically exempted under the provisions of 12.3.

12.3 For pipe whose dimensions equal or exceed NPS10, the purchaser, with the agreement of the manufacturer, is permitted to waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory markings the letters "NH."

12.4 The nondestructive electric test shall be in accordance with Specification A999/A999M.

13. Lengths

13.1 Pipe lengths shall be in accordance with the following regular practice:

13.1.1 Unless otherwise agreed upon, all sizes from NPS ½ to and including NPS 8 are available in a length up to 24 ft with the permitted range of 15 to 24 ft. Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

13.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and no pipe shall be more than ¼ in. [6 mm] over the specified length.

13.1.3 No jointers are permitted unless otherwise specified.

14. Workmanship, Finish, and Appearance

14.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Removal of imperfections by grinding is permitted, provided the wall thicknesses are not decreased to less than that permitted in the Permissible Variations in Wall Thickness section of Specification A999/A999M.

15. Repair by Welding

15.1 For welded pipe whose diameter equals or exceeds NPS 6, and whose nominal wall thickness equals or exceeds 0.200, it is permitted to make weld repairs to the weld seam with the addition of compatible filler metal using the same procedures specified for plate defects in the section on Repair by Welding of Specification A999/A999M.

15.2 Weld repairs of the weld seam shall not exceed 20 % of the seam length.

15.3 Weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filler rod qualified to the most current AWS Specification A5.9 as the grade of stainless steel pipe being repaired and as shown in Table 6. Alternatively, subject to approval by the purchaser, weld repairs shall be made only with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties.

15.4 Pipes that have had weld seam repairs with filler metal shall be uniquely identified and shall be so stated and identified

TABLE 6 Pipe and Filler Metal Specification

Pipe	Filler Metal		
	UNS Designation	AWS A5.9 Class	UNS Designation
TP201	S20100	...	...
TP201LN	S20153	...	...
TP304	S30400	ER308	S30800, W30840
TP304L	S30403	ER308L	S30883, W30843
TP304N	S30451	ER308	S30880, W30840
TP304LN	S30453	ER308L	S30883, W30843
TP304H	S30409	ER308	S30880, W30840
...	S30601	...	...
TP309Cb	S30940	...	...
TP309S	S30908	...	...
TP310Cb	S31040	...	...
TP310S	S31008	...	...
...	S31266	ERNiCrMo-4	N10276
		ERNiCrMo-10	N06022
		ERNiCrMo-13	N06059
		ERNiCrMo-14	N06686
		ERNiCrMo-17	N06200
	S31272	...	...
TP316	S31600	ER316	S31680, W31640
TP316L	S31603	ER316L	S31683, W31643
TP316N	S31651	ER316	S31680, W31640
TP316LN	S31653	ER316L	S31683, W31643
...	S31655	...	...
TP316H	S31609	ER316H	S31680, W31640
...	S31730	ERNiCr-3, or ERNiCrMo-3, or ERNiCrMo-4	N06082, N06625, N10276
TP321	S32100	ER321	S32180, W32140
		ER347	S34780, W34740
TP347	S34700	ER347	S34780, W34740
TP348	S34800	ER347	S34780, W34740
TPXM-19	S22100	ER209	S20980, W32240
TPXM-29	S28300	ER240	S23980, W32440
...	N08367	...	N06625
Alloy 20	N08020	ER320	N08021
		ER320LR	N08022
	N08028	ER383	N08028
	N08029	ERNiCrMo-3 ^A	N06625
		ERNiCrMo-13 ^A	N06059
...	S20400	ER209	S20980, W32240
800	N08800	ERNiCr-3 ^A	N06082
800H	N08810	ERNiCr-3 ^A	N06082
	N08811	ERNiCr-3 ^A	N06082
...	N08925	...	N06625
...	N08926	...	N06625

^AAWS A5.14 Class.

on the certificate of tests. When filler metal other than that listed in Table 6 is used, the filler metal shall be identified on the certificate of tests.

16. Certification

16.1 In addition to the information required by Specification A999/A999M, the certification shall state whether or not the material was hydrostatically tested. If the material was nondestructively tested, the certification shall so state and shall state which standard practice was followed and what reference discontinuities were used.

17. Marking

17.1 In addition to the marking specified in Specification A999/A999M, the marking shall include the NPS (nominal pipe size) or outside diameter and schedule number or average wall thickness, heat number, and NH when hydrotesting is not

performed and ET when eddy-current testing is performed or UT when ultrasonic testing is performed. The marking shall also include the manufacturer's private identifying mark, the marking requirement of 12.3, if applicable, and whether seamless (SML), welded (WLD), or heavily cold-worked (HCW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

18. Government Procurement

18.1 *Scale Free Pipe for Government Procurement:*

18.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry, contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specifications.

18.1.2 The requirements of Specification A999/A999M for pipe and Specification A1016/A1016M for tubes shall be applicable when pipe or tube is ordered to this specification.

18.1.3 Pipe and tube shall be one of the following grades as specified herein:

Grade	UNS Designation
TP304	S30400
TP304L	S30403
TP304N	S30451
TP316	S31600
TP316L	S31603
TP316N	S31651
TP317	S31700

TP317L	S31703
TP321	S32100
TP347	S34700

18.1.4 *Part Number:*

Example: ASTM A312/A312M Pipe 304 NPS 12 SCH 40S SMLS

Specification Number	ASTM A312
Pipe	P
Grade	304
NPS	12
Wall	0.375
SMLS OR WELDED	SML

18.1.4.1

Specification Number	ASTM A312
Tube	T
Grade	304
Outside Diameter	0.250
Wall	0.035
SMLS OR WELDED	WLD

18.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 4:

18.1.5.1 Pipe or tube,

18.1.5.2 Part number,

18.1.5.3 Ultrasonic inspection, if required,

18.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions,

18.1.5.5 Intergranular corrosion test, and

18.1.5.6 Level of preservation and packing required.

19. Keywords

19.1 austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This requirement is applicable only to pipe NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section

from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 The entire length of weld in each double welded pipe shall be radiographically examined, using X-radiation, in accordance with Paragraph UW-51 of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. In addition to the marking required by Section 13 each pipe shall be marked "RT" after the specification and grade. Requirements of S5 shall be required in the certification.

S6. Stabilizing Heat Treatment

S6.1 Subsequent to the solution anneal required in 6.2, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be as agreed upon between the purchaser and vendor.

S7. Intergranular Corrosion Test

S7.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

S7.1.1 Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades. The applicability of this test and the preparation of the sample for testing for grades containing greater than 3 % molybdenum shall be as agreed by the purchaser and manufacturer.

NOTE S7.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S7.2 A stabilization heat treatment in accordance with Supplementary Requirement S6 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S8. Minimum Wall Pipe

S8.1 When specified by the purchaser, pipe shall be furnished on a minimum wall basis. The wall of such pipe shall not fall below the thickness specified. In addition to the marking required by Section 17, the pipe shall be marked S8.

S9. Weld Decay Test

S9.1 When specified in the purchase order, one sample from each lot of pipe shall be subject to testing in a boiling solution of 50 % reagent grade hydrochloric acid and 50 % water.

S9.2 The sample, of approximately 2-in. [50-mm] length, shall be prepared from a production length of pipe. Depending on the size of the pipe, it is permitted to section the sample longitudinally to allow it to fit in the Erlenmeyer flask. As a minimum, the tested sample shall include the entire weld and adjacent area and the full length of base metal 180° across from the weld. All burrs and sharp edges shall be removed by light grinding. Dust and grease shall be removed by cleaning with soap and water or other suitable solvents.

S9.3 The hydrochloric acid solution shall be prepared by slowly adding reagent grade (approximately 37 %) hydrochloric acid to an equal volume of distilled water.

Warning—Protect eyes and use rubber gloves when handling acid. Mixing and testing shall be performed in a protective enclosure.

S9.4 The test container shall be a 1-L Erlenmeyer flask equipped with ground-glass joints and an Ahline condenser. The volume of the solution shall be approximately 700 mL.

S9.5 The thickness of the weld and the base metal 180° from the weld shall be measured near both ends of the sample. These measurements shall be made with a micrometer with an anvil shape suitable for measuring the thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.6 The sample sections, both weld and base metal, shall be immersed in the flask containing the solution. Boiling chips shall be added and the solution brought to a boil. Boiling shall be maintained through the duration of the test. The time of testing shall be that which is required to remove 40 to 60 % of the original base metal thickness (usually 2 h or less). If more than 60 % of the base metal thickness remains, it is permitted to terminate the test after 24 h.

S9.7 At the end of the test period, the samples shall be removed from the solution, rinsed with distilled water, and dried.

S9.8 The thickness measurements as in S9.5 shall be repeated. The anvil shape of the micrometer used shall be suitable for measuring the minimum remaining thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.9 The corrosion ratio, R , shall be calculated as follows:

$$R = (W_o - W)/(B_o - B)$$

where:

W_o = average weld-metal thickness before the test,
 W = average weld-metal thickness after the test,
 B_o = average base-metal thickness before the test, and
 B = average base-metal thickness after the test,

S9.9.1 The corrosion ratio for HCW pipe shall be as specified in 11.5.

S9.9.2 The corrosion ratio shall be 1.25 or less, or as further restricted in the purchase order, when the weld decay test is specified for welded (WLD) pipe.

APPENDIX

(Nonmandatory Information)

X1. DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

X1.1 Table X1.1 is based on Table number 1 of the American National Standard for stainless steel pipe (ASME B36.19) but not identical.

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
	in.	mm	Schedule 5S ^A		Schedule 10S ^A		Schedule 40S		Schedule 80S	
			in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.3	...	...	0.049	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.7	...	...	0.065	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.1	...	...	0.065	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.3	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.7	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1	1.315	33.4	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.2	0.065	1.65	0.109	2.77	0.140	3.58	0.191	4.85
1 1/2	1.900	48.3	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.3	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.0	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.9	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.6	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.3	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.3	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.53
6	6.625	168.3	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.1	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.1	0.134	3.40	0.165	4.19	0.365	9.27	0.500 ^B	12.70 ^B
12	12.750	323.9	0.156	3.96	0.180	4.57	0.375 ^B	9.53 ^B	0.500 ^B	12.70 ^B
14	14.000	355.6	0.156	3.96	0.188 ^B	4.78 ^B	0.375 ^B	9.53 ^B	0.500 ^B	12.70 ^B
16	16.000	406.4	0.165	4.19	0.188 ^B	4.78 ^B	0.375 ^B	9.53 ^B	0.500 ^B	12.70 ^B
18	18.000	457	0.165	4.19	0.188 ^B	4.78 ^B	0.375 ^B	9.53 ^B	0.500 ^B	12.70 ^B
20	20.000	508	0.188	4.78	0.218 ^B	5.54 ^B	0.375 ^B	9.53 ^B	0.500 ^B	12.70 ^B
22	22.000	559	0.188	4.78	0.218 ^B	5.54 ^B	...	...	...	...
24	24.000	610	0.218	5.54	0.250	6.35	0.375 ^B	9.53 ^B	0.500 ^B	12.70 ^B
30	30.000	762	0.250	6.35	0.312	7.92	...	...	...	...

^A Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ASME B1.20.1).

^B These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ASME B36.10M).

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SPECIFICATION FOR ALLOY-STEEL AND STAINLESS STEEL BOLTING FOR LOW-TEMPERATURE SERVICE



SA-320/SA-320M



(Identical with ASTM Specification A320/A320M-11a.)

Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service

1. Scope

1.1 This specification covers alloy steel bolting for pressure vessels, valves, flanges, and fittings for low-temperature service. See Specification A962/A962M for the definition of bolting. The bars shall be hot-wrought and may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When strain hardened austenitic stainless steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including both ferritic and austenitic steels designated L7, B8, etc. Selection will depend on design, service conditions, mechanical properties, and low-temperature characteristics. The mechanical requirements of Table 1 indicate the diameters for which the minimum mechanical properties apply to the various grades and classes, and Table 2 stipulates the requirements for Charpy impact energy absorption. The manufacturer should determine that the material can conform to these requirements before parts are manufactured. For example, when Grade L43 is specified to meet the Table 2 impact energy values at $-150\text{ }^{\circ}\text{F}$ [$-101\text{ }^{\circ}\text{C}$], additional restrictions (such as procuring a steel with lower P and S contents than might normally be supplied) in the chemical composition for AISI 4340 are likely to be required.

NOTE 1—The committee formulating this specification has included several grades of material that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable.

1.3 The following referenced general requirements are indispensable for application of this specification: Specification A962/A962M.

1.4 Nuts for use with bolting are covered in Section 10 and the nut material shall be impact tested.

1.5 Supplementary Requirements are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified in the purchase order or contract.

1.6 This specification is expressed in both inch-pound units and SI units; however, unless the purchase order or contract specifies the applicable *M* specification designation (SI) units, the inch-pound units shall apply.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 ASTM Standards:

A194/A194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

E566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals

F436 Specification for Hardened Steel Washers

F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

2.2 ASME Standards:

B1.1 Screw Threads

B18.22.1 Plain Washers

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all information necessary to purchase the needed materials. Examples of such information include, but are not limited to, the following:

3.1.1 Quantity and size,

3.1.2 Heat-treated condition, that is, for the austenitic stainless steels, solution-treated (Class 1); solution-treated after finishing (Class 1A); and annealed and strain-hardened (Class 2),

3.1.3 Description of items required (bars, bolts, screws, or studs),

3.1.4 Nuts and washers, if required by the purchaser, in accordance with Section 10, and

3.1.5 Special requirements, in accordance with 5.1.1, 5.1.2, 5.1.3, and 13.1.

4. Common Requirements

4.1 Bolting supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, macroetch (carbon and alloy steels only) marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between the requirements in this specification and Specification A962/A962M, this specification shall prevail.

4.2 For L7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150 °F [620 °C] minimum, shall be done after machining and forming operations, including thread rolling and any type of cutting.

5. Materials and Manufacture

5.1 Heat Treatment:

5.1.1 Bolting shall be allowed to cool to room temperature after rolling or forging. Grades L7, L7A, L7B, L7C, L7M, L43, L1, L70, L71, L72, and L73 shall be reheated to above the upper critical temperature and liquid quenched and tempered. Grades B8, B8C, B8M, B8T, B8F, B8P, B8LN, and B8MLN shall receive a carbide solution treatment. Products made from such material are described as Class 1. This shall consist of holding the material for a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling in air or in a liquid medium at a rate sufficient to prevent reprecipitation of the carbide. Material thus treated is described as Class 1. If specified in the purchase order, material shall be solution treated in the finished condition; material so treated is described as Class 1A.

5.1.2 When increased mechanical properties are desired, austenitic bolting shall be solution annealed and strain hardened if specified in the purchase order; material so treated is identified as Class 2.

5.1.3 If scale-free bright finish is required, this shall be specified in the purchase order.

5.1.4 For L7M bolting, the final heat treatment, which may be the tempering or stress-relieving operation conducted at 1150 °F [620 °C] minimum, shall be done after machining or rolling of the threads and any type of cutting.

6. Mechanical Requirements

6.1 Tensile Properties:

6.1.1 The material as represented by the tension specimens shall conform to the requirements as to tensile properties prescribed in Table 1 at room temperature after heat treatment (see 5.1.1). Alternatively, Class 2 Strain Hardened Headed Fasteners shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Table 1. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

6.1.2 Number of Tests:

6.1.2.1 For heat-treated bars, one tension test and one impact test consisting of three specimens shall be made for each diameter of each heat represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size, and subjected to the same heat treatment. Not fewer than two tensile tests and two impact tests are required for each lot containing 20 000 lbs [9000 kg] or less. Every additional 10 000 lbs [4500 kg] or fraction thereof requires an additional tensile test and impact test.

6.1.2.2 For studs, bolts, screws, etc., one tension test and one set of three impact specimens shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size, lb [kg]
1½ [30] and under	1500 [680] or fraction thereof
Over 1½ [30] to 1¾ [45], incl	4500 [2040] or fraction thereof
Over 1¾ [45] to 2½ [65], incl	6000 [2700] or fraction thereof
Over 2½ [65]	100 pieces or fraction thereof

6.1.2.3 *Full Size Specimens, Headed Fasteners*—Headed fasteners 1 ½ in. in body diameter and smaller, with body length three times the diameter or longer, and which are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 6.1.3. This testing shall be in addition to tensile testing as specified in 6.1.1. The lot size shall be shown in 6.1.2.2. Failure shall occur in the body or threaded sections with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

6.1.3 *Full Size Fasteners, Wedge Tensile Testing*—When applicable, see 6.1.2.3. Headed fasteners shall be wedge tested full size in accordance with Annex A3 of Test Methods and Definitions A370 and shall conform to the tensile strength shown in Table 1. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

TABLE 1 Mechanical Requirements

Class and Grade, Diameter, in [mm]	Heat Treatment	Minimum Tempering Temperature °F [°C]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] (0.2 % offset)	Elongation in 2 in. or 50 mm min, %	Reduction of Area, min, %	Hardness max
Ferritic Steels							
L7, L7A, L7B, L7C, L70, L71, L72, L73			125	105	16	50	321 HBW or 35 HRC
2½ [65] and under ^A	quenched and tempered	1100 [593]	[860]	[725]			
L43			125	105	16	50	321 HBW or 35 HRC
4 [100] and under ^A	quenched and tempered	1100 [593]	[860]	[725]			
L7M			100	80	18	50	235 HBW ^B or 99 HRB
2½ [65] and under ^A	quenched and tempered	1150 [620]	[690]	[550]			
L1			125	105	16	50	...
1 [25] and under ^A	quenched and tempered		[860]	[725]			
Austenitic Steels ^C							
Class 1: B8, B8C, B8M, B8P, B8F, B8T, B8LN, B8MLN, all diameters	carbide solution treated		75 [515]	30 [205]	30	50	223 HBW ^D or 96 HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, B8MLNA, all diameters	carbide solution treated in the finished condition		75 [515]	30 [205]	30	50	192 HBW or 90 HRB
Class 2: B8, B8C, B8P, B8F, B8T:	carbide solution treated and strain hardened						
¾ [20] and under			125 [860]	100 [690]	12	35	321 HBW or 35 HRC
over ¾ to 1 [20 to 25], incl			115 [795]	80 [550]	15	30	321 HBW or 35 HRC
over 1 to 1¼ [25 to 32], incl			105 [725]	65 [450]	20	35	321 HBW or 35 HRC
over 1¼ to 1½ [32 to 40], incl ^A			100 [690]	50 [345]	28	45	321 HBW or 35 HRC
Class 2: B8M:	carbide solution treated and strain hardened						
¾ [20] and under			110 [760]	95 [655]	15	45	321 HBW or 35 HRC
over ¾ to 1 [20 to 25], incl			100 [690]	80 [550]	20	45	321 HBW or 35 HRC
over 1 to 1¼ [25 to 32], incl			95 [655]	65 [450]	25	45	321 HBW or 35 HRC
over 1¼ to 1½ [32 to 40], incl ^A			90 [620]	50 [345]	30	45	321 HBW or 35 HRC

^A These upper diameter limits were established on the basis that these were the largest sizes commonly available that consistently met specification property limits. They are not intended as absolute limits beyond which bolting materials could no longer be certified to the specification.

^B To meet the tensile requirements, the Brinell hardness shall not be less than 200 HBW or 93 HRB.

^C Class 1 products are made from solution-treated material. Class 1A products are solution treated in the finished condition for corrosion resistance; heat treatment is critical for enhancing this physical property and meeting the mechanical property requirements. Class 2 products are made from solution-treated material that has been strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the cross section, particularly in sizes over ¾ in. [20 mm] in diameter.

^D For sizes ¾ in. [20 mm] in diameter and smaller, a maximum hardness of 241 HBW (100 HRB) is permitted.

TABLE 2 Impact Energy Absorption Requirements

Size of Specimen, mm	Minimum Impact Value Required for Average of Each Set of Three Specimens, ft·lbf [J]	Minimum Impact Value Permitted for One Specimen Only of a Set, ft·lbf [J]
All Grades Except L1 ⁴		
10 by 10	20 [27]	15 [20]
10 by 7.5	16 [22]	12 [16]
Grade L1		
10 by 10	40 [54]	30 [41]
10 by 7.5	32 [44]	24 [32]

⁴ See 6.2.1.1 for permitted exemptions.

$$T_s = UTS \times A_s \quad (1)$$

where:

T_s = Wedge tensile strength
 UTS = Tensile strength specified in Table 1, and
 A_s = Stress area, square inches, as shown in ASME B1.1 or calculated as follows:

$$A_s = 0.785 (D - (0.974/n))^2 \quad (2)$$

where:

D = Nominal thread size, and
 n = The number of threads per inch.

6.2 Impact Properties:

6.2.1 Requirements:

6.2.1.1 Impact tests are required for the grades shown in Table 3. Class 1, 1A, and 2 austenitic steels for temperatures above -325 °F [-200 °C]; Class 1 and 1A austenitic Grades B8, B8A, B8P, B8PA, B8C, B8CA, B8LN, and B8LNA above -425 °F [-255 °C]; and ferritic or austenitic bolting ½ in. (12.5 mm) and smaller, are exempt from impact testing, unless Supplementary Requirement S1 is specified in the purchase order (see 1.4). All other material furnished under this specification shall be tested. Material of Grades L7, L7A, L7B, L7C, L7M, L43, L70, L71, L72, and L73 shall show a minimum impact energy absorption of 20 ft · lbf [27 J] and of Grade L1 a minimum impact energy absorption of 40 ft · lbf [54 J] at the test temperature when tested by the procedure specified in the applicable portions of Sections 19 to 28 of Test Methods and Definitions A370. The temperature of the coolant used for chilling the test specimens shall be controlled within ±3 °F [1.5 °C]. Test temperatures for ferritic grades are listed in Table 4. Exceptions to this requirement are permissible, and the impact tests may be made at specified temperatures different than those shown in Table 4, provided the test temperature is at least as low as the intended service temperature and the bolting is suitably marked to identify the reported test temperature. When impact testing is required for austenitic grades, test criteria shall be agreed upon between the supplier and purchaser.

6.2.1.2 The impact test requirements for standard and sub-size Charpy test specimens are prescribed in Table 2.

6.2.2 Number of Tests:

6.2.2.1 The test requirements for heat-treated bars are given in 6.1.2.1.

6.2.2.2 For test requirements on studs, bolts, screws, etc., see 6.1.2.2.

6.2.2.3 Impact tests are not required to be made on heat-treated bars, bolts, screws, studs, and stud bolts ½ in. [12.5 mm] and under in diameter.

6.2.3 *Test Specimens*—For sections 1 in. [25 mm] or less in diameter, test specimens shall be taken at the axis; for sections over 1 in. [25 mm] in diameter, midway between the axis and the surface.

6.3 Hardness Requirements:

6.3.1 The hardness shall conform to the requirements prescribed in Table 1. Hardness testing shall be performed in accordance with either Specification A962/A962M or with Test Methods F606.

6.3.2 The maximum hardness of Grade L7M shall be 235 HBW or 99 HRB (conversion in accordance with Table Number 2B of Test Methods and Definitions A370). Minimum hardness shall not be less than 200 HBW or 93 HRB. Conformance to this hardness shall be ensured by testing each bolt or stud by Brinell or Rockwell B methods in accordance with 6.3.1.

6.3.2.1 The use of 100 % electromagnetic testing for hardness as an alternative to 100 % indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100 % examined in accordance with Practice E566. Following electromagnetic testing for hardness, a random sample of a minimum of 100 pieces in each purchase lot (as defined in 6.1.2.2) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled, or tested 100 % by indentation hardness methods.

6.3.2.2 In the event a controversy exists relative to minimum strength, tension tests shall prevail over hardness readings. Products which have been tested and found acceptable shall have a line under the grade symbol.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 3.

8. Workmanship, Finish, and Appearance

8.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish.

9. Retests

9.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests and one additional impact test consisting of three specimens shall be made from such lot, all of which shall conform to the requirements specified.

10. Nuts and Washers

10.1 Bolts, studs, and stud bolts of Grades L7, L7A, L7B, L7C, L43, L1, L70, L71, L72, and L73 shall be equipped with

TABLE 3 Chemical Requirements (Composition, %)^A

Type	Ferritic Steels											
Grade Symbol	L7, L7M, L70		L7A, L71		L7B, L72		L7C, L73		L43		L1	
Description . . .	Chromium-Molybdenum ^B		Carbon-Molybdenum (AISI 4037)		Chromium-Molybdenum (AISI 4137)		Nickel-Chromium-Molybdenum (AISI 8740)		Nickel-Chromium-Molybdenum (AISI 4340)		Low-Carbon Boron	
	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under
Carbon	0.38–0.48 ^C	0.02	0.35–0.40	0.02	0.35–0.40	0.02	0.38–0.43	0.02	0.38–0.43	0.02	0.17–0.24	0.01
Manganese	0.75–1.00	0.04	0.70–0.90	0.03	0.70–0.90	0.03	0.75–1.00	0.04	0.60–0.85	0.03	0.70–1.40	0.04
Phosphorus, max	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.050	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.30	0.02
Nickel	...	...	...	...	...	...	0.40–0.70	0.03	1.65–2.00	0.05	...	...
Chromium	0.80–1.10	0.05	...	...	0.80–1.10	0.05	0.40–0.60	0.03	0.70–0.90	0.03	...	...
Molybdenum	0.15–0.25	0.02	0.20–0.30	0.02	0.15–0.25	0.02	0.20–0.30	0.02	0.20–0.30	0.02	...	...
Boron	...	...	...	...	...	...	...	...	...	...	0.001–0.003	...
Type	Austenitic Steels, Classes 1, 1A, and 2 ^D											
Grade Symbol	B8, B8A						B8C, B8CA					
UNS Designation	S 30400(304)						S 34700(347)					
	Range, %		Product Variation, % Over or Under		Range, %		Product Variation, % Over or Under		Range, %		Product Variation, % Over or Under	
Carbon, max	0.08		0.01 over		0.08		0.01 over		0.08		0.01 over	
Manganese, max	2.00		0.04 over		2.00		0.04 over		2.00		0.04 over	
Phosphorus, max	0.045		0.010 over		0.045		0.010 over		0.045		0.010 over	
Sulfur, max	0.030		0.005 over		0.030		0.005 over		0.030		0.005 over	
Silicon, max	1.00		0.05 over		1.00		0.05 over		1.00		0.05 over	
Nickel	8.0–11.0		0.15		9.0–12.0		0.15		9.0–12.0		0.15	
Chromium	18.0–20.0		0.20		17.0–19.0		0.20		17.0–19.0		0.20	
Columbium + Tantalum	...		...		10 × carbon content, min. –1.10 max		...		10 × carbon content, min. –1.10 max		0.05 under	
Type	Austenitic Steels, Classes 1, 1A, and 2 ^D											
Grade Symbol	B8T, B8TA			B8P, B8PA			B8F, B8FA			B8M, B8MA		
UNS Designation	S 32100(321)			S 30500			S 30300(303)			S 30323(303Se)		
	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.15	0.01 over	0.15	0.01 over	0.08	0.01 over	0.08	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.20	0.010 over	0.20	0.010 over	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030, max	0.005 over	0.030, max	0.005 over	0.15, min	0.020	0.06, max	0.010 over	0.030, max	0.005 over	0.030, max	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Nickel	9.0–12.0	0.15	10.5–13.0	0.15	8.0–10.0	0.10	8.0–10.0	0.10	10.0–14.0	0.15	10.0–14.0	0.15
Chromium	17.0–19.0	0.20	17.0–19.0	0.20	17.0–19.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	16.0–18.0	0.20
Molybdenum	...	...	...	...	...	...	...	...	2.00–3.00	0.10	2.00–3.00	0.10
Selenium	...	...	...	...	...	...	0.15–0.35	0.03 under	...	...	...	...
Titanium	5 × carbon content, min	0.05 under	...	...	...	...	...	...	...	...	...	...
Nitrogen	0.10, max	0.01	...	...	...	...	...	...	...	...	...	...
Type	Austenitic Steels, Classes 1 and 1A											
Grade Symbol	B8LN, B8LNA						B8MLN, B8MLNA					
UNS Designation	S 30453						S 31653					
	Range, %		Product Variation, % Over or Under		Range, %		Product Variation, % Over or Under		Range, %		Product Variation, % Over or Under	
Carbon, max	0.030		0.005 over		0.030		0.005 over		0.030		0.005 over	
Manganese, max	2.00		0.04 over		2.00		0.04 over		2.00		0.04 over	

TABLE 3 Continued

Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over
Nickel	8.0–10.5	0.15	10.0–14.0	0.15
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Molybdenum	...	...	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

^A The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grade B8F, in which selenium is specified and required.

^B Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

^C For the L7M grade, a minimum carbon content of 0.28 % is permitted provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

^D Class 1 are made from solution-treated material. Class 1A products (B8A, B8CA, B8MA, B8PA, B8FA, and B8TA) are solution-treated in the finished condition. Class 2 products are solution-treated and strain-hardened.

TABLE 4 Recommended Test Temperature for Stock Parts

Grade	Test Temperature	
	°F	°C
L7M, L70, L71, L72, L73	–100	–73
L7, L7A, L7B, L7C	–150	–101
L43	–150	–101
L1	–100	–73

ferritic alloy nuts conforming to Grade 4 or Grade 7 of Specification A194/A194M or a grade of steel similar to the studs. Grade 7M nuts at a hardness not exceeding 235 HBW (or equivalent) shall be used with Grade L7M bolts, studs, and stud bolts. All nut materials, including those which may be supplied under Specification A194/A194M, shall be subject to the impact requirements of this specification in the following manner: impact tests shall be made on test specimens taken from the bar or plate from the heat of steel used for manufacturing the nuts, and heat treated with the nut blanks.

10.2 Bolts, studs, and stud bolts of Grades B8, B8C, B8T, B8P, B8F, B8M, B8LN, and B8MLN shall be equipped with austenitic alloy nuts conforming to Grades 8, 8C, 8T, 8F, 8M, 8LN, and 8MLN for Specification A194/A194M. Impact tests are not required for Grades 8F, 8M, 8T, and 8MLN for temperatures above –325 °F [–200 °C] and for Grades 8, 8P, 8C, and 8LN above –425 °F [–255 °C].

10.3 If the purchaser requires nuts with a Charpy impact energy absorption of not less than 20 ft · lbf [27 J] at temperatures below –150 °F [–100 °C], he may require that the nuts conform to Grades 8, 8C, 8M, 8P, 8T, 8F, 8LN, or 8MLN of Specification A194/A194M.

10.4 Washers for use with ferritic steel bolting shall conform to Specification F436.

10.5 Washers for use with austenitic steel bolting shall be made of austenitic steel as agreed upon between the manufacturer and purchaser.

10.6 Washer dimensions shall be in accordance with requirements of ASME B18.22.1, unless otherwise specified in the purchase order.

11. Threads

11.1 Where practical, all threads shall be formed after heat treatment. Class 1A, Grades B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA are to be solution-treated in the finished condition.

12. Certification

12.1 Certification is required. See Specification A962/A962M.

13. Product Marking

13.1 In addition to the requirements of Specification A962/A962M, the grade symbol marked shall be as shown in Table 3. In the case of Class 2, Grades B8, B8C, B8M, B8P, B8F, and B8T strain hardened as provided in Table 1, a line shall be stamped under the grade symbol in order to distinguish it from Class 1 and Class 1A bolting which has not been strain hardened. In the case of Class 1A, the marking B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA identifies the material as being in the solution-treated condition in the finished state. Grade L7M shall be 100 % evaluated in conformance with this specification and shall have a line under the grade symbol.

13.2 Nuts from materials that have been impact tested shall be marked with the letter “L.”

14. Keywords

14.1 additional elements; austenitic stainless steel; bolts—steel; chromium-molybdenum steel; fasteners—steel; markings on fittings; nickel-chromium-molybdenum alloy steel; pressure vessel service; stainless steel bolting; starting material; steel bars—alloy; steel bolting; steel flanges; steel valves; temperature service applications—low

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Impact Properties

S1.1 When impact properties are desired for austenitic steel grades exempt from testing under 6.2.1, test shall be made as agreed between the manufacturer and the purchaser.

S2. Lateral Expansion

S2.1 When lateral expansion measurements for ferritic steels are required in addition to the energy absorption requirements of 6.2.1.1, the minimum value for each specimen of a set must be .015 in. [0.38 mm]. The test temperature shall be specified by the purchaser and agreed upon by the producer.

NOTE S2.1—Grades L7, L7A, L7B will generally have difficulty meeting the minimum value at $-150\text{ }^{\circ}\text{F}$ [$-101\text{ }^{\circ}\text{C}$]. Grade L43 may be preferred.

S3. Hardness Testing of Class 2 Bolting for ASME Applications

S3.1 The maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least $\frac{1}{8}$ in. [3 mm] across, prepared by removing threads. No more material than necessary shall be removed to prepare the flat area. Hardness determinations shall be made at the same frequency as tensile tests.

S4. Restriction to Use Only Ingot Cast Steel

S4.1 The starting material must be ingot cast. Use of continuous cast material is not permitted.

APPENDIX

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the

greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener, so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

SPECIFICATION FOR STRUCTURAL BOLTS, STEEL, HEAT TREATED, 120/105 ksi MINIMUM TENSILE STRENGTH



SA-325

(Identical with ASTM Specification A325-10 except for the deletion of the term “private label distributor” in 15.1 and 15.5.)

Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

1. Scope

1.1 This specification covers two types of quenched and tempered steel heavy hex structural bolts having a minimum tensile strength of 120 ksi for sizes 1.0 in. and less and 105 ksi for sizes over 1.0 to 1½ in., inclusive.

1.2 The bolts are intended for use in structural connections. These connections are covered under the requirements of the Specification for Structural Joints Using ASTM A325 or A490 Bolts, approved by the Research Council on Structural Connections, endorsed by the American Institute of Steel Construction and by the Industrial Fastener Institute.

1.3 The bolts are furnished in sizes ½ to 1½ in., inclusive. They are designated by type, denoting chemical composition as follows:

Type	Description
Type 1	Medium carbon, carbon boron, or medium carbon alloy steel.
Type 2	Withdrawn in November 1991.
Type 3	Weathering steel.

NOTE 1—Bolts for general applications, including anchor bolts, are covered by Specification A449. Also refer to Specification A449 for quenched and tempered steel bolts and studs with diameters greater than 1½ in. but with similar mechanical properties.

1.4 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

NOTE 2—A complete metric companion to Specification A325 has been developed, Specification A325M; therefore, no metric equivalents are presented in this specification.

1.5 This specification is applicable to heavy hex structural bolts only. For bolts of other configurations and thread lengths with similar mechanical properties, see Specification A449.

1.6 Terms used in this specification are defined in Terminology F1789.

1.7 The following safety hazard caveat pertains only to the test methods portion, Section 10, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A194/A194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- A325M Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength (Metric)
- A449 Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
- A490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
- A563 Specification for Carbon and Alloy Steel Nuts
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- D3951 Practice for Commercial Packaging
- F436 Specification for Hardened Steel Washers
- F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners,

Washers, Direct Tension Indicators, and Rivets
 F788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
 F959 Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners
 F1136 Specification for Zinc/Aluminum Corrosion Protective Coatings for Fasteners
 F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
 F1789 Terminology for F16 Mechanical Fasteners
 F2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners
 G101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 ASME Standards:

B 1.1 Unified Screw Threads
 B 18.2.6 Fasteners for Use in Structural Applications
 B 18.24 Part Identification Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for heavy hex structural bolts under this specification shall include the following:

- 3.1.1 Quantity (number of pieces of bolts and accessories).
- 3.1.2 Size, including nominal bolt diameter, thread pitch, and bolt length.
- 3.1.3 Name of product, heavy hex structural bolts.
- 3.1.4 When bolts threaded full length are required, Supplementary Requirement S1 shall be specified.
- 3.1.5 Type of bolt: Type 1 or 3. When type is not specified, either Type 1 or Type 3 shall be furnished at the supplier's option.
- 3.1.6 ASTM designation and year of issue.
- 3.1.7 Other components such as nuts, washers, and compressible washer-type direct-tension indicators, if required.
 - 3.1.7.1 When such other components are specified to be furnished, also state "Nuts, washers, and direct tension indicators, or combination thereof, shall be furnished by lot number."
- 3.1.8 *Zinc Coating*—Specify the zinc coating process required, for example, hot dip, mechanically deposited, Zinc/Aluminum Corrosion Protective Coating or no preference (see 4.3).
- 3.1.9 *Other Finishes*—Specify other protective finish, if required.
- 3.1.10 Test reports, if required (see Section 13).
- 3.1.11 Supplementary or special requirements, if required.
- 3.1.12 For establishment of a part identifying system, see ASME B18.24.

NOTE 3—A typical ordering description follows: 1000 pieces 1 $\frac{1}{8}$ -7 UNC in. dia \times 4 in. long heavy hex structural bolt, Type 1 ASTM A325-02, each with one hardened washer, ASTM F436 Type 1, and one heavy hex nut, ASTM A563 Grade DH. Each component hot-dip zinc-coated. Nuts lubricated.

3.2 Recommended Nuts:

3.2.1 Nuts conforming to the requirements of Specification A563 are the recommended nuts for use with Specification A325 heavy hex structural bolts. The nuts shall be of the class and have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Nut Class and Finish
1, plain (noncoated)	A563-C, C3, D, DH, DH3, plain
1, zinc coated	A563-DH, zinc coated
1, coated in accordance with Specification F1136, Grade 3	A563-DH coated in accordance with Specification F1136, Grade 5
3, plain	A563-C3, DH3, plain

3.2.2 Alternatively, nuts conforming to Specification A194/A194M Gr. 2H are considered a suitable substitute for use with Specification A325 Type 1 heavy hex structural bolts.

3.2.3 When Specification A194/A194M Gr. 2H zinc-coated nuts are supplied, the zinc coating, overtapping, lubrication, and rotational capacity testing shall be in accordance with Specification A563.

3.3 Recommended Washers:

3.3.1 Washers conforming to Specification F436 are the recommended washers for use with Specification A325 heavy hex structural bolts. The washers shall have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Washer Finish
1, plain (uncoated)	plain (uncoated)
1, zinc coated	zinc coated
1, coated in accordance with Specification F1136, Grade 3	coated in accordance with Specification F1136, Grade 3
3, plain	weathering steel, plain

3.4 Other Accessories:

3.4.1 When compressible washer type direct tension indicators are specified to be used with these bolts, they shall conform to Specification F959, Type 325.

4. Materials and Manufacture

4.1 Heat Treatment:

4.1.1 Type 1 bolts produced from medium carbon steel shall be quenched in a liquid medium from the austenitizing temperature. Type 1 bolts produced from medium carbon steel to which chromium, nickel, molybdenum, or boron were intentionally added shall be quenched only in oil from the austenitizing temperature.

4.1.2 Type 3 bolts shall be quenched only in oil from the austenitizing temperature.

4.1.3 Type 1 bolts, regardless of the steel used, and Type 3 bolts shall be tempered by reheating to not less than 800°F.

4.2 *Threading*—Threads shall be cut or rolled.

4.3 *Zinc Coatings, Hot-Dip and Mechanically Deposited, Zinc/Aluminum Corrosion Protective Coating:*

4.3.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot

dip, mechanically deposited, Zinc/Aluminum Corrosion Protective Coating, or no preference.

4.3.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process and the coating shall conform to the coating weight/thickness and performance requirements of Specification F2329.

4.3.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical deposition process and the coating shall conform to the coating weight/thickness and performance requirements of Class 55 of Specification B695.

4.3.4 When Zinc/Aluminum Corrosion Protective Coating is specified, the coating shall conform to the coating weight/thickness and performance requirements of Grade 3 of Specification F1136.

4.3.5 When no preference is specified, the supplier shall furnish either a hot-dip zinc coating in accordance with Specification F2329, a mechanically deposited zinc coating in accordance with Specification B695, Class 55, or a Zinc/Aluminum Corrosion Protective Coating in accordance with Specification F1136, Grade 3. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

4.4 *Lubrication*—When zinc-coated nuts are ordered with the bolts, the nuts shall be lubricated in accordance with Specification A563, Supplementary Requirement S1, to minimize galling.

4.5 *Secondary Processing:*

4.5.1 If any processing, which can affect the mechanical properties or performance of the bolts, is performed after the initial testing, the bolts shall be retested for all specified mechanical properties and performance requirements affected by the reprocessing.

4.5.2 When the secondary process is heat treatment, the bolts shall be tested for all specified mechanical properties. Hot dip zinc-coated bolts shall be tested for all specified mechanical properties and rotational capacity. If zinc-coated nuts are relubricated after the initial rotational capacity tests, the assemblies shall be retested for rotational capacity.

5. Chemical Composition

5.1 Type 1 bolts shall be plain carbon steel, carbon boron steel, alloy steel or alloy boron steel at the manufacturer's option, conforming to the chemical composition specified in Table 1.

5.2 Type 3 bolts shall be weathering steel and shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition, A, B, C, D, E, or F, shall be at the option of the bolt manufacturer. See Guide G101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Product analyses made on finished bolts representing each lot shall conform to the product analysis requirements specified in Tables 1 and 2, as applicable.

TABLE 1 Chemical Requirements for Type 1 Bolts

Element	Carbon Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.15–0.30	0.13–0.32

Element	Carbon Boron Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.10–0.30	0.08–0.32
Boron	0.0005–0.003	0.0005–0.003

Element	Alloy Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Alloying Elements	A	A

Element	Alloy Boron Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Boron	0.0005–0.003	0.0005–0.003
Alloying Elements	A	A

^A Steel, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: Manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 % or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

5.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts.

5.5 Compliance with 5.4 shall be based on certification that heats of steel having any of the listed elements intentionally added were not used to produce the bolts.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A751.

6. Mechanical Properties

6.1 *Hardness*—The bolts shall conform to the hardness specified in Table 3.

6.2 *Tensile Properties:*

6.2.1 Except as permitted in 6.2.1.1 for long bolts and 6.2.1.2 for short bolts, sizes 1.00 in. and smaller having a nominal length of $2\frac{1}{4}D$ and longer, and sizes larger than 1.00

TABLE 2 Chemical Requirements for Type 3 Heavy Hex Structural Bolts^A

Element	Composition, %					
	Type 3 Bolts ^A					
	A	B	C	D	E	F
Carbon:						
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25
Product analysis	0.31–0.42	0.36–0.50	0.14–0.26	0.14–0.26	0.18–0.27	0.19–0.26
Manganese:						
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24
Phosphorus:						
Heat analysis	0.035 max	0.06–0.12	0.035 max	0.035 max	0.035 max	0.035 max
Product analysis	0.040 max	0.06–0.125	0.040 max	0.040 max	0.040 max	0.040 max
Sulfur:						
Heat analysis	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max
Product analysis	0.045 max	0.045 max	0.045 max	0.045 max	0.045 max	0.045 max
Silicon:						
Heat analysis	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35
Product analysis	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37
Copper:						
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43
Nickel:						
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43
Chromium:						
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65
Product analysis	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68
Vanadium:						
Heat analysis	^B	^B	0.020 min	^B	^B	^B
Product analysis	^B	^B	0.010 min	^B	^B	^B
Molybdenum:						
Heat analysis	^B	0.06 max	^B	0.10 max	^B	^B
Product analysis	^B	0.07 max	^B	0.11 max	^B	^B
Titanium:						
Heat analysis	^B	^B	^B	0.05 max	^B	^B
Product analysis	^B	^B	^B	0.06 max	^B	^B

^A A, B, C, D, E, and F are classes of material used for Type 3 bolts. Selection of a class shall be at the option of the bolt manufacturer.

^B These elements are not specified or required.

TABLE 3 Hardness Requirements for Bolts

Bolt Size in.	Nominal Length in.	Brinell		Rockwell C	
		Min	Max	Min	Max
½ to 1, incl	Less than 2D	253	319	25	34
	2D and over	...	319	...	34
1⅛ to 1½, incl	Less than 3D	223	286	19	30
	3D and over	...	286	...	30

D = Nominal diameter or thread size.

in. having a nominal length of 3*D* and longer, shall be wedge tested full size and shall conform to the minimum wedge tensile load and proof load or alternative proof load specified in Table 4. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

6.2.1.1 When the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 5. When bolts are tested by both full-size and machined specimen methods, the full-size test shall take precedence.

6.2.1.2 Sizes 1.00 in. and smaller having a nominal length shorter than 2¼*D* down to 2*D*, inclusive, that cannot be wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load or alternate proof load specified in Table 4. Sizes 1.00 in. and smaller having a nominal length shorter than 2*D* and sizes larger than 1.00 in. with nominal lengths shorter than 3*D* that cannot be axially tensile tested shall be qualified on the basis of hardness.

6.2.2 For bolts on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

6.3 Rotational Capacity Test:

TABLE 4 Tensile Load Requirements for Bolts Tested Full-Size

Bolt Size, Threads per Inch, and Series Designation	Stress Area, ^A in.	Tensile Load, ^B min, lbf	Proof Load, ^B Length Measurement Method	Alternative Proof Load, ^B Yield Strength Method
Column 1	Column 2	Column 3	Column 4	Column 5
½–13 UNC	0.142	17 050	12 050	13 050
⅝–11 UNC	0.226	27 100	19 200	20 800
¾–10 UNC	0.334	40 100	28 400	30 700
⅞–9 UNC	0.462	55 450	39 250	42 500
1–8 UNC	0.606	72 700	51 500	55 750
1½–7 UNC	0.763	80 100	56 450	61 800
1¼–7 UNC	0.969	101 700	71 700	78 500
1⅝–6 UNC	1.155	121 300	85 450	93 550
1½–6 UNC	1.405	147 500	104 000	113 800

^A The stress area is calculated as follows:

$$A_s = 0.7854 [D - (0.9743/n)]^2$$

where:

A_s = stress area, in.²,
 D = nominal bolt size, and
 n = threads per inch.

^B Loads tabulated are based on the following:

Bolt Size, in.	Column 3	Column 4	Column 5
½ to 1, incl	120 000 psi	85 000 psi	92 000 psi
1½ to 1½, incl	105 000 psi	74 000 psi	81 000 psi

6.3.1 *Definition*—The rotational capacity test is intended to evaluate the presence of a lubricant, the efficiency of the lubricant, and the compatibility of assemblies as represented by the components selected for testing.

6.3.2 *Requirement*—Zinc-coated bolts, zinc-coated washers, and zinc-coated and lubricated nuts tested full size in an assembled joint or tension measuring device, in accordance with 10.2, shall not show signs of failure when subjected to the nut rotation in Table 6. The test shall be performed by the responsible party (see Section 14) prior to shipment after zinc coating and lubrication of nuts (see 10.2 and Note 4).

6.3.3 *Acceptance Criterion*—The bolt and nut assembly shall be considered as non-conforming if the assembly fails to pass any one of the following specified requirements:

6.3.3.1 Inability to install the assembly to the nut rotation in Table 6.

6.3.3.2 Inability to remove the nut after installing to the rotation specified in Table 6.

6.3.3.3 Shear failure of the threads as determined by visual examination of bolt and nut threads following removal.

6.3.3.4 Torsional or torsional/tension failure of the bolt. Elongation of the bolt, in the threads between the nut and bolt head, is to be expected at the required rotation and is not to be classified as a failure.

7. Dimensions

7.1 Head and Body:

7.1.1 The bolts shall conform to the dimensions for heavy hex structural bolts specified in ASME B18.2.6.

7.1.2 The thread length shall not be changed except as provided in Supplementary Requirement S1. Bolts with thread lengths other than those required by this specification shall be ordered under Specification A449.

7.2 Threads:

7.2.1 *Uncoated*—Threads shall be the Unified Coarse Thread Series as specified in ASME B1.1, and shall have Class 2A tolerances.

7.2.2 *Coated*—Unless otherwise specified, zinc-coated bolts to be used with zinc-coated nuts or tapped holes that are tapped oversize, in accordance with Specification A563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating, the maximum limits of pitch and major diameter shall not exceed the Class 2A limit by more than the following amounts:

Nominal Bolt Diameter (in.)	Oversize Limit, in. ^A	
	Hot-Dip Zinc	Mechanical Zinc
½	0.018	0.012
⅝, ¾, ¾	0.020	0.013
⅞	0.022	0.015
1 to 1¼	0.024	0.016
1⅝, 1½	0.027	0.018

^A Hot-dip zinc nuts are tapped oversize after coating, and mechanical zinc-coated nuts are tapped oversize before coating.

7.2.3 The gaging limit for bolts shall be verified during manufacture. In case of dispute, a calibrated thread ring gage of the same size as the oversize limit in 7.2.2 (Class X tolerance, gage tolerance plus) shall be used to verify compliance. The gage shall assemble with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve controversy, shall be conducted at the frequency specified in the quality assurance provisions of ASME B18.2.6.

8. Workmanship

8.1 The allowable limits, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F788/F788M.

9. Number of Tests and Retests

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.5.

9.1.2 When bolts are furnished by a source other than the manufacturer, the Responsible Party as defined in 14 shall be responsible for assuring all tests have been performed and the bolts comply with the requirements of this specification (see 4.5).

9.2 *Purpose of Lot Inspection*—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors,

TABLE 5 Tensile Strength Requirements for Specimens Machined from Bolts

Bolt Diameter, in.	Tensile Strength, min, psi (MPa)	Yield Strength, min, psi (MPa)	Elongation, in 4D, min, %	Reduction of Area, min, %
½ to 1, incl.	120 000 (825)	92 000 (635)	14	35
Over 1 to 1½	105 000 (725)	81 000 (560)	14	35 [†]

[†] Table alignment was editorially corrected in March 2010

TABLE 6 Rotational Capacity Test for Zinc-Coated Bolts

Nominal Length in.	Nominal Nut Rotation, degrees (turn)
Up to and including 4 × dia	240 (⅔)
Over 4 × dia, but not exceeding 8 × dia	360 (1)
Over 8 × dia, but not exceeding 12 × dia	420 (1⅓)
Over 12 × dia.	Test not applicable

and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 Lot Method—All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 Lot Definition—A lot shall be a quantity of uniquely identified heavy hex structural bolts of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same process, in the same manner so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

9.5 Number of Tests—The minimum number of tests from each lot for the tests specified below shall be as follows:

Tests	Number of Tests in Accordance With
Hardness, tensile strength, proof load, and rotational capacity	Practice F1470
Coating weight/thickness	The referenced coating specification ^A
Surface discontinuities	Specification F788/F788M
Dimensions and thread fit	ASME B18.2.6

^A Practice F1470 applies if the coating specification does not specify a testing frequency.

10. Test Methods

10.1 Tensile, Proof Load, and Hardness:

10.1.1 Tensile, proof load, and hardness tests shall be conducted in accordance with Test Methods F606.

10.1.2 Tensile strength shall be determined using the Wedge or Axial Tension Testing Method of Full Size Product Method or the Machined Test Specimens Method depending on size and nominal length as specified in 6.2.1-6.2.2. Fracture on full-size tests shall be in the body or threads of the bolt without a fracture at the junction of the head and body.

10.1.3 Proof load shall be determined using Method 1, Length Measurement, or Method 2, Yield Strength, at the option of the manufacturer.

10.2 Rotational Capacity—The zinc-coated bolt shall be placed in a steel joint or tension measuring device and assembled with a zinc-coated washer and a zinc-coated and lubricated nut with which the bolt is intended to be used (see Note 4). The nut shall have been provided with the lubricant described in the last paragraph of the Manufacturing Processes section of Specification A563. The joint shall be one or more flat structural steel plates or fixture stack up with a total thickness, including the washer, such that 3 to 5 full threads of the bolt are located between the bearing surfaces of the bolt head and nut. The hole in the joint shall have the same nominal diameter as the hole in the washer. The initial tightening of the nut shall produce a load in the bolt not less than 10 % of the specified proof load. After initial tightening, the nut position shall be marked relative to the bolt, and the rotation shown in Table 6 shall be applied. During rotation, the bolt head shall be restrained from turning. After the tightening rotation has been applied, the assembly shall be taken apart and examined for compliance with 6.3.3.

NOTE 4—Rotational capacity tests shall apply only to matched assembly lots that contain one A325 bolt, one A563 lubricated nut, and one F436 washer that have been zinc coated in accordance with either Specifications F2329 or B695. Both the bolt and nut components of the matched assembly shall be zinc coated using the same process.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

11.2 The purchaser's representative shall have free entry to all parts of the manufacturer's works, or supplier's place of business, that concern the manufacture or supply of the material ordered. The manufacturer or supplier shall afford the purchaser's representative all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to

interfere unnecessarily with the operation of the manufacturer's works or supplier's place of business.

12. Rejection and Rehearing

12.1 Disposition of nonconforming bolts shall be in accordance with the Practice F1470 section titled "Disposition of Nonconforming Lots."

13. Certification

13.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 14, shall furnish the purchaser a test report that includes the following:

13.1.1 Heat analysis, heat number, and a statement certifying that heats having the elements listed in 5.4 intentionally added were not used to produce the bolts,

13.1.2 Results of hardness, tensile, and proof load tests,

13.1.3 Results of rotational capacity tests. This shall include the test method used (solid plate or tension measuring device); and the statement "Nuts lubricated" for zinc-coated nuts when shipped with zinc-coated bolts,

13.1.4 Zinc coating measured coating weight/thickness for coated bolts,

13.1.5 Statement of compliance of visual inspection for surface discontinuities (Section 8),

13.1.6 Statement of compliance with dimensional and thread fit requirements,

13.1.7 Lot number and purchase order number,

13.1.8 Complete mailing address of responsible party, and

13.1.9 Title and signature of the individual assigned certification responsibility by the company officers.

13.2 Failure to include all the required information on the test report shall be cause for rejection.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

15. Product Marking

15.1 *Manufacturer's Identification*—All Type 1 and 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer.

15.2 *Grade Identification:*

15.2.1 Type 1 bolts shall be marked "A325."

15.2.2 Type 3 bolts shall be marked "A325" with the "A325" underlined. The use of additional distinguishing marks to indicate that the bolts are weathering steel shall be at the manufacturer's option.

15.3 *Marking Location and Methods*—All marking shall be located on the top of the bolt head and shall be either raised or depressed at the manufacturer's option.

15.4 *Acceptance Criteria*—Bolts which are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

15.5 Type and manufacturer's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

16. Packaging and Package Marking

16.1 *Packaging:*

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D3951.

16.1.2 When zinc coated nuts are included on the same order as zinc coated bolts, the bolts and nuts shall be shipped in the same container.

16.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 *Package Marking:*

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and type,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Lot number; when nuts, washers or direct tension indicators, or combination thereof, are ordered with A325 heavy hex structural bolts, the shipping unit shall be marked with the lot number in addition to the marking required by the applicable product specification,

16.2.1.6 Purchase order number, and

16.2.1.7 Country of origin.

17. Keywords

17.1 bolts; carbon steel; steel; structural; weathering steel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Bolts Threaded Full Length

S1.1 Bolts with nominal lengths equal to or shorter than four times the nominal bolt diameter shall be threaded full length. Bolts need not have a shoulder, and the distance from the underhead bearing surface to the first complete (full form) thread, as measured with a GO thread ring gage, assembled by

hand as far as the thread will permit, shall not exceed the length of $2\frac{1}{2}$ threads for bolt sizes 1 in. and smaller, and $3\frac{1}{2}$ threads for bolt sizes larger than 1 in.

S1.2 Bolts shall be marked in accordance with Section 15, except that the symbol shall be “A325 T” instead of “A325.”

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SPECIFICATION FOR SEAMLESS AND WELDED STEEL PIPE FOR LOW-TEMPERATURE SERVICE AND OTHER APPLICATIONS WITH REQUIRED NOTCH TOUGHNESS



SA-333/SA-333M



(Identical with ASTM Specification A333/A333M-16.)

Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness

1. Scope

1.1 This specification covers nominal (average) wall seamless and welded carbon and alloy steel pipe intended for use at low temperatures and in other applications requiring notch toughness. Several grades of ferritic steel are included as listed in Table 1. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse effect on impact properties.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 ASTM Standards:

A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe
A671 Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
E23 Test Methods for Notched Bar Impact Testing of Metallic Materials

E165 Practice for Liquid Penetrant Examination for General Industry

E709 Guide for Magnetic Particle Testing

2.2 ASME Boiler and Pressure Vessel Code:

Section VIII

Section IX

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (seamless or welded pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (NPS or outside diameter and schedule number of average wall thickness),

3.1.5 Lengths (specific or random) (Section 9), (see the Permissible Variations in Length section of Specification A999/A999M),

3.1.6 End finish (see the Ends section of Specification A999/A999M),

3.1.7 Optional requirements, (see the Heat Analysis requirement in the Chemical Composition section of A999/A999M, the Repair by Welding section, and the section on Nondestructive Test Requirements),

3.1.8 Test report required, (see the Certification section of Specification A999/A999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

3.1.11 Supplementary requirements, if any (subsize impact specimens, pipe for hydrofluoric acid alkylation service).

4. Materials and Manufacture

4.1 *Manufacture*—Except as provided in paragraph 4.2, the pipe shall be made by the seamless or welding process with the

TABLE 1 Chemical Requirements^B

Element	Composition, %								
	Grade 1	Grade 3	Grade 4	Grade 6	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11
Carbon, max	0.30	0.19	0.12	0.30	0.19	0.13	0.20	0.20	0.10
Manganese	0.40–1.06 ^A	0.31–0.64	0.50–1.05	0.29–1.06 ^A	0.90 max	0.90 max	0.40–1.06	1.15–1.50	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.035	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015	0.025
Silicon	...	0.18–0.37	0.08–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.10–0.35	0.35 max
Nickel	...	3.18–3.82	0.47–0.98	0.40 max	2.03–2.57	8.40–9.60	1.60–2.24	0.25 max	35.0–37.0
Chromium	...	...	0.44–1.01	0.30 max	...	...	...	0.15 max	0.50 max
Copper	...	...	0.40–0.75	0.40 max	...	...	0.75–1.25	0.15 max	...
Aluminum	...	...	0.04–0.30	...	...	...	...	0.06 max	...
Vanadium, max	...	...	...	0.08	...	...	...	0.12	...
Columbium, max	...	...	...	0.02 ^C	...	...	...	0.05	...
Molybdenum, max	...	...	...	0.12	...	...	...	0.05	0.50 max
Cobalt	...	...	...	...	...	...	...	...	0.50 max

^A For each reduction of 0.01 % carbon below 0.30 %, an increase of 0.05 % manganese above 1.06 % would be permitted to a maximum of 1.35 % manganese.

^B Where an ellipsis (...) appears in this table, there is no requirement and analysis for the element need not to be determined or reported.

^C By agreement between the manufacturer and the purchaser, the limit for columbium may be increased up to 0.05 % on heat analysis and 0.06 % on product analysis.

addition of no filler metal in the welding operation. Grade 4 shall be made by the seamless process.

NOTE 2—For electric-fusion-welded pipe, with filler metal added, fabricated of pressure vessel quality plates, see Specification A671.

4.2 Grade 11 pipe may be produced by welding with or without the addition of filler metal. The following requirements shall apply for Grade 11 welded with the addition of filler metal.

4.2.1 The joints shall be full-penetration, full fusion double-welded or single-welded butt joints employing fusion welding processes as defined in “Definitions,” ASME Boiler and Pressure Vessel Code, Section IX. This specification makes no provision for any difference in weld quality requirements regardless of the weld joint type employed (single or double) in making the weld. Where backing strips are employed, the ring or strip material shall be the same as the plate being joined. Backing rings or strips shall be completely removed after welding, prior to any required radiography, and the exposed weld surface shall be examined visually for conformance to the requirements of 4.2.2. Welds made by procedures employing backing strips or rings which remain in place are prohibited. Welding procedures and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

4.2.2 The weld surface on either side of the weld may be flush with the base plate or may have a reasonably uniform crown, not to exceed 1/8 in. [3 mm]. Any weld reinforcement may be removed at the manufacturer’s option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be reasonably smooth and free from irregularities. The deposited metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

4.2.3 *Radiographic Examination*—All welded joints shall be fully radiographed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition, paragraph UW-51.

4.2.3.1 As an alternative, the welded joints may be ultrasonically examined in accordance with Appendix 12 of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

4.2.4 *Repair Welding*—Weld metal defects shall be repaired by removal to sound metal and repair welding if approved by the purchaser.

4.2.4.1 The repair shall be blended smoothly into the surrounding base metal surface and examined by the magnetic particle examination in accordance with Practice E709, or by the liquid penetrant method in accordance with Practice E165.

4.2.4.2 Each repair weld of a cavity where the cavity, before repair welding, has a depth exceeding the lesser of 3/8 in. [9.5 mm] or 10.5 % of the nominal thickness shall be radiographically examined as required for the original welds.

4.2.5 *Transverse Tension Test*—One test shall be made to represent each lot (Note 3) of finished pipe. The test specimens shall be taken across the welded joint. The tension test results of the welded joints shall conform to the tensile properties for Grade 11 in Table 2.

4.2.5.1 The test specimens shall be taken from the end of the finished pipe. As an alternative, the tension test specimens may be taken from a welded prolongation of the same material as the pipe, which is attached to the end of the pipe and welded as a prolongation of the pipe longitudinal seam.

4.2.5.2 The test specimens shall be in accordance with Section IX, Part QW, paragraph QW-150 of the ASME Boiler and Pressure Vessel Code and shall be one of the types shown in QW-462.1 of that code. The tension test specimen may be flattened cold before final machining to size.

4.2.6 *Transverse Guided-Bend Weld Test*—One transverse guided bend test (two specimens) shall be made to represent each lot (Note 3) of finished pipe.

4.2.6.1 The two bend test specimens shall be taken from the weld at the end of the finished pipe. As an alternative, by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material

TABLE 2 Tensile Requirements

	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10		Grade 11		
	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	
Tensile strength, min	55 000	380	65 000	450	60 000	415	60 000	415	65 000	450	100 000	690	63 000	435	80 000	550	65 000	450	
Yield strength, min	30 000	205	35 000	240	35 000	240	35 000	240	35 000	240	75 000	515	46 000	315	65 000	450	35 000	240	
	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	
Elongation in 2 in. or 50 mm, (or 4D), min, %: Basic minimum elongation for walls 1/16 in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section When standard round 2-in. or 50-mm gage length or proportionally smaller size test specimen with the gage length equal to 4D (4 times the diameter) is used For strip tests, a deduction for each 1/32 in. [0.8 mm] decrease in wall thickness below 9/16 in. [8 mm] from the basic minimum elongation of the following percentage	35	25	30	20	30	16.5	30	16.5	30	22	22	...	28	...	22	...	18 ^A	...	
	28	20	22	14	22	12	22	12	22	14	16	...	...	...	16	...	...	...
	1.75 ^B	1.25 ^B	1.50 ^B	1.00 ^B	1.50 ^B	1.00 ^B	1.50 ^B	1.00 ^B	1.50 ^B	1.00 ^B	1.25 ^B	...	1.50 ^B	...	1.25 ^B	...	...	...
Wall Thickness	Elongation in 2 in. or 50 mm, min, % ^C																		
	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10				
in.	mm	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse
1/16 (0.312)	8	35	25	30	20	30	16	30	16	30	22	22	...	28	...	22	...	22	...
1/32 (0.281)	7.2	33	24	28	19	28	15	28	15	28	21	21	...	26	...	21	...	21	...
1/4 (0.250)	6.4	32	23	27	18	27	15	27	15	27	20	20	...	25	...	20	...	20	...
7/32 (0.219)	5.6	30	...	26	...	26	...	26	...	26	...	18	...	24	...	18	...	18	...
3/16 (0.188)	4.8	28	...	24	...	24	...	24	...	24	...	17	...	22	...	17	...	17	...
5/32 (0.156)	4	26	...	22	...	22	...	22	...	22	...	16	...	20	...	16	...	16	...
1/8 (0.125)	3.2	25	...	21	...	21	...	21	...	21	...	15	...	19	...	15	...	15	...
3/32 (0.094)	2.4	23	...	20	...	20	...	20	...	20	...	13	...	18	...	13	...	13	...
1/16 (0.062)	1.6	21	...	18	...	18	...	18	...	18	...	12	...	16	...	12	...	12	...

^A Elongation of Grade 11 is for all walls and small sizes tested in full section.

^B The following table gives the calculated minimum values.

^C Calculated elongation requirements shall be rounded to the nearest whole number.

Note—The preceding table gives the computed minimum elongation values for each 1/32-in. [0.80-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
1	Longitudinal	$E = 56 t + 17.50$ [$E = 2.19t + 17.50$]
	Transverse	$E = 40 t + 12.50$ [$E = 1.56t + 12.50$]
3	Longitudinal	$E = 48 t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32 t + 10.00$ [$E = 1.25t + 10.00$]
4	Longitudinal	$E = 48 t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32 t + 6.50$ [$E = 1.25 t + 6.50$]
6	Longitudinal	$E = 48 t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32 t + 6.50$ [$E = 1.25 t + 6.50$]
7	Longitudinal	$E = 48 t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32 t + 11.00$ [$E = 1.25t + 11.00$]
8 and 10	Longitudinal	$E = 40 t + 9.50$ [$E = 1.56t + 9.50$]
	Longitudinal	$E = 48 t + 13.00$ [$E = 1.87 t + 13.00$]

where:

E = elongation in 2 in. or 50 mm, in %, and
 t = actual thickness of specimen, in. [mm].

as the pipe, the test plate being attached to the end of the pipe and welded as a prolongation of the pipe longitudinal seam.

4.2.6.2 The bend test shall be in accordance with QW-160 of Section IX of the ASME Boiler and Pressure Vessel Code.

4.2.7 Charpy V-notch Impact Tests—Impact tests on welded joints shall include tests on weld metal and heat affected zones and shall meet the same requirements as the base metal. (See Tables 3 and 4).

TABLE 3 Impact Requirements for Grades 1, 3, 4, 6, 7, 9, 10, and 11

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens ^A		Minimum Notched Bar Impact Value of One Specimen Only of a Set ^A	
	ft-lbf	J	ft-lbf	J
10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

^A Straight line interpolation for intermediate values is permitted.

TABLE 4 Impact Temperature

Grade	Minimum Impact Test Temperature	
	°F	°C
1	-50	-45
3	-150	-100
4	-150	-100
6	-50	-45
7	-100	-75
8	-320	-195
9	-100	-75
10	-75	-60
11	-320	-195

4.2.7.1 Each set of weld metal impact test specimens shall be taken across the weld with the notch in the weld metal. Each test specimen shall be oriented so that the notch is normal to the surface of the material and one face of the specimen shall be within $\frac{1}{16}$ in. [1.5 mm] of the surface of the material.

4.2.7.2 Each set of heat affected zone impact test specimens shall be taken across the weld and of sufficient length to locate, after etching, the notch in the heat affected zone. The notch shall be cut approximately normal to the surface of the material in such a manner as to include as much heat affected zone material as possible in the resulting fracture.

NOTE 3—The term “lot” applies to all pipe (may include more than one heat of steel) within a $\frac{3}{16}$ in. [4.7 mm] range of thickness and welded to the weld procedure, and when heat treated, done to the same heat-treating procedure and in the same furnace. The maximum lot size shall be 200 linear ft [60 m] of pipe.

4.3 Heat Treatment:

4.3.1 All seamless and welded pipe, other than Grades 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

4.3.1.1 Normalize by heating to a uniform temperature of not less than 1500 °F [815 °C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

4.3.1.2 Normalize as in 4.3.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.3.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750 °F [845 to 945 °C] and cool in air or in a controlled atmosphere furnace from an initial temperature of not less than 1550 °F [845 °C].

4.3.1.4 Treat as in 4.3.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.3.1.5 Seamless pipe of Grades 1, 6, and 10 may be heat treated by heating to a uniform temperature of not less than 1500 °F [815 °C], followed by quenching in liquid and reheating to a suitable tempering temperature, in place of any of the other heat treatments provided for in 4.3.1.

4.3.2 Grade 8 pipe shall be heat treated by the manufacturer by either of the following methods:

4.3.2.1 *Quenched and Tempered*—Heat to a uniform temperature of 1475 ± 25 °F [800 ± 15 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125 °F [565 to 605 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300 °F [165 °C]/h.

4.3.2.2 *Double Normalized and Tempered*—Heat to a uniform temperature of 1650 ± 25 °F [900 ± 15 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25 °F [790 ± 15 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125 °F [565 to 605 °C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300 °F [165 °C]/h.

4.3.3 Whether to anneal Grade 11 pipe is per agreement between purchaser and supplier. When Grade 11 pipe is annealed, it shall be normalized in the range of 1400 to 1600 °F [760 to 870 °C].

4.3.4 Material from which test specimens are obtained shall be in the same condition of heat treatment as the pipe furnished. Material from which specimens are to be taken shall be heat treated prior to preparation of the specimens.

4.3.5 When specified in the order the test specimens shall be taken from full thickness test pieces which have been stress relieved after having been removed from the heat-treated pipe. The test pieces shall be gradually and uniformly heated to the prescribed temperature, held at that temperature for a period of time in accordance with Table 5, and then furnace cooled at a temperature not exceeding 600 °F [315 °C]. Grade 8 shall be

TABLE 5 Stress Relieving of Test Pieces

Metal Temperature ^{A,B}				Minimum Holding Time, h/in. [min/mm] of Thickness
Grades 1, 3, 6, 7, and 10		Grade 4 ^C		
°F	°C	°F	°C	
1100	600	1150	620	1 [2.4]
1050	565	1100	600	2 [4.7]
1000	540	1050	565	3 [7.1]

^A For intermediate temperatures, the holding time shall be determined by straight-line interpolation.

^B Grade 8 shall be stress relieved at 1025 to 1085 °F, [550 to 585 °C], held for a minimum time of 2 h for thickness up to 1.0 in. [25.4 mm], plus a minimum of 1 h for each additional inch [25.4 mm] of thickness and cooled at a minimum rate of 300 °F [165 °C]/h in air or water to a temperature not exceeding 600 °F [315 °C].

^C Unless otherwise specified, Grade 4 shall be stress relieved at 1150 °F [620 °C].

cooled at a minimum rate of 300 °F [165 °C]/h in air or water to a temperature not exceeding 600 °F [315 °C].

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

5.2 When Grades 1, 6, or 10 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one billet or two samples of flat-rolled stock from each heat or of two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Length of Pipe in Lot
Under 2	400 or fraction thereof
2 to 6	200 or fraction thereof
Over 6	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

8. Impact Requirements

8.1 For Grades 1, 3, 4, 6, 7, 9, 10, and 11, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 14.1 shall be not less than the values prescribed in Table 3.

8.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

8.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

8.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional

specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

8.2.2 Lateral expansion values shall be determined by the procedure in Test Methods and Definitions A370.

8.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

9. Lengths

9.1 If definite lengths are not required, pipe may be ordered either in single random lengths of 16 to 22 ft (Note 4) with maximum 5 % of the lengths between 12 and 16 ft (Note 4), or in double random lengths with a minimum average of 35 ft (Note 4) and an absolute minimum length of 22 ft (Note 4) with maximum 5 % of the lengths between 16 and 22 ft (Note 4).

NOTE 4—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

10. Workmanship, Finish, and Appearance

10.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to ensure compliance with 10.2.

10.2 Surface imperfections that penetrate more than 12½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

10.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

10.2.2 Repaired in accordance with the repair welding provisions of 10.5.

10.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

10.2.4 The defective pipe may be rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with 10.2, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions and pits, any of which imperfections are deeper than ⅛ in. [1.6 mm], and

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 10.1 to be deeper than 5 % of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 10.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

10.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by

this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

10.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

10.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A999/A999M.

10.7 The finished pipe shall be reasonably straight.

11. General Requirements

11.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

12. Mechanical Testing

12.1 *Sampling*—For mechanical testing, the term “lot” applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. If the final heat treatment is in a batch-type furnace, the lot shall include only those pipes that are heat treated in the same furnace charge.

12.2 *Transverse or Longitudinal Tensile Test and Flattening Test*—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each lot. If heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 pipes.

12.3 *Impact Test*—One notched bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished pipe. This test shall represent only pipe from the same heat and the same heat-treatment load, the wall thicknesses of which do not exceed by more than ¼ in. [6.3 mm] the wall thicknesses of the pipe from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50 °F [30 °C] range and equipped with recording pyrometers so that complete records of heat treatment are available, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

12.4 *Impact Tests (Welded Pipe)*—On welded pipe, additional impact tests of the same number as required in 12.3 shall be made to test the weld.

12.5 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

12.6 Results obtained from these tests shall be reported to the purchaser or his representative.

13. Specimens for Impact Test

13.1 Notched bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E23,

Type A with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

13.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe while the axis of the notch shall be perpendicular to the surface. On wall thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located ½ in. [12.5 mm] from the outer surface.

13.3 When testing welds the specimen shall be, whenever diameter and thickness permit, transverse to the longitudinal axis of the pipe with the notch of the specimen in the welded joint and perpendicular to the surface. When diameter and thickness do not permit obtaining transverse specimens, longitudinal specimens in accordance with 13.2 shall be obtained; the bottom of the notch shall be located at the weld joint.

14. Impact Test

14.1 Except when the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, all material furnished to this specification and marked in accordance with Section 16 shall be tested for impact resistance at the minimum temperature for the respective grades as shown in Table 4.

14.1.1 Special impact tests on individual lots of material may be made at other temperatures as agreed upon between the manufacturer and the purchaser.

14.1.2 When subsize Charpy impact specimens are used and the width along the notch is less than 80 % of the actual wall thickness of the original material, the specified Charpy impact test temperature for Grades 1, 3, 4, 6, 7, 9, 10, and 11 shall be lower than the minimum temperature shown in Table 4 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 6) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width

TABLE 6 Impact Temperature Reduction

Specimen Width Along Notch or Actual Material Thickness		Temperature Reduction, Degrees Colder ^A	
in.	mm	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 (¾ std. size)	5	3
0.276	7	8	4
0.262	6.67 (⅔ std. size)	10	5
0.236	6	15	8
0.197	5 (½ std. size)	20	11
0.158	4	30	17
0.131	3.33 (⅓ std. size)	35	19
0.118	3	40	22
0.099	2.5 (¼ std. size)	50	28

^A Straight line interpolation for intermediate values is permitted.

actually tested. Appendix X1 shows some examples of how the temperature reductions are determined.

14.2 The notched bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type test of Test Methods E23.

14.3 Impact tests specified for temperatures lower than 70 °F [20 °C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within 3 °F [2 °C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15. Hydrostatic or Nondestructive Electric Test

15.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

15.2 The hydrostatic test shall be in accordance with Specification A999/A999M.

15.3 *Nondestructive Electric Test*—Nondestructive electric tests shall be in accordance with Specification A999/A999M, with the following addition:

15.3.1 If the test signals were produced by visual imperfections (listed in 15.3.2), the pipe may be accepted based on visual examination, provided the imperfection is less than 0.004 in. (0.1 mm) or 12½ % of the specified wall thickness (whichever is greater).

15.3.2 *Visual Imperfections*:

- 15.3.2.1 Scratches,
- 15.3.2.2 Surface roughness,
- 15.3.2.3 Dings,
- 15.3.2.4 Straightener marks,
- 15.3.2.5 Cutting chips,
- 15.3.2.6 Steel die stamps,
- 15.3.2.7 Stop marks, or
- 15.3.2.8 Pipe reducer ripple.

16. Product Marking

16.1 Except as modified in 16.1.1, in addition to the marking prescribed in Specification A999/A999M, the marking shall include whether hot finished, cold drawn, seamless or welded, the schedule number and the letters “LT” followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

16.1.1 When the size of the finished pipe is insufficient to obtain subsize impact specimens, the marking shall not include the letters “LT” followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

16.1.2 When the pipe is furnished in the quenched and tempered condition, the marking shall include the letters “QT,” and the heat treatment condition shall be reported to the purchaser or his representative.

17. Keywords

17.1 low; low temperature service; seamless steel pipe; stainless steel pipe; steel pipe; temperature service applications

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the contract or order.

S1. Subsize Impact Specimens

S1.1 When the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, testing shall be a matter of agreement between the manufacturer and the purchaser.

S2. Requirements for Pipe for Hydrofluoric Acid Alkylation Service

S2.1 The carbon equivalent (CE), based on heat analysis, shall not exceed 0.43 % if the specified wall thickness is equal to or less than 1 in. [25.4 mm] or 0.45 % if the specified wall thickness is greater than 1 in. [25.4 mm].

S2.2 The carbon equivalent shall be determined using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S2.3 Based upon heat analysis in mass percent, the vanadium content shall not exceed 0.02 %, the niobium content shall not exceed 0.02 % and the sum of the vanadium and niobium contents shall not exceed 0.03 %.

S2.4 Based upon heat analysis in mass percent, the sum of the nickel and copper contents shall not exceed 0.15 %.

S2.5 Based upon heat analysis in mass percent, the carbon content shall not be less than 0.18 %.

S2.6 Welding consumables for repair welds shall be of low hydrogen type. E60XX electrodes shall not be used, and the resultant weld chemistry shall meet the chemical composition requirements specified for the pipe.

S2.7 The designation “HF” shall be stamped or marked on each pipe to signify that the pipe complies with this supplementary requirement.

APPENDIX**(Nonmandatory Information)****X1. DETERMINATION OF TEMPERATURE REDUCTIONS**

X1.1 Under the circumstances stated in 14.1.2, the impact test temperatures specified in Table 4 must be lowered. The following examples are offered to describe the application of the provisions of 14.1.2.

X1.1.1 When subsize specimens are used (see 10.1) and the width along the notch of the subsize specimen is 80 % or greater of the actual wall thickness of the original material, the provisions of 14.1.2 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80 % of the actual wall thickness of the pipe, the

required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 6 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm (1/3 standard size), the test temperature would have to be lowered by 25 °F [14 °C]. That is, the temperature reduction corresponding to the subsize specimen is 35 °F [19 °C]; the temperature reduction corresponding to the actual pipe thickness is 10 °F [5 °C]; the difference between these two values is the required reduction in test temperature.

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SPECIFICATION FOR SEAMLESS AND WELDED CARBON AND ALLOY-STEEL TUBES FOR LOW-TEMPERATURE SERVICE



SA-334/SA-334M



(21)

(Identical with ASTM Specification A334/A334M-04a(2016).)

SPECIFICATION FOR SEAMLESS AND WELDED CARBON AND ALLOY-STEEL TUBES FOR LOW- TEMPERATURE SERVICE



SA-334/SA-334M



[Identical with ASTM Specification A 334/A 334M-04a(2016).]

1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, seamless and welded, carbon and alloy-steel tubes intended for use at low temperatures. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse affect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

NOTE 1 — For tubing smaller than $\frac{1}{2}$ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 1 shall apply. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter and with a wall thickness under 0.015 in. [0.4 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required to describe the desired material adequately:

- 3.1.1** Quantity (feet, metres, or number of lengths),
- 3.1.2** Name of material (seamless or welded tubes),
- 3.1.3** Grade (Table 1),
- 3.1.4** Size (outside diameter and minimum wall thickness),
- 3.1.5** Length (specific or random),
- 3.1.6** Optional requirements (other temperatures, Section 14; hydrostatic or electric test, Section 16),
- 3.1.7** Test report required, (Certification Section of Specification A 1016/A 1016M),
- 3.1.8** Specification designation, and
- 3.1.9** Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 1016/A 1016M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 The tubes shall be made by the seamless or automatic welding process with no addition of filler metal in the welding operation.

6. Heat Treatment

6.1 All seamless and welded tubes, other than Grades 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

6.1.1 Normalize by heating to a uniform temperature of not less than 1550°F [845°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

6.1.2 Normalize as in 10.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750°F [845 to 955°C] and cool in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

6.1.4 Treat as in 6.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.2 Grade 8 tubes shall be heat treated by the manufacturer by either of the following methods.

6.2.1 *Quenched and Tempered* — Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300°F [165°C]/h.

6.2.2 *Double Normalized and Tempered* — Heat to a uniform temperature of 1650 ± 25°F [900 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25°F [790 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300°F [165°C]/h.

6.3 Material from which impact specimens are obtained shall be in the same condition of heat treatment as the finished tubes.

6.4 Whether to anneal Grade 11 tubes is per agreement between purchaser and supplier. When Grade 11 tubes are annealed they shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7.2 When Grades 1 or 6 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made for each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot shall be rejected or, at the option of the manufacturer, each billet, length of flat-rolled stock, or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes which do not meet the requirements of the specification shall be rejected.

9. Sampling

9.1 For flattening, flare, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

9.2 For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

11. Hardness Requirements

11.1 The tubes shall have a hardness number not exceeding those prescribed in Table 4.

12. Impact Requirements

12.1 For Grades 1, 3, 6, 7 and 9, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 14.1 shall be not less than the values prescribed in Table 5. The impact test is not required for Grade 11.

12.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

12.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch not less than 0.015 in. [0.38 mm].

12.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

12.2.2 Lateral expansion values shall be determined in accordance with Test Methods and Definitions A 370.

12.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

13. Mechanical Tests

13.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

13.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube of each lot but not the one used for the flare or flange test.

13.3 Flare Test (Seamless Tubes) — One flare test shall be made on specimens from each end of one finished tube of each lot, but not the one used for the flattening test.

13.4 Flange Test (Welded Tubes) — One flange test shall be made on specimens from each end of one finished tube of each lot, but not the one used for the flattening test.

13.5 Reverse Flattening Test — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

13.6 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

13.7 Impact Tests — One notched-bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished tube. This test shall represent only tubes from the same heat, which have wall thicknesses not exceeding by more than $\frac{1}{4}$ in. [6.3 mm] the wall thicknesses of the tube from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50°F [30°C] range and equipped with recording pyrometers which yield complete heat-treatment records, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

13.8 Impact Tests (Welded Tubes) — On welded tube, additional impact tests of the same number as required in 13.7 shall be made to test the weld.

13.9 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

14. Specimens for Impact Test

14.1 Notched-bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E 23, Type A, with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

14.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the tube while the axis of the notch shall be perpendicular to the surface. On wall thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located $\frac{1}{2}$ in. [12.5 mm] from the outer surface.

14.3 When testing welds the specimen shall be, whenever diameter and thickness permits, transverse to the longitudinal axis of the tube with the notch of the specimen

in the welded joint and perpendicular to the surface. When diameter and thickness does not permit obtaining transverse specimens, longitudinal specimens in accordance with 14.2 shall be obtained. The bottom of the notch shall be located at the weld joint.

15. Impact Test

15.1 Except when the size of the finished tube is insufficient to permit obtaining subsize impact specimens, all material furnished under this specification and marked in accordance with Section 17 shall be tested for impact resistance at the temperature for the respective grades as prescribed in Table 6.

15.1.1 Special impact tests on individual lots of material may be made at other temperatures if agreed upon between the manufacturer and the purchaser.

15.2 The notched-bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type of test of Test Methods E 23.

15.3 Impact tests specified for temperatures lower than +70°F [20°C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within ±3°F [2°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15.4 When subsize Charpy impact specimens are used and the width along the notch is less than 80% of the actual wall thickness of the original material, the specified Charpy

impact test temperature for Grades 1, 3, 6, 7, and 9 shall be lower than the minimum temperature shown in Table 6 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 7) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to Charpy specimen width actually tested. The appendix shows some examples of how the temperature reductions are determined.

16. Hydrostatic or Nondestructive Electric Test

16.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test in accordance with Specification A 1016/A 1016M. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

17. Product Marking

17.1 Except as modified in 16.1.1, in addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include whether hot-finished, cold-drawn, seamless, or welded, and the letters "LT" followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

17.1.1 When the size of the finished tube is insufficient to obtain subsize impact specimens, the marking shall not include the letters LT followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %						
	Grade 1 [Note (1)]	Grade 3	Grade 6 [Note (1)]	Grade 7	Grade 8	Grade 9	Grade 11
Carbon, max	0.30	0.19	0.30	0.19	0.13	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.29–1.06	0.90 max	0.90 max	0.40–1.06	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Silicon	...	0.18–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.35 max
Nickel	...	3.18–3.82	...	2.03–2.57	8.40–9.60	1.60–2.24	35.0–37.0
Chromium	...	...	...	...	...	...	0.50 max
Copper	...	...	...	...	...	0.75–1.25	...
Cobalt	...	...	...	...	...	...	0.50 max
Molybdenum	...	...	...	...	...	...	0.50 max

NOTE:

(1) For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% will be permitted to a maximum of 1.35% manganese.

TABLE 2
HEAT-TREATMENT LOT

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Under 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter, or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in thickness	not more than 75 tubes
1 in. [25.4 mm] or under in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

	Grade 1		Grade 3		Grade 6		Grade 7		Grade 8		Grade 9		Grade 11	
	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
Tensile Strength, min	55	380	65	450	60	415	65	450	100	690	63	435	65	450
Yield Strength, min	30	205	35	240	35	240	35	240	75	520	46	315	35	240
Elongation in 2 in. or 50 mm (or 4 <i>D</i>), min, %:														
Basic minimum elongation for walls $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35		30		30		30		22		28		18	[Note (1)]
When standard round 2 in. or 50 mm gage length or proportionally smaller size specimen with the gage length equal to 4 <i>D</i> (4 times the diameter) is used	28		22		22		22		16		...		...
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.75		1.50		1.50		1.50		1.25		1.50		...	
	[Note (2)]		[Note (2)]		[Note (2)]		[Note (2)]		[Note (2)]		[Note (2)]			

NOTES:

- (1) Elongation of Grade 11 is for all walls and for small sizes tested in full section.
- (2) The following table gives the calculated minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min % [Note (1)]					
in.	mm	Grade 1	Grade 3	Grade 6	Grade 7	Grade 8	Grade 9
$\frac{5}{16}$ (0.312)	8	35	30	30	30	22	28
$\frac{9}{32}$ (0.281)	7.2	33	28	28	28	21	26
$\frac{1}{4}$ (0.250)	6.4	32	27	27	27	20	25
$\frac{7}{32}$ (0.219)	5.6	30	26	26	26	18	24
$\frac{3}{16}$ (0.188)	4.8	28	24	24	24	17	22
$\frac{5}{32}$ (0.156)	4	26	22	22	22	16	20
$\frac{1}{8}$ (0.125)	3.2	25	21	21	21	15	19
$\frac{3}{32}$ (0.094)	2.4	23	20	20	20	13	18
$\frac{1}{16}$ (0.062)	1.6	21	18	18	18	12	16

NOTE:

- (1) Calculated elongation requirements shall be rounded to the nearest whole number.

NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equations.

Grade	Equation [Note (3)]
1	$E = 56t + 17.50$ [$E = 2.19t + 17.50$]
3	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
6	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
7	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
8	$E = 40t + 9.50$ [$E = 1.56t + 9.50$]
9	$E = 48t + 13.00$ [$E = 1.87t + 13.00$]

where:

E = elongation in 2 in. or 50 mm, %, and
 t = actual thickness of specimen, in. [mm]

TABLE 4
MAXIMUM HARDNESS NUMBER

Grade	Rockwell	Brinell
1	B 85	163
3	B 90	190
6	B 90	190
7	B 90	190
8	...	...
11	B 90	190

TABLE 5
IMPACT REQUIREMENTS FOR GRADES 1, 3, 6, 7, AND 9

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens [Note (1)]		Minimum Notched Bar Impact Value of One Specimen Only of a Set [Note (1)]	
	ft·lbf	J	ft·lbf	J
	10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

NOTE:

(1) Straight line interpolation for intermediate values is permitted.

TABLE 6
IMPACT TEMPERATURE

Grade	Impact Test Temperature	
	°F	°C
1	-50	-45
3	-150	-100
6	-50	-45
7	-100	-75
8	-320	-195
9	-100	-75

TABLE 7
IMPACT TEMPERATURE REDUCTION

Specimen Width Along Notch or Actual Material Thickness [Note (1)]		Temperature Reduction, Degrees Colder	
Inches	Millimeters	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 ($\frac{3}{4}$ standard size)	5	3
0.276	7	8	4
0.262	6.67 ($\frac{2}{3}$ standard size)	10	5
0.236	6	15	8
0.197	5 ($\frac{1}{2}$ standard size)	20	11
0.158	4	30	17
0.131	3.33 ($\frac{1}{3}$ standard size)	35	19
0.118	3	40	22
0.099	2.5 ($\frac{1}{4}$ standard size)	50	28

NOTE:

(1) Straight line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Nonstandard Test Specimens

S1.1 When the size of the finished tube is insufficient to permit obtaining subsize impact specimens, testing shall be a matter of agreement between the manufacturer and the purchaser.

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TEMPERATURE REDUCTIONS

X1.1 Under the circumstances stated in 15.4, the impact test temperatures specified in Table 6 must be lowered. The following examples are offered to describe the application of the provisions of 15.4.

X1.1.1 When subsize specimens are used (see 14.1) and the width along the notch of the subsize specimen is 80% or greater of the actual wall thickness of the original material, the provisions of 15.4 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80% of the actual wall thickness of the pipe, the required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 7 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm ($\frac{1}{3}$ standard size), the test temperature would have to be lowered by 25°F [14°C] (that is, the temperature reduction corresponding to the subsize specimen is 35°F [19°C], the temperature reduction corresponding to the actual pipe thickness is 10°F [5°C]; the difference between these two values is the required reduction in test temperature).

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SPECIFICATION FOR SEAMLESS FERRITIC ALLOY-STEEL PIPE FOR HIGH-TEMPERATURE SERVICE



SA-335/SA-335M

(Identical with ASTM Specification A335/A335M-18 except for the revision to 9.5 to replace the words “as agreed upon in accordance with Note D in Table 2” with “performed”.)

Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service

1. Scope

1.1 This specification covers nominal wall and minimum wall seamless ferritic alloy-steel pipe intended for high-temperature service. Pipe ordered to this specification shall be suitable for bending, flanging (vanstoning), and similar forming operations, and for fusion welding. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

1.2 Several grades of ferritic steels (see Note 1) are covered. Their compositions are given in Table 1.

NOTE 1—Ferritic steels in this specification are defined as low- and intermediate-alloy steels containing up to and including 10 % chromium.

1.3 Supplementary requirements (S1 to S8) of an optional nature are provided. Supplementary requirements S1 through S6 call for additional tests to be made, and when desired, shall be so stated in the order together with the number of such tests required.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

- A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe
- E92 Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials
- E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing
- E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation
- E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
- E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
- E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 ASME Standard:

- B36.10M Welded and Seamless Wrought Steel Pipe

2.3 AWS Specifications

- A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
- A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
- A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

TABLE 1 Chemical Requirements

Grade	UNS Designation ^A	Composition, %							
		Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Others
P1	K11522	0.10–0.20	0.30–0.80	0.025	0.025	0.10–0.50	...	0.44–0.65	...
P2	K11547	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65	...
P5	K41545	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	...
P5b	K51545	0.15 max	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45–0.65	...
P5c	K41245	0.12 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	... ^B
P9	K90941	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	...
P11	K11597	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65	...
P12	K11562	0.05–0.15	0.30–0.61	0.025	0.025	0.50 max	0.80–1.25	0.44–0.65	...
P15	K11578	0.05–0.15	0.30–0.60	0.025	0.025	1.15–1.65	...	0.44–0.65	...
P21	K31545	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06	...
P22	K21590	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13	...
P23	K41650	0.04–0.10	0.10–0.60	0.030 max	0.010 max	0.50 max	1.90–2.60	0.05–0.30	V 0.20–0.30 Cb 0.02–0.08 B 0.0010–0.006 N 0.015 max Al 0.030 max W 1.45–1.75 Ni 0.40 max Ti 0.005–0.060 Ti/N $\geq 3.5^C$
P24	K30736	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	2.20–2.60	0.90–1.10	V 0.20–0.30 Ti 0.06–0.10 N 0.012 max Al 0.02 max B 0.0015–0.007
P36	K21001	0.10–0.17	0.80–1.20	0.030 max	0.025 max	0.25–0.50	0.30 max	0.25–0.50	Ni 1.00–1.30 Cu 0.50–0.80 Cb 0.015–0.045 V 0.02 max N 0.02 max Al 0.050 max
P91 Type 1	K91560	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	V 0.18–0.25 N 0.030–0.070 Ni 0.40 max Al 0.02 max Cb 0.06–0.10 Ti 0.01 max Zr 0.01 max
P91 Type 2 Heat Product	K91560	0.08–0.12 0.07–0.13	0.30–0.50 ^D	0.020 ^D	0.005 ^D	0.20–0.40 ^D	8.00–9.50 ^D	0.85–1.05 0.80–1.05	V Heat 0.18–0.25 Product 0.16–0.27 Ni 0.20 max ^D Al 0.020 max ^D N 0.035–0.070 ^D N/Al ratio ≥ 4.0 Cb Heat 0.06–0.10 Product 0.05–0.11 Ti 0.01 max ^D Zr 0.01 max ^D Sn 0.010 max ^D Sb 0.003 max ^D As 0.010 max ^D B 0.001 max ^D W 0.05 max ^D Cu 0.10 max ^D
P92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	8.50–9.50	0.30–0.60	V 0.15–0.25 N 0.03–0.07 Ni 0.40 max Al 0.02 max Cb 0.04–0.09 W 1.5–2.00 B 0.001–0.006 Ti 0.01 max Zr 0.01 max

TABLE 1 *Continued*

Grade	UNS Designation ^A	Composition, %							
		Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Others
P122	K92930	0.07–0.14	0.70 max	0.020	0.010	0.50 max	10.00–11.50	0.25–0.60	V 0.15–0.30 W 1.50–2.50 Cu 0.30–1.70 Cb 0.04–0.10 B 0.0005–0.005 N 0.040–0.100 Ni 0.50 max Al 0.020 max Ti 0.01 max Zr 0.01 max
P911	K91061	0.09–0.13	0.30–0.60	0.020 max	0.010 max	0.10–0.50	8.5–9.5	0.90–1.10	V 0.18–0.25 Ni 0.40 max Cb 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.02 max W 0.90–1.10 Ti 0.01 max Zr 0.01 max

^A New designation established in accordance with Practice E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

^B Grade P5c shall have a titanium content of not less than 4 times the carbon content and not more than 0.70 %; or a columbium content of 8 to 10 times the carbon content.

^C Alternatively, in lieu of this ratio minimum, the material shall have a minimum hardness of 275 HV in the hardened condition, defined as after austenitizing and cooling to room temperature but prior to tempering. Hardness testing shall be performed at mid-thickness of the product. Hardness test frequency shall be two samples of product per heat treatment lot and the hardness testing results shall be reported on the material test report.

^D Applies to both heat and product analyses.

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

2.4 Other Documents:

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless alloy steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size using one of the following:

3.1.5.1 NPS and schedule number,

3.1.5.2 Outside diameter and nominal wall thickness,

3.1.5.3 Outside diameter and minimum wall thickness,

3.1.5.4 Inside diameter and nominal wall thickness, and

3.1.5.5 Inside diameter and minimum wall thickness.

3.1.6 Length (specific or random),

3.1.7 End finish (Ends Section of Specification A999/A999M),

3.1.8 Optional requirements (Section 8, 12, and 13 of this specification. See the Sections on Hydrostatic Test Requirements and Permissible Variation in Weight for Seamless Pipe in Specification A999/A999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or any supplementary requirements selected, or both.

3.1.11 The flattening or bend test shall be performed on 5 % of the pipe (or fewer in accordance with 14.2) unless Supplementary Requirement S3 is specified.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 Pipe may be either hot finished or cold drawn with the finishing treatment as required in 5.2.

5.2 Heat Treatment:

5.2.1 All pipe shall be reheated for heat treatment and heat treated in accordance with the requirements of Table 2.

NOTE 3—It is recommended that the temperature for tempering should be at least 100 °F [50 °C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100 °F [600 °C].

NOTE 4—Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

TABLE 2 Heat Treatment Requirements^A

Grade	Heat Treat Type	Normalizing Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]
P1	full or isothermal anneal or normalize and temper or subcritical anneal	...	...	...
		...	...	1200 [650] 1200–1300 [650–705]
P2	full or isothermal anneal or normalize and temper or subcritical anneal	...	...	...
		...	...	1250 [675] 1200–1300 [650–705]
P5	full or isothermal anneal or normalize and temper	...	...	...
		...	...	1250 [675]
P5b	full or isothermal anneal or normalize and temper	...	...	...
		...	...	1250 [675]
P5c	subcritical anneal	...	...	...
		...	...	1325–1375 [715–745]
P9	full or isothermal anneal or normalize and temper	...	...	...
		...	...	1250 [675]
P11	full or isothermal anneal or normalize and temper	...	...	...
		...	...	1200 [650]
P12	full or isothermal anneal or normalize and temper or subcritical anneal	...	...	...
		...	...	1200 [650] 1200–1300 [650–705]
P15	full or isothermal anneal or normalize and temper	...	...	...
		...	...	1200 [650]
P21	full or isothermal anneal or normalize and temper	...	...	...
		...	...	1250 [675]
P22	full or isothermal anneal or normalize and temper	...	...	...
		...	...	1250 [675]
P23	normalize and temper	1900–1975 [1040–1080]	air or accelerated cooling	1350–1470 [730–800]
			air or accelerated cooling	
P24	normalize and temper	1800–1870 [980–1020]	air or accelerated cooling	1350–1420 [730–770]
			air or accelerated cooling	
P36	normalize and temper ^B	1650 [900]	...	1100 [595]
			...	
P91 Type 1 and Type 2	normalize and temper or quench and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800] ^C
			...	1350–1470 [730–800]
P92	normalize and temper	1900–1975 [1040–1080]	^D	1350–1470 [730–800]
			^D	1350–1470 [730–800]
P122	normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800]
			...	1350–1470 [730–800]
P911	normalize and temper	1900–1975 [1040–1080]	^D	1365–1435 [740–780]
			^D	1365–1435 [740–780]

^AWhere ellipses (...) appear in this table there is no requirement.

^BAlternatively, Grade P36, Class 2 shall be cooled from the austenitizing temperature by accelerated cooling in air or by liquid quenching.

^CExcept when Supplementary Requirement S7 is specified by the purchaser.

^DAccelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Workmanship, Finish, and Appearance

7.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to ensure compliance with 7.2.

7.2 Surface imperfections that penetrate more than 12½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

7.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

7.2.2 Repaired in accordance with the repair welding provisions of 7.6.

7.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

7.2.4 Rejected.

7.3 To provide a workmanlike finish and basis for evaluating conformance with 7.2, the pipe manufacturer shall remove by grinding the following:

7.3.1 Mechanical marks, abrasions (see Note 5) and pits, any of which imperfections are deeper than 1/16 in. [1.6 mm].

NOTE 5—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, and the like.

7.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with 7.1 to be deeper than 5 % of the nominal wall thickness.

7.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 7.2 are not scattered, but appear over a large area in excess of what is

considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

7.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

7.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

7.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A999/A999M.

7.6.1 All repair welds in P91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair P91 Type 1 and Type 2 shall not exceed 1.0 %.

7.6.2 All repair welds in P92, P911, and P122, shall be made using welding consumables meeting the chemical requirements for the grade in Table 1.

7.6.3 After weld repair, Grades P23, P91 Type 1 and Type 2, P92, and P122 shall be heat treated at 1350–1470 °F [730–800 °C].

7.6.4 After weld repair, Grade P911 shall be heat treated at 1365–1435 °F [740–780 °C].

7.6.5 After weld repair, Grade P24 shall be heat treated at 1350–1420 °F [730–770 °C].

7.7 The finished pipe shall be reasonably straight.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of two pipes from each lot as defined hereafter shall be made by the manufacturer. A lot is all pipe of the same nominal size and wall thickness (schedule) which is produced from the same heat of steel and shall be limited as follows:

NPS Designator	Maximum Number of Lengths in a Lot
Under 2	400
2 to 5	200
6 and over	100

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

8.3 For grade P91 Type 1 the carbon content may vary for the product analysis by –0.01 % and +0.02 % from the specified range as per Table 1.

8.4 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in 6.1, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Tensile and Hardness Requirements

9.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

9.2 Table 4 lists elongation requirements.

9.3 Pipe of Grade P91 Type 1 and Type 2 shall have a hardness within the range of 190 to 250 HBW or 196 to 265 HV or 91 HRBW to 25 HRC. Pipe of Grades P24, P36, P92, P122, and P911 shall have a hardness not exceeding 250 HBW or 265 HV or 25 HRC. Pipe of grade P23 shall have a hardness not exceeding 220 HBW or 220 HV or 97 HRBW.

9.4 Table 5 gives the computed minimum elongation values for each 1/32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following formula:

Direction of Test	Equation ^B
Longitudinal, all grades except P23, P91 Type 1 and Type 2, P92, P122, and P911	$E = 48t + 15.00$ [$E = 1.87 t + 15.00$]
Transverse, all grades except P23, P91 Type 1 and Type 2, P92, P122, and P911	$E = 32t + 10.00$ [$E = 1.25 t + 10.00$]
Longitudinal, P23, P24, P91 Type 1 and Type 2, P92, P122, and P911	$E = 32t + 10.00$ [$E = 1.25 t + 10.00$]
Longitudinal, P36	$E = 32t + 5.0$ [$E = 1.25 t + 5.0$]

where:

E = elongation in 2 in. or 50 mm, %, and
 t = actual thickness of specimens, in. [mm].

9.5 For Grade P91 Type 1 and Type 2, when quenching and tempering has been performed, the tensile and hardness properties shall be met and verified on material taken from the half-thickness location.

TABLE 3 Tensile Requirements

	Grade								
	P1, P2	P12	P23	P24	P91 Type 1 and Type 2	P92, P911 P36 Class 1	P122	P36 Class 2	All Others
Tensile strength, min:									
ksi	55	60	74	85	85	90	90	95.5	60
MPa	380	415	510	585	585	620	620	660	415
Yield strength, min:									
ksi	30	32	58	60	60	64	58	66.5	30
MPa	205	220	400	415	415	440	400	460	205

TABLE 4 Elongation Requirements

Elongation Requirements					
	All grades except P23, P36 P91 Type 1 and Type 2, P92, P122, and P911		P23, P24, P91 Type 1 and Type 2, P92, P122, and P 911		P36
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal
Elongation in 2 in. or 50 mm, (or 4D), min, %:					
Basic minimum elongation for wall 5/16 in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	30	20	20	...	15
When standard round 2-in. or 50-mm gage length or proportionally smaller size specimen with the gage length equal to 4D (4 times the diameter) is used	22	14	20	13	...
For strip tests a deduction for each 1/32-in. [0.8 mm] decrease in wall thickness below in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.50 ^A	1.00 ^A	1.00 ^A	...	1.00 ^A

^A Table 5 gives the calculated minimum values.

TABLE 5 Calculated Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %			
		All grades except P23, P36, P91 Type 1 and Type 2, P92, P122, and P911		P23, P24, P91, Type 1 and Type 2, P92, P122, and P911	P36
in.	mm	Longitudinal	Transverse	Longitudinal	Longitudinal
5/16 (0.312)	8	30	20	20	15
3/32 (0.281)	7.2	28	19	19	14
1/4 (0.250)	6.4	27	18	18	13
7/32 (0.219)	5.6	26	...	17	12
3/16 (0.188)	4.8	24	...	16	11
5/32 (0.156)	4	22	...	15	10
1/8 (0.125)	3.2	21	...	14	9
3/32 (0.094)	2.4	20	...	13	8
1/16 (0.062)	1.6	18	...	12	7

10. Permissible Variations in Diameter

10.1 For pipe ordered to NPS [DN] or outside diameter, variations in outside diameter shall not exceed those specified in Table 6.

10.2 For pipe ordered to inside diameter, the inside diameter shall not vary more than ± 1 % from the specified inside diameter.

11. Permissible Variations in Wall Thickness

11.1 In addition to the implicit limitation of wall thickness for pipe imposed by the limitation on weight in Specification A999/A999M, the wall thickness for pipe at any point shall be within the tolerances specified in Table 7. The minimum wall thickness and outside diameter for inspection for compliance

TABLE 6 Permissible Variations in Outside Diameter

NPS [DN] Designator	Over		Under	
	in.	mm	in.	mm
1/8 to 1 1/2 [6 to 40], incl.	1/64 (0.015)	0.40	1/64 (0.015)	0.40
Over 1 1/2 to 4 [40 to 100], incl.	1/32 (0.031)	0.79	1/32 (0.031)	0.79
Over 4 to 8 [100 to 200], incl.	1/16 (0.062)	1.59	1/32 (0.031)	0.79
Over 8 to 12 [200 to 300], incl.	3/32 (0.093)	2.38	1/32 (0.031)	0.79
Over 12 [300]	± 1 % of the specified outside diameter			

with this requirement for pipe ordered by NPS [DN] and schedule number is shown in ASME B36.10M.

TABLE 7 Permitted Variations in Wall Thickness

NPS [DN] Designator	Tolerance, % from Specified	
	Over	Under
1/8 to 2 1/2 [6 to 65] incl., all t/D ratios ^A	20.0	12.5
Above 2 1/2 [65], t/D ≤ 5 % ^A	22.5	12.5
Above 2 1/2 [65], t/D > 5 % ^A	15.0	12.5

^A t = Specified Wall Thickness; D = Specified Outside Diameter.

12. Hydrostatic Test

12.1 The requirements for grades other than P91 Type 1 and Type 2, P92, P911, and P122 are shown in 12.1.1 – 12.1.4.

12.1.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to the hydrostatic test, except as provided for in 12.1.4.

12.1.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.1.3 and 12.1.4.

12.1.3 When specified by the purchaser, pipe of all other sizes shall be furnished without the hydrostatic test and without nondestructive examination.

12.1.4 When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

12.2 The requirements for grades P91 Type 1 and Type 2, P92, P911, and P122 are shown in 12.2.1 – 12.2.3.

12.2.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to both the hydrostatic test and the ultrasonic test as shown in Section 13.

12.2.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.2.3.

12.2.3 When specified by the purchaser, pipe of all other sizes shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

13. Nondestructive Examination

13.1 When required by 12.1.2 or 12.2 above, or when specified in the purchase order in addition to the hydrostatic test (12.2.3), each pipe shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309, or Practice E570. Except for Grades P91 Type 1 and Type 2, P92, P911, and P122, the type of nondestructive examination shall be at the option of the manufacturer, unless otherwise specified in the order. Grades P91 Type 1 and Type 2, P92, P911, and P122 shall be examined by an examination method in accordance with Practice E213. When specified in the order, pipe of Grades P91 Type 1 and Type 2, P92, P911, and P122 shall be examined by an examination method in accordance with Practices E309 or E570, in addition to the examination method in accordance with Practice E213. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

13.2 Following conditions apply in lieu or in addition to those in Specification A999/A999M:

13.2.1 The width of the notch shall not exceed the depth.

13.2.2 If upon any standardization, the reference signal amplitude has decreased by more than 25 % (2 db), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization shall be re-tested.

13.2.3 Pipes producing a signal equal to or greater than the signal produced by the reference standard shall be subject to one of the following four dispositions:

13.2.3.1 The pipes may be rejected without further examination, at the discretion of the manufacturer.

13.2.3.2 The pipes shall be rejected if the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections.

13.2.3.3 The pipes may be repaired by grinding (in accordance with 7.2.1), welding (in accordance with 7.6) or sectioning (in accordance with 7.2.3). To be accepted, a repaired pipe must pass the same nondestructive examination by which it was rejected, and it must meet the remaining wall thickness requirements of this specification.

13.2.3.4 If the test signals were produced by visual imperfections such as those listed below, the pipes may be evaluated in accordance with the provisions of Section 7:

- (a) Scratches,
- (b) Surface roughness,
- (c) Dings,
- (d) Straightener marks,
- (e) Cutting chips,
- (f) Steel die stamps,
- (g) Stop marks, or
- (h) Pipe reducer ripple.

14. Mechanical Tests Required

14.1 *Lot*—For mechanical testing, a lot is all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

14.2 *Transverse or Longitudinal Tension Test, Hardness Test, and Flattening or Bend Test*—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each treated lot. For small lots, at least 1 pipe shall be tested. For material heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 pipe. Unless otherwise specified, the flattening test or bend test shall be chosen at the manufacturer's option.

14.3 Hardness Test:

14.3.1 The Vickers hardness testing shall be made in accordance with Test Method E92.

14.3.2 For pipes with wall thickness 0.200 in. [5.1 mm] or over, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load shall be used at the option of the manufacturer.

14.3.3 For pipes with wall thickness 0.065 in. [1.7 mm] or over, but less than 0.200 in. [5.1 mm], the Rockwell hardness test shall be used.

14.3.4 For pipes with wall thickness less than 0.065 in. [1.7 mm], the hardness test shall not be required.

14.3.5 The Brinell test shall be made, at the option of the manufacturer, on the outside of the pipe near the end, on the outside of a specimen cut from the pipe, or on the wall cross section of a specimen cut from the pipe. This test shall be made so that the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

14.3.6 The Rockwell hardness test shall, at the option of the manufacturer, be made on the inside surface, on the wall cross section, or on a flat of the outside surface.

14.3.7 For pipe of Grades P23, P24, P36, P91 Type 1 and Type 2, P92, P122 and P911, Brinell, Vickers, or Rockwell hardness tests shall be made on a specimen from each lot. For pipe of all other grades, a hardness test is not required.

14.4 *Flattening Test:*

14.4.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end of the pipe with the number of tests as specified in 14.2. Crop ends may be used. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

14.5 *Bend Test:*

14.5.1 For pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less shall be subjected to the bend test instead of the flattening test. Other pipe whose diameter equals or exceeds NPS 10 may be given the bend test in place of the flattening test subject to the approval of the purchaser.

14.5.2 The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25 mm].

14.5.3 Test specimens for the bend test shall be cut from one end of the pipe with the number of tests as specified in 14.2

and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.5 by 12.5 mm] in section or 1 by ½ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over 1/16 in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe, respectively.

15. **Certification**

15.1 Certification and test reports, as described in Section 25 of Specification A999/A999M, are required.

15.2 In addition to the information required by Specification A999/A999M, the certification shall state whether or not the pipe was hydrostatically tested. If the pipe was nondestructively examined, the certification shall so state and shall show which practice was followed and what reference discontinuities were used. In addition, the test method information as given in Table 8 shall be appended to the specification number and grade shown on the certification.

16. **Product Marking**

16.1 In addition to the marking prescribed in Specification A999/A999M, the marking shall include the length, an additional symbol “S”, if the pipe conforms to any of the Supplementary Requirements S1 to S6, the schedule number, if the pipe is ordered to a schedule number, and the heat number or manufacturer’s number by which the heat can be identified. Furthermore, the marking designated in Table 8 to indicate the test method(s) shall be included. Marking may be by stenciling, stamping, or rolling. Pipe that has been weld repaired in accordance with 7.6 shall be marked “WR.”

16.2 P91 shall be additionally marked with the appropriate Type.

17. **Government Procurement**

17.1 *Scale Free Pipe:*

17.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free

TABLE 8 Test Method Information for Certification and Marking

Ultrasonic	Flux Leakage	Eddy Current	Hydrostatic	Marking
NO	NO	NO	YES	TEST PRESSURE ^A
YES	NO	NO	NO	UT
NO	YES	NO	NO	FL
NO	NO	YES	NO	EC
YES	YES	NO	NO	UT/FL
YES	NO	YES	NO	UT/EC
NO	NO	NO	NO	NH
YES	NO	NO	YES	UT/TEST PRESSURE ^A
NO	YES	NO	YES	FL/TEST PRESSURE ^A
NO	NO	YES	YES	EC/TEST PRESSURE ^A

^ATest pressure is to be in psi [MPa].

pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

17.1.2 The requirements of Specification A999/A999M for pipe shall be applicable when pipe is ordered to this specification.

17.1.3 Pipe shall be one of the following grades as specified herein:

Grade	UNS Designation
P11	K11597
P22	K21590
P5	K41545

17.1.4 Part Number:

17.1.4.1 Pipe shall be ordered to nominal pipe size and schedule specified in ASME B36.10M

Example: A335/A335M Pipe P-11 NPS 12 Sch 40

Specification Number	ASTM A335/A335M
Pipe	P
Grade	P-11
NPS	12
Wall	0.375

17.1.4.2

Specification Number	ASTM A335/A335M
Tube	T
Grade	P-11
Outside Diameter	0.250
Wall	0.035

17.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 3:

17.1.5.1 Pipe or tube,

17.1.5.2 Part number,

17.1.5.3 Ultrasonic inspection, if required,

17.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions, and

17.1.5.5 Level of preservation and packing required.

18. Keywords

18.1 alloy steel pipe; high temperature service; seamless steel pipe; steel pipe; temperature service applications

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound. The bend test shall be substituted for the flattening

test for pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less.

S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

NOTE S4.1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macro Etch Test for Routine Inspection of Iron and Steel, described in the *Metals Handbook*, Am. Soc. for Metals, 1948 edition, p. 389, be followed.

S5. Photomicrographs

S5.1 When requested by the purchaser and so stated in the order, the manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition for each individual size and wall thickness from each heat, for pipe NPS 3 and over. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be

required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as finished.

S6. Photomicrographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from each end of one or more pipes from each lot of pipe NPS 3 and larger in the as-finished condition. The purchaser shall state in the order the number of pipes to be tested from each lot. When photomicrographs are required on each length, the photomicrographs from each lot of pipe in the as-finished condition which may be required under Supplementary Requirement S5 may be omitted. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Alternative Heat Treatment—Grade P91 Type 1 and Type 2

S7.1 Grade P91 shall be normalized in accordance with Table 2 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be purchaser's responsibility to subsequently temper at 1350–1470 °F [730–800 °C] minimum. All mechanical tests shall be made on material heat treated in accordance with Table 2. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the pipe.

S8. Melting Practice—Grades P2 and P12

S8.1 Specific limits, if any, on grain size or deoxidation practice shall be a matter of agreement between the manufacturer and purchaser.

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SPECIFICATION FOR ALLOY STEEL FORGINGS FOR PRESSURE AND HIGH-TEMPERATURE PARTS



SA-336/SA-336M



(Identical with ASTM Specification A336/A336M-18.)

Standard Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts

1. Scope

1.1 This specification covers ferritic steel forgings for boilers, pressure vessels, high-temperature parts, and associated equipment.

1.2 Forgings made of steel grades listed in Specification A335/A335M, may also be ordered under this specification. The chemical, tensile, heat treatment, and marking requirements of Specification A335/A335M shall apply, except the forging shall conform to the chemical requirements of Tables 1 and 2 of Specification A335/A335M only with respect to heat analysis. On product analysis they may deviate from these limits to the extent permitted in Table 1 of this specification.

1.3 Supplementary Requirements S1 to S9 are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.5 Specification A336/A336M formerly included austenitic steel forgings, which are now found in Specification A965/A965M.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 ASTM Standards:

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A335/A335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A788/A788M Specification for Steel Forgings, General Requirements

A965/A965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts

E165/E165M Practice for Liquid Penetrant Examination for General Industry

2.2 ASME Boiler and Pressure Vessel Code:

Section III Nuclear Power Plant Components

Section IX Welding and Brazing Qualifications

2.3 AWS Specifications:

A5.5/A5.5M Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

TABLE 1 Tensile Requirements

	Ferritic Steels																			
	Grade																			
	F1	F11, Class 2	F11, Class 3	F11, Class 1	F12	F5	F5A	F9	F6	F6NM	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F91, Type 1 and Type 2	F911	F92	F3V	F3VCb	F22V
Tensile strength, ksi [MPa]	70-95 [485-660]	70-95 [485-660]	75-100 [515-690]	60-85 [415-585]	70-95 [485-660]	60-85 [415-585]	80-105 [550-725]	85-110 [585-760]	85-110 [585-760]	115-140 [790-965]	75-100 [515-690]	60-85 [415-585]	75-100 [515-690]	60-85 [415-585]	90-110 [620-760]	90-120 [620-830]	90-120 [620-830]	85-110 [585-760]	85-110 [585-760]	85-110 [585-760]
Yield strength, min, ksi [MPa]	40 [275]	40 [275]	45 [310]	30 [205]	40 [275]	36 [250]	50 [345]	55 [380]	55 [380]	90 [620]	45 [310]	30 [205]	45 [310]	30 [205]	60 [415]	64 [440]	64 [440]	60 [415]	60 [415]	60 [415]
Elongation in 2 in. or 50 mm, min, %	20	20	18	20	20	20	19	20	18	15	19	20	19	20	20	20	20	18	18	18
Reduction of area, min, %	40	40	40	45	40	40	35	40	35	45	40	45	40	45	40	40	45	45	45	45

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A788/A788M, the purchaser should include with the inquiry and order the following information:

3.1.1 A drawing or sketch that shows test locations when the testing is in accordance with 8.1.1.3.

3.1.2 The intended use of forgings if 5.1 is applicable.

3.2 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

3.4 For hubbed flatheads and tube sheets ordered for ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S12 of Specification A788/A788M shall be specified.

3.5 At the purchaser's request the forgings shall be rough machined before heat treatment (5.2).

3.6 For Section III, Part NB of the ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S3 shall be specified.

4. Melting and Forging

4.1 In addition to the melting and forging requirements of Specification A788/A788M, which may be supplemented by Supplementary Requirement S8, the following conditions apply:

4.1.1 A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

5. Machining

5.1 Forged pressure vessels for steam power service shall have the inner surface machined or ground. Unfired pressure vessels shall have the inner surfaces sufficiently free of scale to permit inspection.

5.2 Unless otherwise specified by the purchaser, when rough machining is performed, it may be done either before or after heat treatment at the manufacturer's option.

6. Heat Treatment

6.1 Except as permitted in 6.1.1 for Grade F22V, and in 6.1.2 for Grade F91 Type 1 and Type 2 and Grade F92, the steel forgings shall be annealed or normalized and tempered but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. For all grades, normalizing or liquid quenching shall be followed by tempering at a subcritical temperature as shown in 6.1.4.

6.1.1 Grade F22V forgings shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option.

6.1.1.1 For Grade F22V forgings the minimum austenitizing temperature shall be 1650 °F [900 °C].

6.1.2 Grade F91 Type 1 and Type 2 forgings having any section thickness greater than 3 in. [75 mm] shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option. Grade F92 forgings shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option.

6.1.2.1 For Grade F91 Type 1 and Type 2, F911, and F92 forgings, the austenitizing temperature shall be in the range of 1900 to 1975 °F [1040 to 1080 °C].

6.1.3 For Grade F6NM the austenitizing temperature shall be 1850 °F [1010 °C] minimum. The tempering temperature range shall be as shown in 6.1.4.

6.1.4 Except for the following grades, the minimum tempering temperature shall be 1100 °F [595 °C]:

Grade	Tempering Temperature Minimum or Range, °F [°C]
F6	1150 [620]
F6NM	1040–1120 [560–600]
F11, Class 2	1150 [620]
F11, Class 3	1150 [620]
F11, Class 1	1150 [620]
F5, F5a	1250 [675]
F9	1250 [675]
F21, Class 1	1250 [675]
F3V, F3VCb	1250 [675]
F22, Class 1	1250 [675]
F22V	1250 [675]
F91 Type 1 and Type 2, F92	1350–1470 [730–800]
F911	1365–1435 [740–780]
F22, Class 3	1250 [675]

7. Chemical Composition

7.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M and shall comply with Table 2.

7.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat. The product analysis for columbium and calcium for Grade F22V shall conform to the requirements of Table 2 of this specification. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A788/A788M.

8. Mechanical Properties

8.1 *General Requirements*—The material shall conform to the requirements for mechanical properties prescribed in Table 1. The largest obtainable tension test specimen as specified in Test Methods and Definitions A370 shall be used.

8.1.1 Except as required in 3.4, for annealed, normalized, and tempered or quenched and tempered forgings, the longitudinal axis of the tension test specimens, and, when required, Charpy impact test specimens, shall be parallel to the direction of major working of the forging, except when Supplementary Requirement S2 is specified. For upset disk forgings, the longitudinal axis of the test specimen shall be in the tangential direction.

TABLE 2 Chemical Requirements^A

Composition, %									
Element	Grade								
	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5 ^B	F5A ^B	F9	F6	F6NM
Carbon	0.20–0.30	0.10–0.20	0.05–0.15	0.10–0.20	0.15 max	0.25 max	0.15 max	0.12 max	0.05 max
Manganese	0.60–0.80	0.30–0.80	0.30–0.60	0.30–0.80	0.30–0.60	0.60 max	0.30–0.60	1.00 max	0.50–1.00
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.020
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015
Silicon	0.20–0.35	0.50–1.00	0.50–1.00	0.10–0.60	0.50 max	0.50 max	0.50–1.00	1.00 max	0.60 max
Nickel	...	...	...	...	0.50 max	0.50 max	...	0.50 max	3.5–5.5
Chromium	...	1.00–1.50	1.00–1.50	0.80–1.10	4.0–6.0	4.0–6.0	8.0–10.0	11.5–13.5	11.5–14
Molybdenum	0.40–0.60	0.45–0.65	0.44–0.65	0.45–0.65	0.45–0.65	0.45–0.65	0.90–1.10	...	0.50–1.00

Grade									
Element	F21, Classes 1 and 3		F22, Classes 1 and 3						
	Grade F91 Type 1	Grade F91 Type 2	Grade F911	Grade F92	F3V	F3VCb	F22V		
Carbon	0.05–0.15	0.05–0.15	0.09–0.13	0.07–0.13	0.10–0.15	0.10–0.15	0.11–0.15		
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60		
Phosphorus, max	0.025	0.025	0.020	0.020	0.020	0.020	0.015		
Sulfur, max	0.025	0.025	0.010	0.010	0.020	0.010	0.010		
Silicon	0.50 max	0.50 max	0.10–0.50	0.50	0.10 max	0.10 max	0.10 max		
Nickel	...	...	0.40 max	0.40	...	0.25 max	0.25 max		
Chromium	2.7–3.3	2.00–2.50	8.5–9.5	8.5–9.50	2.7–3.3	2.7–3.3	2.00–2.50		
Molybdenum	0.80–1.06	0.90–1.10	0.90–1.10	0.30–0.60	0.90–1.10	0.90–1.10	0.90–1.10		
Vanadium	...	...	0.18–0.25	0.15–0.25	0.20–0.30	0.20–0.30	0.25–0.35		
Copper	...	...	...	...	...	...	...
Nitrogen	...	...	0.04–0.09	0.030–0.070	...	...	...
Columbium ^C	...	...	0.06–0.10	0.04–0.09	...	0.015–0.070	0.07 max		
Heat Product	...	0.07–0.13	...	...	...	...	...
Manganese	0.30–0.60	0.30–0.50 ^D	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60		
Phosphorus, max	0.025	0.020 ^D	0.020	0.020	0.020	0.020	0.015		
Sulfur, max	0.025	0.005 ^D	0.010	0.010	0.020	0.010	0.010		
Silicon	0.20–0.50	0.20–0.40 ^D	0.10–0.50	0.50	0.10 max	0.10 max	0.10 max		
Nickel	0.40 max	0.20 max ^D	0.40 max	0.40	...	0.25 max	0.25 max		
Chromium	8.0–9.5	8.0–9.5 ^D	8.5–9.5	8.5–9.50	2.7–3.3	2.7–3.3	2.00–2.50		
Molybdenum	0.85–1.05	0.85–1.05	0.90–1.10	0.30–0.60	0.90–1.10	0.90–1.10	0.90–1.10		
Vanadium	0.18–0.25	0.18–0.25	0.18–0.25	0.15–0.25	0.20–0.30	0.20–0.30	0.25–0.35		
Heat Product	...	0.16–0.27	...	...	...	...	...
Columbium ^C	0.06–0.10	0.06–0.10	0.06–0.10	0.04–0.09	...	0.015–0.070	0.07 max		
Nitrogen	0.03–0.07	0.035–0.070 ^D	0.04–0.09	0.030–0.070	...	...	...
Aluminum	0.02 max ^D	0.02 max ^D	0.02 max ^D	0.02	...	...	...
Boron	...	0.001 max ^D	0.0003–0.006	0.001–0.006	0.001–0.003	...	0.0020 max		
N/Al ratio	...	≥4.0	...	...	...	...	...
Tungsten	...	0.05 max ^D	0.90–1.10	1.50–2.00	...	...	...
Titanium	0.01 max ^D	0.01 max ^D	0.01 max ^D	0.01	0.015–0.035	0.015 max	0.030 max		
Copper	...	0.10 max ^D	...	...	...	0.25 max	0.20 max		
Calcium	...	...	...	...	...	0.0005–0.0150	0.015 max ^E		
Zirconium	0.01 max ^D	0.01 max ^D	0.01 max ^D	0.01	...	...	...
Tin	...	0.010 max ^D	...	...	...	...	...
Antimony	...	0.003 max ^D	...	...	...	...	...
Arsenic	...	0.010 max ^D	...	...	...	...	...

^A Where ellipses (...) appear in this table, there is no requirement, and the element need neither be analyzed for nor reported.

^B The present Grade F5A (0.25 %, maximum carbon) previous to 1955 was assigned the identification symbol F5. Identification symbol F5 has been assigned to the 0.15 %, maximum, carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding, fittings, etc.

^C Columbium (Cb) and Niobium (Nb) are alternate names for Element 41 in the Periodic Table of the Elements.

^D Applies to both heat and product analyses.

^E For Grade F22V, rare earth metals (REM) may be added in place of calcium subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

8.1.1.1 Except as provided for liquid quenched and tempered forgings in 8.1.1.3, the longitudinal axis of the specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks or midway

between the center and surface of solid forgings. For hollow forgings, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed, as defined in

8.1.3, the tension test specimens shall be taken from a location that represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane. Alternatively, and when specified by the purchaser, the specimens shall be taken in accordance with Supplementary Requirement S3.

8.1.1.2 For liquid quenched and tempered forgings, the test specimens shall have their longitudinal axis at least $\frac{1}{4} T$ of the maximum heat-treated thickness from any surface and with the mid-length of the specimens at least one T from any second surface. This is normally referred to as $\frac{1}{4} T \times T$, where T is the maximum heat-treated thickness. A thermal buffer may be used to adhere to the above condition.

8.1.1.3 For liquid quenched and tempered forgings with prior purchaser approval, test specimens may be taken at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance ($2t$) from any second surface. However, the test depth shall not be nearer to one heat-treated surface than $\frac{3}{4}$ in. [19 mm] and to the second treated surface than $1\frac{1}{2}$ in. [38 mm]. This method of test specimen location normally (known as $tx2t$ testing) applies to thick and complex pressure vessel components where the testing in accordance with 8.1.1.2 is not practical. Sketches showing the proposed exact test locations shall be approved by the purchaser when this method is used.

8.1.2 Except as specified in this specification, tests for acceptance shall be made after heat treatment has been completed in accordance with Section 6. When the ends of the cylindrical forgings are closed in by re-forging, the cylindrical forgings may be normalized and tempered or annealed and tested before re-forging. After re-forging, the entire forging shall be re-heat treated in the same manner and at the same temperature range as employed when the forging was heat treated before certification testing.

8.1.3 When mutually agreed upon between the manufacturer and the purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same type of hot-working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than $T \times T \times 3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 1—In using separately forged test blocks, attention is drawn to the effect of mass differences between the production forgings and the test blocks. This can be particularly significant when forgings are either normalized and tempered or quenched and tempered.

8.2 *Number and Location of Tests*—The number and location of tests are based on forging length, weight, and heat treatment and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length

and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 *Annealed or Normalized and Tempered Forgings:*

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 *Quenched and Tempered Forgings:*

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 to 10 000 lb [2250 to 4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 Quenched and tempered forgings that exceed 12 ft [3.7 m] in length shall be tension tested at both ends of the forging under test.

8.2.2.4 For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension test specimens shall be taken from each forging. These shall be offset 180° from each other except that if the length of the forging, excluding test prolongations, exceeds 12 ft [3.7 m], then one specimen shall be taken from each end of the forging.

8.3 *Notch Toughness Requirements—Grades F3V, F3VCb, F22V, and F6NM:*

8.3.1 Impact test specimens shall be Charpy V-notch, as shown in Test Methods and Definitions A370. The usage of subsized specimens due to material limitations must have prior purchaser approval.

8.3.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 8.1 and 8.2. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

8.3.3 The longitudinal axis and mid-length of impact specimens shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat treated surface of the forging.

8.3.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft-lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft-lbf [54 J] and it shall meet a minimum value of 35 ft-lbf [48 J].

8.3.5 The impact test temperature shall be not warmer than 0 °F [−18 °C].

8.3.6 Unless Supplementary Requirement S13 of Specification A788/A788M is specified by the purchaser, for Grade F6NM forgings a minimum average absorbed energy of 20 ft-lbf [27 J] for each test shall apply at a temperature not warmer than −100 °F [−73 °C].

9. Ultrasonic Examination

9.1 For F91 Type 1 and Type 2 and F92 hollow forgings, either S20, Ultrasonic Examination, or S22, Ultrasonic Examination from the Bore Surface, of Specification A788/A788M, shall be mandatory.

10. Workmanship, Finish, and Appearance

10.1 When forgings have been heat treated by quenching and tempering, all accessible surfaces shall subsequently be examined for quench cracks by the magnetic particle method in accordance with Practice A275/A275M.

11. Repair Welding

11.1 Repair welding of forgings may be permitted but only at the option of the purchaser. Such repair welds shall be made in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

11.2 All repair welds in F91 Type 1 and Type 2 shall be made with one of the following welding processes and consumables: SMAW, SFA 5.5 E90XX-B9; SAW, SFA 5.23 EB9 + flux; GTAW, SFA 5.28 ER90S-B9; and FCAW 5.29 E91T1-B9.

In addition, the sum of the Ni+Mn content of all welding consumables used to fabricate F91 Type 1 and Type 2 forgings shall not exceed 1.0 %.

11.3 All repair welds in F92 shall be made with one of the following processes: SMAW, SAW, GTAW, or FCAW; and the composition of the welding consumables shall meet the requirements for F92 in Table 2.

12. Marking

12.1 In addition to the marking requirements of Specification A788/A788M, the specification marking shall be followed by the letter A for annealed, N for normalized and tempered, or Q for liquid quenched and tempered as applicable.

12.2 For F91 additional marking shall include the appropriate Type.

13. Test Reports

13.1 The certification requirements of Specification A788/A788M shall apply.

14. Keywords

14.1 chromium alloy steel; chromium-molybdenum steel; martensitic stainless steel; pressure containing parts; pressure vessel service; steel forgings—alloy; temperature service applications—high

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be specified.

S2. Transverse Mechanical Testing

S2.1 Instead of test specimens taken in accordance with 8.1.1, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The tension test results shall conform with requirements of Table 1, with the exception of the ductility limits which shall be as prescribed in Table S2.1. When required, the Charpy impact test results shall conform to 8.3.

S3. Alternative Test Specimen Requirements

S3.1 The test requirements for materials of the ASME Boiler and Pressure Code, Section III, Article NB-2223.3, shall be used in place of that specified in 8.1.1.1.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S6. Liquid Penetrant Examination

S6.1 After forgings have been heat treated by quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Practice E165/E165M as an alternative to magnetic particle examination.

S7. Marking

S7.1 Forgings shall be marked at a location indicated by the purchaser in the purchase order or drawing.

TABLE S2.1 Ductility Limits

	Grade																			
	F1	F11, Class 2	F11, Class 3	F11, Class 2	F12	F5	F5A	F9	F6	F6NM	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F3V	F46	F22V	F91 Type 1 and Type 2	F911	F92
Elongation in 2 in. or 50 mm, min, %	20	18	18	19	18	19	19	18	18	14	18	19	18	20	17	40	17	19	16	16
Reduction of area, min, %	30	35	30	40	25	35	35	35	35	40	35	35	25	35	35	50	35	40	30	30

S8. Forging Requirements

S8.1 Large drum forgings shall be made from solid cast ingots, punched, bored, or trepanned, or from hollow ingots cast in metal molds. The walls of the hollowed or hollow ingots shall be reduced in thickness at least one-half by forging on mandrels.

S8.2 Drum forgings with one solid closed end may be hollow forged in closed dies or on a draw bench provided the metal is worked thoroughly.

S8.3 Drum forgings, either with open ends or one solid closed end, may also be produced by hot extrusion provided the metal is worked thoroughly.

S8.4 Small drum forgings may be made as solid forgings, subsequently bored, provided the purchaser agrees to this method of forging. The cross-sectional area of the solid forgings shall have a reduction by forging from that of the ingot in the ratio of not less than 3:1.

S8.5 Small sections or component parts of pressure vessels, which are to be subsequently assembled to form drums, may be made by expanding on a mandrel under a press or hammer, by hot extrusion or by ring rolling methods, provided the wall thickness is reduced at least one-half in the process.

S8.6 Heads or covers shall be forged as disks, upset from blocks cut from ingots or billets. The length of block before upsetting shall be at least twice the thickness of the as-forged head or cover.

S9. Individual Forging

S9.1 Forgings, whether identical or not identical, shall be produced individually. They shall not be forged in multiple and separated prior to or after heat treatment.

S9.2 The shape and size of individual forgings shall be agreed between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

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SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL FORGINGS, REQUIRING NOTCH TOUGHNESS TESTING FOR PIPING COMPONENTS



SA-350/SA-350M

(Identical with ASTM Specification A350/A350M-02b except for the deletion of 6.1.2 and 14.1, revision to 14.2.5, and test reports have been made mandatory.)

SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL FORGINGS, REQUIRING NOTCH TOUGHNESS TESTING FOR PIPING COMPONENTS



SA-350/SA-350M

(Identical with ASTM Specification A 350/A 350M-02b except for the deletion of 6.1.2 and 14.1, revision to 14.2.5, and test reports have been made mandatory.)

1. Scope

1.1 This specification covers several grades of carbon and low-alloy steel forged or ring-rolled flanges, forged fittings and valves intended primarily for low-temperature service and requiring notch toughness testing. They are made to specified dimensions, or to dimensional standards, such as the ASME and API Specifications referenced in Section 2. Although this specification covers some piping components machined from rolled bar and seamless tubular materials (see 5.3.3), it does not cover raw material produced in these product forms.

1.2 No limitation on size is intended beyond the ability of the manufacturer to obtain the specified requirements. However, Class 3 of Grade LF787 is only available in the quenched-and-precipitation heat treated condition.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1 — Refer to Test Methods and Definitions A 370 for notes on significance of notched-bar impact testing.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 788 Specification for Steel Forgings, General Requirements
- A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.2 ASME Standards:

- B 16.5 Steel Pipe Flanges and Flanged Fittings
- B 16.9 Factory-Made Wrought Steel Butt-Welding Fittings
- B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
- B 16.11 Forged Steel Fittings, Socket-Welding and Threaded
- B 16.30 Unfired Pressure Vessel Flange Dimensions
- B 16.34 Valves-Flanged, Threaded, and Welding End
- B 16.47 Large Diameter Steel Flanges

2.3 ASME Boiler and Pressure Vessel Code: Section IX Welding Qualifications

2.4 AWS Standards:

- A 5.1 Mild Steel Covered Arc-Welding Electrodes
- A 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

2.5 API Standards:

- 600 Steel Gate Valves with Flanged or Butt-Welding Ends
- 602 Compact Design Carbon Steel Gate Valves for Refinery Use
- 605 Large Diameter Carbon Steel Flanges

3. Ordering Information

3.1 It is the purchaser’s responsibility to specify in the purchase order information necessary to purchase the

needed material. In addition to the ordering information guidelines in Specification A 961, orders should include the following information:

3.1.1 Additional requirements (see Table 1 footnotes).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

5. Manufacture

5.1 Melting Process — The steel shall be produced by any of the following primary processes: open-hearth, basic oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslag remelting (ESR), or vacuum-arc remelting (VAR).

5.1.1 The steel shall be fully killed, fine-grain practice.

5.1.2 The molten steel may be vacuum treated prior to or during pouring of the ingot.

5.2 Discard — A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

5.3 Forging Process:

5.3.1 Material for forgings shall consist of ingots, or forged, rolled, or strandcast blooms, billets, slabs, or bars.

5.3.2 The finished product shall be a forging as defined in the Terminology section of Specification A 788.

5.3.3 Except for flanges of all types, hollow, cylindrically-shaped parts may be machined from rolled bar or seamless tubular materials provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, may be machined from hot-rolled or forged bar up through and including NPS 4. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.4 Heat Treatment:

5.4.1 After hot working and before reheating for heat treatment, the forging shall be allowed to cool substantially below the transformation range.

5.4.2 Forgings of grades other than Grade LF787 shall be furnished in the normalized, or in the normalized and tempered, or in the quenched and tempered condition described by the following procedures:

5.4.2.1 Normalize — Heat to a temperature that produces an austenitic structure, holding sufficient time to attain uniform temperature throughout. Cool uniformly in still air.

5.4.2.2 Normalize and Temper — Subsequent to normalize, reheat to 1100°F [590°C] minimum, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness, but in no case less than 30 min. Cool in still air.

5.4.2.3 Quench and Temper — The procedure for quenching shall consist of either (1) fully austenitizing the forgings followed by quenching in a suitable liquid medium or (2) using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially reaustenitize, followed by quenching in a suitable liquid medium. All quenched forgings shall be tempered by reheating to a temperature between 1100°F [590°C] and the lower transformation temperature, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness but in no case less than 30 min. Cool in still air.

5.4.3 Grade LF787 forgings shall be furnished in either the normalized-and-precipitation heat treated condition or in the quenched-and-precipitation heat treated condition. The heat treatment procedures shall be as follows:

5.4.3.1 Normalized-and-Precipitation Heat Treated — Heat to a temperature in the range from 1600 to 1725°F [870 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than ½ h, and remove from the furnace and cool in air. Subsequently, heat to a temperature in the range from 1000 to 1200°F [540 to 650°C], soak at the temperature for not less than ½ h, and cool at any convenient rate.

5.4.3.2 Quenched-and-Precipitation Heat Treated — Heat to a temperature in the range from 1600 to 1725°F [879 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than ½ h and quench in a suitable liquid medium by immersion; reheat to a temperature in the range from 1000 to 1225°F [540 to 665°C], hold at the temperature for not less than ½ h, and cool at any convenient rate.

6. Chemical Composition

6.1 Heat Analysis:

6.1.1 A chemical heat analysis in accordance with Specification A 961 shall be made and conform to the

requirements as to chemical composition prescribed in Table 1. Lead steels shall not be permitted.

6.1.2 DELETED

6.2 Product Analysis:

6.2.1 The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A 961.

7. Mechanical Properties

7.1 Tension Tests:

7.1.1 Requirements — The material shall conform to requirements for tensile properties in Table 2.

7.1.1.1 The test specimen shall be obtained from a rough or finished forging, or prolongation thereof. For forgings under 10 000 lbs, at time of heat treatment, it may be obtained from separately forged test blanks from the same heat of steel as the production forgings. The test blank shall be reduced by forging in a manner similar to that for the products represented, and shall receive approximately the same hot working and reduction and the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 7.1.2.1.

7.1.1.2 The test specimen shall represent all forgings from the same heat and heat-treatment load whose maximum thicknesses do not exceed the thickness of the test forging or blank by more than $\frac{1}{4}$ in. [6 mm].

7.1.2 Number of Tests — One tension test at room temperature shall be made in accordance with 7.1.1.2 from each heat in each heat-treatment load.

7.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within $\pm 25^\circ\text{F}$ [$\pm 14^\circ\text{C}$] of the required heat-treatment temperature and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat-treating cycles are used on the forgings represented by the tension test, then one tension test from each heat shall be required, instead of one tension test from each heat in each heat treatment load in accordance with 7.1.1.2.

7.1.3 Test Locations and Orientations — The test specimen shall be removed from the heaviest section of the forging or test blank, at locations described in 7.1.3.1, 7.1.3.2, 7.1.3.5 or as close to these locations as practical, subject to forging size and geometry.

7.1.3.1 For forgings or test blanks having a maximum heat-treated thickness, T , of 2 in. [50 mm] or less, the longitudinal axis of the test specimen shall be taken at mid-thickness and its mid-length shall be at least 2 in. [50 mm] from a second heat treated surface, exclusive of the

T dimension surfaces. (This is normally referred to as $\frac{1}{2} T$ by 2 in. [50 mm]).

7.1.3.2 For forgings or test blanks having a maximum heat-treated thickness, T , greater than 2 in. [50 mm], the central axis of the test specimen shall be taken at least $\frac{1}{4} T$ from the nearest heat-treated surface and at least T or 4 in. [100 mm], whichever is less, from any second heat-treated surface. For quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat-treated surface. See Fig. 1 for test specimen location in separately forged test blanks for quenched and tempered forgings.

7.1.3.3 Metal Buffers — The required distances from heat treated surfaces may be obtained with metal buffers instead of integral expansions. Buffer material may be carbon or low alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at $\frac{1}{2}$ in. [13 mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to assure freedom from cracks unless the welded areas are completely removed by subsequent machining.

7.1.3.4 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank.

7.1.3.5 With prior purchaser approval, tests may be taken at a depth (t) corresponding to the distance from the area of significant loading to the nearest heat treated surface and at least twice this distance ($2t$) from any second surface. However, the test depth shall not be nearer to one treated surface than $\frac{3}{4}$ in. [19 mm] and to the second treated surface than $1\frac{1}{2}$ in. [38 mm]. This method of test location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where $\frac{1}{4} T \times T$ testing (7.1.3.2) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

7.1.4 Test Method — Testing shall be performed in accordance with Test Methods and Definitions A 370. The test specimen shall be as large as is practicable and shall be machined to the form and dimensions of Fig. 5 of Test Methods and Definitions A 370. When seamless tubular materials are used, testing shall be performed on longitudinal specimens in accordance with Annex A2, Steel Tubular Products, of Test Methods and Definitions A 370.

7.2 Impact Test:

7.2.1 Requirements — The material shall conform to the requirements for impact properties in Table 3 when tested at the applicable standard temperature in Table 4 within the limits of 7.2.4.2 and 7.2.4.3. When subsize specimens are used, the impact energy values obtained

shall conform to Table 5 at energy values proportional to standard size. Exceptions to this requirement are permissible when Supplementary Requirement S1 is specified by the purchaser. Impact tests may be made at temperatures different from those in Table 4, provided that the test temperature is at least as low as the intended service temperature, and that the forging is suitably marked to identify the reported test temperature.

7.2.1.1 The test specimens shall be machined from material obtained as in 7.1.

7.2.2 Number of Tests — Three specimens shall constitute one test set. There shall be the same number of test sets as tension tests in 7.1.2.

7.2.3 Test Locations and Orientations — The test specimen shall be located and oriented as described in 7.1.3. The area under the notch of the impact test specimen shall be used to locate the specimen with respect to the second heat-treated surface. The base of the notch shall be perpendicular to the nearest heat-treated surface.

7.2.4 Test Method — The notched bar impact test shall be made in accordance with the procedure for the Charpy V-notch type test as described in Test Methods and Definitions A 370.

7.2.4.1 Standard size specimens shown in Fig. 11 of Test Methods and Definitions A 370 shall be used for the impact test. Where the material is of insufficient thickness, or the shape of the forging precludes standard size, the largest obtainable subsize specimen described in Test Methods and Definitions A 370 shall be used.

7.2.4.2 Where subsize specimens are used and represent forged material with thicknesses equal to or greater than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 8 mm, such specimen shall be tested at the temperature in Table 4. Where the largest obtainable specimen has a width along the notch less than 8 mm, the temperature for testing shall be lower than the temperature in Table 4 by the amount shown in Table 6 for the actual specimen width tested.

7.2.4.3 Where subsize specimens are used and represent forged material with thicknesses less than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 80% of the forging thickness, the specimen shall be tested at the temperature in Table 4. Where the largest obtainable specimen has a width along the notch of less than 80% of the material thickness, the temperature for testing shall be lower than the temperature in Table 4 by an amount equal to the difference (referring to Table 6) between the temperature reduction corresponding to the thickness of the material represented, and the temperature reduction corresponding to the specimen width actually tested.

7.3 Hardness Test:

7.3.1 Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 7.1.2.1 to ensure that hardness of the forgings does not exceed 197 HB after heat treatment for mechanical properties. The hardness measurements shall be made in accordance with Test Methods and Definitions A 370. When only one forging is produced, it shall be hardness tested to ensure that it meets the 197 HB maximum of this specification. The purchaser may verify that this requirement has been met by testing at any location on the forging, provided that such testing does not render the forging useless.

8. Hydrostatic Test

8.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished item. Such tests shall be conducted by the manufacturer only when Supplementary Requirement S57 of Specification A 961 is specified.

9. Workmanship, Finish, and Appearance

9.1 Forgings shall conform to the requirements of Specification A 961.

10. Retests

10.1 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

11. Rework and Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

11.2 Individually tested forgings meeting all requirements shall be acceptable.

11.3 Repair by Welding — Weld repairs shall be permitted (see Supplementary Requirement S58 of Specification A 961) at the discretion of the manufacturer with the following limitations and requirements:

11.3.1 Repair by welding shall be made using welding procedures and welders qualified in accordance with ASME Section IX of the Code. The weld procedure qualification test shall also include impact tests of the weld metal and heat-affected zone. All impact test specimens shall have the longitudinal axis transverse to the weld and the base of the notch normal to the weld surface. Weld

specimens shall have the notch in weld metal and heat-affected zone specimens shall have the notch in the heat-affected zone. The specimens shall be as large as permitted by the weldment thickness. Where full-size specimens can be obtained and where there is sufficient weldment thickness, the weld specimen shall be taken with one side of the specimen within $\frac{1}{16}$ in. [1.6 mm] of the weld surface. Heat-affected zone impact test specimens shall be taken at the same depth and locations applicable to the forging in 7.1.3.1 and 7.1.3.2. When forgings are thermally treated after repair welding, the weld procedure test plate shall be subjected to the same thermal treatment. The mechanical properties of the weld procedure qualification test shall conform to Section 7.

11.3.2 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle, or liquid penetrant inspection prior to welding.

11.3.3 For Grade LF1 forgings, and LF2 forgings that are to be only stress-relieved after repair welding, the weld metal shall be deposited using carbon steel electrodes E 7015, E 7016, or E 7018, complying with AWS A 5.1. For Grade LF2 forgings in all other conditions of post-weld heat treatment, the weld metal shall be deposited using low-alloy steel electrodes E 7015-A1; E 7016-A1, or E 7018-A1 complying with AWS 5.5; for Grade LF3 forgings the weld metal shall be deposited using low-alloy steel electrodes E 8016-C2 or E 8018-C2 complying with AWS A 5.5; for Grades LF5, LF9, and LF787 forgings, the weld metal shall be deposited using low-alloy steel electrodes E 8016-C1 or E 8018-C1 complying with AWS A 5.5. For Grade LF6, the electrodes shall be low-hydrogen, E-XX15, E-XX16, or E-XX18 complying with AWS A 5.1 or A 5.5, as applicable.

11.3.4 After repair welding, the area welded shall be completely free of defects as verified by magnetic particle or liquid penetrant inspection.

11.3.5 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100°F [590°C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be reheat treated in accordance with 5.4.

11.3.6 When the purchaser specifies Supplementary Requirement S5, the same requirements shall apply to the weld procedure qualification tests.

11.3.7 Repair by welding shall not exceed 10% of the surface area of the forging or $33\frac{1}{3}\%$ of the wall thickness of the finished forging, or $\frac{3}{8}$ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

11.3.8 When approval of the purchaser is obtained, the limitations set forth in 11.3.7 may be exceeded, but all other requirements of 11.3 shall apply.

12. Inspection

12.1 Inspection provisions of Specification A 961 shall apply.

13. Rejection and Rehearing

13.1 Purchaser shall comply with provisions of Specification A 961.

14. Certification

14.1 DELETED

14.2 Test reports are required, they shall include certification that all requirements of this specification have been met, and shall be traceable to the forging represented. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

14.2.1 Type heat treatment, Section 5,

14.2.2 Chemical analysis results, Section 6 (Table 1),

14.2.3 Product analysis results, 6.2 (Table 1),

14.2.4 Tensile property results, Section 7 (Table 2) report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

14.2.5 Impact test results, 7.2 (Table 3, Table 4, Table 5, and Table 6), including specimen size if subsized samples were used,

14.2.6 Hardness results, 7.3.1,

14.2.7 Any supplementary testing required by the purchase order, and

14.2.8 If repaired by welding, letter W is to follow the ASTM designation.

15. Product Marking

15.1 In addition to the marking requirements of Specification A 961, manufacturer's name (see Note 2) or symbol shall be permanently marked on each forging.

NOTE 2 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

15.1.1 If the forgings have been quenched and tempered or quenched-and-precipitation heat treated, the letters QT shall be stamped on the forgings following the ASTM designation.

15.1.2 Forgings repaired by welding shall be marked with the letter W following the ASTM designation.

15.2 If identification stamps are objectionable and detrimental to the forging, and when so stated on the purchase

order, the marks may be painted or stenciled on the forging, or stamped on a metal or plastic tag which shall be securely attached to the forging.

15.3 When test reports are required, additional marks shall be used as necessary to identify the part with the test report.

15.4 If the test temperature is other than the standard temperature specified in Table 4, the mark shall also include the suffix letter S to the grade and class and the test temperature. A prefix 0 to the test temperature shall indicate a less than 0°F [-18°C] value. For example, LF2S 0175 denotes a test temperature of -175°F [-115°C] for an LF2 part.

15.5 Parts meeting all requirements for more than one class may be marked with more than one class such as LF2 CL1/CL2; LF5 CL1/CL2, and so forth.

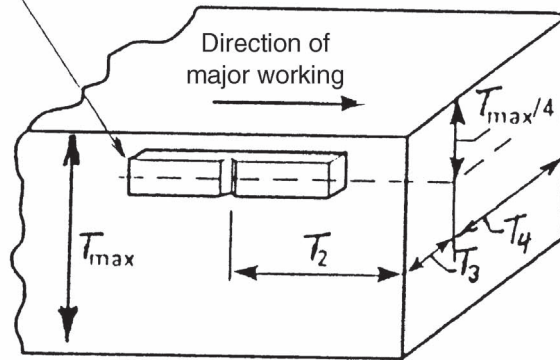
15.6 Bar Coding — In addition to the requirements in 15.1, 15.2, 15.3, 15.4, and 15.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

16. Keywords

16.1 carbon equivalent; pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, alloy; steel forgings, carbon; steel valves; temperature service applications, low

FIG. 1 TEST SPECIMEN LOCATION FOR QUENCHED AND TEMPERED FORGINGS

Tensile or impact test specimen
(Impact test specimen shown in Fig. 1)



NOTE 1 — For material with thickness T greater than 2 in. [50 mm], $T_2 = T_3 = T_4 \geq T_{\max}$
where:
 T_{\max} = maximum heat treated thickness

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, wt. %						
	Grade LF1	Grade LF2	Grade LF3	Grade LF5	Grade LF6	Grade LF9	Grade LF787
Carbon, max	0.30	0.30	0.20	0.30	0.22	0.20	0.07
Manganese	0.60–1.35	0.60–1.35	0.90 max	0.60–1.35	1.15–1.50	0.40–1.06	0.40–0.70
Phosphorus, max	0.035	0.035	0.035	0.035	0.025	0.035	0.025
Sulfur, max	0.040	0.040	0.040	0.040	0.025	0.040	0.025
Silicon ^A	0.15–0.30	0.15–0.30	0.20–0.35	0.20–0.35	0.15–0.30	...	0.40 max
Nickel	0.40 max ^B	0.40 max ^B	3.3–3.7	1.0–2.0	0.40 max ^B	1.60–2.24	0.70–1.00
Chromium	0.30 max ^{B,C}	0.30 max ^{B,C}	0.30 max ^C	0.30 max ^C	0.30 max ^{B,C}	0.30 max ^C	0.60–0.90
Molybdenum	0.12 max ^{B,C}	0.12 max ^{B,C}	0.12 max ^C	0.12 max ^C	0.12 max ^{B,C}	0.12 max ^C	0.15–0.25
Copper	0.40 max ^B	0.40 max ^B	0.40 max ^C	0.40 max ^C	0.40 max ^B	0.75–1.25	1.00–1.30
Columbium	0.02 max	0.02 max	0.02 max	0.02 max	0.02 max	0.02 max	0.02 min
Vanadium	0.08 max	0.08 max	0.03 max	0.03 max	0.04–0.11	0.03 max	0.03 max
Nitrogen	...	...	...	...	0.01–0.030	...	...

^A When vacuum carbon-deoxidation is required by Supplementary Requirement S4, the silicon content shall be 0.12% maximum.

^B The sum of copper, nickel, chromium, vanadium, and molybdenum shall not exceed 1.00% on heat analysis.

^C The sum of chromium and molybdenum shall not exceed 0.32% on heat analysis.

TABLE 2
TENSILE PROPERTIES AT ROOM TEMPERATURE^A

	Grades							
	LF1 and LF5 Class 1	LF2 Classes 1 and 2	LF3 Classes 1 and 2 LF5 Class 2	LF6		LF9	LF787	
				Class 1	Classes 2 and 3		Class 2	Class 3
Tensile strength, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	70–95 [485–655]	66–91 [455–630]	75–100 [515–690]	63–88 [435–605]	65–85 [450–585]	75–95 [515–655]
Yield strength, min, ksi [MPa] ^{B,C}	30 [205]	36 [250]	37.5 [260]	52 [360]	60 [415]	46 [315]	55 [380]	65 [450]
Elongation:								
Standard round specimen, or small proportional specimen, min % in 4D gage length	25	22	22	22	20	25	20	20
Strip specimen for wall thickness $\frac{5}{16}$ in. (7.94 mm) and over and for all small sizes tested in full section; min % in 2 in. (50 mm)	28	30	30	30	28	28	28	28
Equation for calculating min elongation for strip specimens thinner than $\frac{5}{16}$ in. (7.94 mm); min % in 2 in. (50 mm) <i>t</i> = actual thickness in inches	$48t + 13$	$48t + 15$	$48t + 15$	$48t + 15$	$48t + 13$	$48t + 13$	$48t + 13$	$48t + 13$
Reduction of area, min, %	38	30	35	40	40	38	45	45

^A See 7.3 for hardness tests.

^B Determined by either the 0.2% offset method or the 0.5% extension under load method.

^C For round specimens only.

TABLE 3
CHARPY V-NOTCH ENERGY REQUIREMENTS FOR STANDARD SIZE [10 by 10 mm] SPECIMENS

Grade	Minimum Impact Energy Required for Average of Each Set of Three Specimens, ft-lbf [J]	Minimum Impact Energy Permitted for One Specimen only of a Set, ft-lbf [J]
LF1 and LF9	13 [18]	10 [14]
LF2, Class 1	15 [20]	12 [16]
LF3, Class 1	15 [20]	12 [16]
LF5, Class 1 and 2	15 [20]	12 [16]
LF787, Classes 2 and 3	15 [20]	12 [16]
LF6, Class 1	15 [20]	12 [16]
LF2, Class 2	20 [27]	15 [20]
LF3, Class 2	20 [27]	15 [20]
LF6, Classes 2 and 3	20 [27]	15 [20]

TABLE 4
STANDARD IMPACT TEST TEMPERATURE FOR
STANDARD SIZE [10 by 10 mm] SPECIMENS

Grade	Test Temperature, °F [°C]
LF1	-20 [-29]
LF2, Class 1	-50 [-46]
LF2, Class 2	0 [-18]
LF3, Classes 1 and 2	-150 [-101]
LF5, Classes 1 and 2	-75 [-59]
LF6, Classes 1 and 2	-60 [-51]
LF6, Class 3	0 [-18]
LF9	-100 [-73]
LF787, Class 2	-75 [-59]
LF787, Class 3	-100 [-73]

TABLE 5
MINIMUM EQUIVALENT ABSORBED ENERGY FT-LBF (J) FOR VARIOUS
SPECIMEN SIZES^A

Standard Size [10 by 10 mm]	$\frac{3}{4}$ Size [10 by 7.5 mm]	$\frac{2}{3}$ Size [10 by 6.6 mm]	$\frac{1}{2}$ Size [10 by 5 mm]	$\frac{1}{3}$ Size [10 by 3.3 mm]	$\frac{1}{4}$ Size [10 by 2.5 mm]
15 [20]	12 [16]	10 [14]	8 [11]	5 [7]	4 [6]
13 [18]	10 [14]	9 [12]	7 [10]	5 [7]	4 [6]
12 [16]	10 [14]	9 [12]	7 [10]	4 [6]	3 [5]
10 [14]	8 [11]	7 [10]	5 [7]	3 [5]	3 [5]

^A Straight-line interpolation for intermediate values is permitted.

TABLE 6
CHARPY IMPACT TEST TEMPERATURE REDUCTION BELOW TABLE 5 TEST
TEMPERATURE WHEN THE SUBSIZE CHARPY IMPACT WIDTH ALONG NOTCH IS
LESS THAN 80% OF THE FORGING THICKNESS

Size of Bar	Thickness of the Material Represented (see 7.2.4.3), or Charpy, Impact Specimen Width Along the Notch ^A , in. [mm]	Temperature Reduction, °F [°C]
Standard	0.394 [10]	0 [0]
Standard	0.354 [9]	0 [0]
Standard	0.315 [8]	0 [0]
$\frac{3}{4}$ -size	0.295 [7.5]	5 [3]
$\frac{3}{4}$ -size	0.276 [7]	8 [5]
$\frac{2}{3}$ -size	0.262 [6.67]	10 [6]
$\frac{2}{3}$ -size	0.236 [6]	15 [8]
$\frac{1}{2}$ -size	0.197 [5]	20 [11]
$\frac{1}{2}$ -size	0.158 [4]	30 [17]
$\frac{1}{3}$ -size	0.131 [3.33]	35 [20]
$\frac{1}{3}$ -size	0.118 [3]	40 [22]
$\frac{1}{4}$ -size	0.099 [2.5]	50 [28]

^A Straight-line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

In addition to any supplementary requirements of Specification A 961, the following supplementary requirements shall apply only when specified by the purchaser in the order:

S1. Other Impact Test Temperatures

S1.1 Impact test temperatures lower or higher than the standard temperature in Table 4 of this specification shall be used.

S1.1.1 When higher test temperatures are employed, the actual test temperature may not be higher than that given in Table S1.1.1.

S1.2 The test temperature shall be specified by the purchaser. When subsize specimens are used, the manufacturer shall adjust the test temperature in accordance with the size restrictions of 7.2.4.2 and 7.2.4.3.

S1.3 The forging shall be marked with the specified test temperature in accordance with 15.4. A lower temperature shall not be marked on the forging because of the use of subsize specimens.

S1.4 The test results shall comply with Table 3 for standard size specimens, and with Table 5 for subsize specimens.

S2. Stress-Relieved Test Specimens

S2.1 The test specimens shall be stress relieved. Stress relieving shall be done after heat treatment in 5.4 and before machining the specimens from the heat-treated test material.

S2.2 The purchaser shall furnish the forging manufacturer with details of the stress-relief treatment desired.

S3. Lateral Expansion

S3.1 Lateral expansion of the Charpy V-notch test in accordance with Section 25 of Test Methods and Definitions A 370 shall be measured and reported.

S4. Vacuum Carbon-Deoxidized Steels

S4.1 Material made to Grades LF1, LF2, LF3, LF5, and LF9 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.12% maximum. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S5. Special Impact Test Requirements for Flanges (Note S5.1)

S5.1 Charpy test specimens shall be cut from an actual flange representing each size, heat, and heat-treatment lot. If more than one size flange is represented by the same heat and heat-treatment lot, the maximum size flange shall be considered representative.

S5.2 The number, location, and orientation of the test specimens shall be stated on the order.

S5.3 The test results shall comply with Table 3 for standard size specimens, and with Table 5 for subsize specimens.

NOTE S5.1 — These special requirements should be considered for services when the applied stresses approach the maximum permissible limits of the governing code, or the installation is subject to severe cyclic conditions (7000 or more cycles over the expected life of the installation), or both.

S6. Carbon Equivalent

S6.1 The maximum carbon equivalent based on heat analysis shall be as shown in Table S6.1.

S6.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S6.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

TABLE S1.1.1
MAXIMUM SUPPLEMENTAL TEST
TEMPERATURES

Grade	Maximum Test Temperature, °F (°C)
LF1	-10 [-23]
LF2, Class 1	-35 [-37]
LF3, Classes 1 and 2	-125 [-87]
LF5, Classes 1 and 2	-60 [-51]
LF6, Classes 1 and 2	-40 [-40]
LF9	-80 [-62]
LF787, Class 2	-60 [-51]
LF787, Class 3	-80 [-62]
LF2, Class 2	+10 [-12]
LF6, Class 3	+10 [-12]

TABLE S6.1
MAXIMUM CARBON EQUIVALENT VALUE

Grade	Max. Thickness Less Than or Equal to 2 in.	Max. Thickness Greater Than 2 in.
LF1	0.45	0.46
LF2 CL1 and CL2	0.47	0.48
LF6 CL1	0.45	0.46
LF6 CL2	0.47	0.48

**SPECIFICATION FOR CASTINGS, AUSTENITIC,
AUSTENITIC-FERRITIC (DUPLEX), FOR
PRESSURE-CONTAINING PARTS**



SA-351/SA-351M



(Identical with ASTM Specification A351/A351M-00.)

SPECIFICATION FOR CASTINGS, AUSTENITIC, AUSTENITIC-FERRITIC (DUPLEX), FOR PRESSURE-CONTAINING PARTS



SA-351/SA-351M



(Identical with ASTM Specification A 351/A 351M-00.)

1. Scope

1.1 This specification covers austenitic and austenitic-ferritic (duplex) steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1).

NOTE 1 — Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M, and low-alloy steel castings by Specification A 217/A 217M.

1.2 A number of grades of austenitic and austenitic-ferritic steel castings are included in this specification. Since these grades possess varying degrees of suitability for service at high temperatures or in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and high-temperature or corrosion-resistant characteristics, or both.

1.2.1 Because of thermal instability, Grades CE20N, CF3A, CF3MA, and CF8A are not recommended for service at temperatures above 800°F [425°C].

1.2.2 Because of embrittlement phases, Grade CD4MCu is not recommended for service at temperatures above 600°F [316°C].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E 165 Test Method for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturers Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Components (Visual Method)

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 The post weld heat treatment requirements of Supplementary Requirement S11 may be specified when austenitic castings other than HK, HT, or CT15C are to be subjected to severe corrosive service.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing).

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 Supplementary requirements desired, including the standards of acceptance.

5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 All castings shall receive a heat treatment at the temperature specified in Table 1, followed by a quench in water or rapid cool by other means except as noted.

NOTE 2 — Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

8. Tensile Properties

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and

hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP 55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²], shall be radiographed to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S6 specified, weld repairs shall be inspected by liquid penetrant examination to the same standards that are used to inspect the castings.

NOTE 3 — When austenitic steel castings are to be used in services where they will be subject to stress corrosion, the purchaser should so indicate in his order and such castings should be solution-heat treated following all weld repairs.

11. Keywords

11.1 austenitic stainless steel; duplex stainless steel; pressure containing parts; stainless steel; steel castings

TABLE 1
HEAT-TREATMENT REQUIREMENTS

Grade	Temperature, min	
	°F	°C
HK30, HK40, HT30, CT15C	as-cast	as-cast
CF3, CF3A, CF8, CF8A, CF3M, CF3MA, CF8M, CF3MN, CG3M, CF10, CF10M, CG8M, CD4MCu	1900	1040
CF10SMnN, CF8C, CF10MC	1950	1065
CD3MWCuN	2010	1100
CN7M, CG6MMN, CE8MN	2050	1120
CK3MCuN, CN3MN, CH8, CH10, CH20, CK20	2100	1150
CE20N ^A	2225	1220

^A Grade shall be quenched in water or the castings may be furnace cooled to 2050°F [1120°C] minimum, held for 15 min minimum and then quenched in water or rapidly cooled by other means.

TABLE 2
CHEMICAL REQUIREMENTS

Element, % (max, except where range is given)	CF3, CF3A	CF8, CF8A	CF3M, CF3MA	CF8M	CF3MN	CF8C	CF10	CF10M (J92901)	CH8	CH10	CH20	CK20	HK30	HK40
Carbon	0.03	0.08	0.03	0.08	0.03	0.08	0.04–0.10	0.04–0.10	0.08	0.04–0.10	0.04–0.20	0.04–0.20	0.25–0.35	0.35–0.45
Manganese	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Silicon	2.00	2.00	1.50	1.50	1.50	2.00	2.00	1.50	1.50	2.00	2.00	1.75	1.75	1.75
Sulfur	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Phosphorus	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Chromium	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	18.0–21.0	18.0–21.0	22.0–26.0	22.0–26.0	22.0–26.0	23.0–27.0	23.0–27.0	23.0–27.0
Nickel	8.0–12.0	8.0–11.0	9.0–13.0	9.0–12.0	9.0–13.0	9.0–12.0	8.0–11.0	9.0–12.0	12.0–15.0	12.0–15.0	12.0–15.0	19.0–22.0	19.0–22.0	19.0–22.0
Molybdenum	0.50	0.50	2.0–3.0	2.0–3.0	2.0–3.0	0.50	0.50	2.0–3.0	0.50	0.50	0.50	0.50	0.50	0.50
Columbium (Niobium)	...	...	...	...	...	^B	...	...	...	...	...	...	...	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nitrogen	...	...	...	...	0.10–0.20	...	...	...	...	...	...	...	...	...
Copper	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Tungsten	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Iron	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Note 1 — Tungsten is a new element for Table 2.

TABLE 2
CHEMICAL REQUIREMENTS (CONT'D)

Element, % (max, except where range is given)	HT30	CF10MC	CN7M	CN3MN	CD4MCu	CE8MN	CG6MMN	CG8M	CF10S- MnN	CT15C	CK3MCuN	CE20N	CG3M (J92999)	CD3M- WCuN ⁴
Carbon	0.25–0.35	0.10	0.07	0.03 max	0.04	0.08	0.06	0.08	0.10	0.05–0.15	0.025	0.20	0.03	0.03
Manganese	2.00	1.50	1.50	2.00 max	1.00	1.00	4.00–6.00	1.50	7.00–9.00	0.15–1.50	1.20	1.50	1.50	1.00
Silicon	2.50	1.50	1.50	1.00 max	1.00	1.50	1.00	1.50	3.50–4.50	0.50–1.50	1.00	1.50	1.50	1.00
Sulfur	0.040	0.040	0.040	0.010 max	0.04	0.040	0.030	0.04	0.030	0.03	0.010	0.040	0.04	0.025
Phosphorus	0.040	0.040	0.040	0.040 max	0.04	0.040	0.040	0.04	0.060	0.03	0.045	0.040	0.04	0.030
Chromium	13.0–17.0	15.0–18.0	19.0–22.0	20.0–22.0	24.5–26.5	22.5–25.5	20.50–23.50	18.0–21.0	16.0–18.0	19.0–21.0	19.5–20.5	23.0–26.0	18.0–21.0	24.0–26.0
Nickel	33.0–37.0	13.0–16.0	27.5–30.5	23.5–25.5	4.75–6.00	8.0–11.0	11.50–13.50	9.0–13.0	8.0–9.0	31.0–34.0	17.5–19.5	8.0–11.0	9.0–13.0	6.5–8.5
Molybdenum	0.50	1.75–2.25	2.0–3.0	6.0–7.0	1.75–2.25	3.0–4.5	1.50–3.00	3.0–4.0	...	...	6.0–7.0	0.50	3.0–4.0	3.0–4.0
Columbium (Niobium)	...	^c	...	...	...	...	0.10–0.30	...	...	0.50–1.50	...	...	...	...
Vanadium	...	...	...	...	...	...	0.10–0.30	...	...	...	...	...	...	...
Nitrogen	...	...	...	0.18–0.26	...	0.10–0.30	0.20–0.40	...	0.08–0.18	...	0.18–0.24	0.08–0.20	...	0.20–0.30
Copper	...	...	3.0–4.0	0.75 max	2.75–3.25	...	...	...	...	...	0.50–1.00	...	...	0.5–1.0
Tungsten	...	...	...	...	...	...	...	...	...	...	...	...	...	0.5–1.0
Iron	...	...	...	...	...	...	...	...	...	...	...	Bal	...	...

Note 1 — Tungsten is a new element for Table 2.

^A % Cr + 3.3% Mo + 16% N ≥ 40.

^B Grade CF8C shall have a columbium content of not less than 8 times the carbon content but not over 1.00%.

^C Grade CF10MC shall have a columbium content of not less than 10 times the carbon content but not over 1.20%.

TABLE 3
TENSILE REQUIREMENTS

	CF3	CF3A	CF8	CF8A	CF3M	CF3MA	CF8M	CF3MN	CF8C	CF10	CF10M (J92901)	CH8	CH10	CH20	CK20	HK30
Tensile strength, min, ksi [MPa]	70 [485]	77 [530]	70 [485]	77 [530]	70 [485]	80 [550]	70 [485]	75 [515]	70 [485]	70 [485]	70 [485]	65 [450]	70 [485]	70 [485]	65 [450]	65 [450]
Yield Strength, ^A min, ksi [MPa]	30 [205]	35 [240]	30 [205]	35 [240]	30 [205]	37 [255]	30 [205]	37 [255]	30 [205]	30 [205]	30 [205]	28 [195]	30 [205]	30 [205]	28 [195]	35 [240]
Elongation in 2 in. or 50 mm, ^B min, %	35.0	35.0	35.0	35.0	30.0	30.0	30.0	35.0	30.0	35.0	30.0	30.0	30.0	30.0	30.0	10.0
Reduction of area, min, %	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

	HK40	HT30	CF10MC	CN7M	CN3MN	CD4MCu	CE8MN	CG6MMN	CG8M	CF10SMnN	CT15C	CK3MCuN	CE20N	CG3M (J92999)	CD3MWCuN
Tensile strength, min, ksi [MPa]	62 [425]	65 [450]	70 [485]	62 [425]	80 [550]	100 [690]	95 [655]	85 [585]	75 [515]	85 [585]	63 [435]	80 [550]	80 [550]	75 [515]	100 [700]
Yield Strength, ^A min, ksi [MPa]	35 [240]	28 [195]	30 [205]	25 [170]	38 [260]	70 [485]	65 [450]	42.5 [295]	35 [240]	42.5 [295]	25 [170]	38 [260]	40 [275]	35 [240]	65 [450]
Elongation in 2 in. or 50 mm, ^B min, %	10.0	15.0	20.0	35.0	35.0	16.0	25.0	30.0	25.0	30.0	20.0	35.0	30.0	25.0	25.0
Reduction of area, min, %	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

^A Determine by the 0.2% offset method.

^B When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Destruction Tests

S5. Radiographic Inspection

S6. Liquid Penetrant Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 165 or Practice E 709.

S11. Post Weld Heat Treatment

S11.1 All austenitic castings, except Grades HK, HT, and CT15C, which have been subjected to weld repairs, shall be given a post weld solution heat treatment.

SPECIFICATION FOR STEEL CASTINGS, FERRITIC AND MARTENSITIC, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR LOW-TEMPERATURE SERVICE



SA-352/SA-352M



(21)

(Identical with ASTM Specification A352/A352M-06(2012).)

Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure- Containing Parts, Suitable for Low-Temperature Service

1. Scope

1.1 This specification covers steel castings for valves, flanges, fittings, and other pressure-containing parts intended primarily for low-temperature service.

1.2 Several grades of ferritic steels and one grade of martensitic steel are covered. Selection of analysis will depend on design and service conditions (Note). The temperature shown is the lowest temperature at which the material ordinarily is required to meet the impact requirements of this specification (see Supplementary Requirement S22, Impact Test Temperatures). Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable (see Appendix X1).

Grade	Usual Minimum Testing Temperatures, °F [°C]
LCA	-25 [-32]
LCB	-50 [-46]
LCC	-50 [-46]
LC1	-75 [-59]
LC2	-100 [-73]
LC2-1	-100 [-73]
LC3	-150 [-101]
LC4	-175 [-115]
LC9	-320 [-196]
CA6NM	-100 [-73]

NOTE 1—This specification covers the low-temperature requirements particularly pertinent for ferritic and martensitic steels. Certain of the grades of austenitic steel castings furnished in accordance with Specification A351/A351M have been found suitable for low-temperature service down to -300°F [-184°C] and others down to -425°F [-254°C]. These grades may be used when impact tested in accordance with Specification A352/A352M with energy levels and temperatures of test mutually agreed upon between the purchaser and the manufacturer. As a guide to the selection of energy levels and testing temperatures, Appendix X1 should be consulted.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A352 and SI units for material ordered to Specification A352M.

2. Referenced Documents

2.1 ASTM Standards:

A351/A351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E165 Practice for Liquid Penetrant Examination for General Industry

E709 Guide for Magnetic Particle Testing

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A703/A703M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A703/A703M constitutes nonconformance with

this specification. In case of conflict between the requirements of this specification and Specification A703/A703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition. It should be recognized that liquid quenching of the ferritic grades is normally required to meet the mechanical properties of heavier sections and will greatly enhance the low-temperature properties of thinner sections.

5.2 Ferritic castings shall be furnished in the normalized and tempered or liquid-quenched and tempered condition, except for Grade LC9, which shall be liquid-quenched and tempered. Castings shall be tempered at a minimum of 1100°F [590°C], except Grade LC4, which shall be 1050°F [565°C], and Grade LC9, which shall be tempered in the range of 1050 to 1175°F [565 to 635°C], followed by cooling in air or liquid.

5.3 CA6NM castings shall be heat-treated by heating to 1850°F [1010°C] minimum, and air cooling to 200°F [95°C] maximum before any optional intermediate temper, but shall cool to 100°F [40°C] maximum before the final temper, which shall be between 1050 and 1150°F [565 and 620°C].

5.4 Castings shall be allowed to cool below the transformation range directly after pouring and solidification before they are reheated for normalizing or liquid quenching.

5.5 *Temperature Control*—Furnace temperature for heat treating shall be controlled by use of pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition for the grade ordered as specified in Table 1.

7. Mechanical Requirements

7.1 Tension Test:

7.1.1 Tensile properties of steel used for the castings shall conform to the requirements specified in Table 1.

7.2 Impact Test:

7.2.1 The notched bar impact properties of the material shall be determined by testing a set of three Charpy V-notch impact specimens for each heat at one of the standard test temperatures shown in Table 1, depending on the intended service temperature (see Appendix X1). The average energy value of the three specimens shall not be less than specified, with not more than

one value permitted below the average minimum specified and no value permitted below the minimum specified for a single specimen.

7.2.2 The notched bar impact test shall be made in accordance with Test Methods and Definitions A370.

7.2.3 Impact test specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A370, Fig. 11.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 2.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10, may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders in accordance with Practice A488/A488M.

9.2 Welding of Grade LC9 shall be accomplished using nonmagnetic filler material of AWS classification ENiCrFe-2, and shall require liquid penetrant inspection of the weld (Supplementary Requirement S6) when magnetic particle inspection (Supplementary Requirement S4) is specified for the casting.

9.3 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic tests, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm] whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²] shall be radiographed to the same standards that are used to inspect the castings.

9.4 Castings containing any repair weld that exceeds 20 % of the wall thickness, or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.² [65 cm²] in area, or that was made to correct hydrostatic test defects shall be stress relieved or heat treated after welding. This mandatory stress relief or heat treatment shall be in accordance with the procedure qualification used. When stress relief is required for Grade LC9, cooling shall be in still air.

TABLE 1 Chemical, Tensile, and Impact Requirements

Type	Carbon Steel	Carbon Steel	Carbon-Manganese Steel	Carbon-Molybdenum Steel	2½ % Nickel Steel	Nickel-Chromium-Molybdenum Steel	3½ % Nickel Steel	4½ % Nickel Steel	9 % Nickel Steel	12½ % Chromium, Nickel-Molybdenum Steel
Grade	LCA	LCB ^A	LCC	LC1	LC2	LC2-1	LC3	LC4	LC9	CA6NM
UNS Number	J02504	J03003	J02505	J12522	J22500	J42215	J31550	J41500	J31300	J91540
Element, % (max, except where range is given)										
Carbon	0.25 ^A	0.30	0.25 ^A	0.25	0.25	0.22	0.15	0.15	0.13	0.06
Silicon	0.60	0.60	0.60	0.60	0.60	0.50	0.60	0.60	0.45	1.00
Manganese	0.70 ^A	1.00	1.20 ^A	0.50-0.80	0.50-0.80	0.55-0.75	0.50-0.80	0.50-0.80	0.90	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.03
Nickel	0.50 ^B	0.50 ^B	0.50 ^B	...	2.00-3.00	2.50-3.50	3.00-4.00	4.00-5.00	8.50-10.0	3.5-4.5
Chromium	0.50 ^B	0.50 ^B	0.50 ^B	...	...	1.35-1.85	...	...	0.50	11.5-14.0
Molybdenum	0.20	0.20 ^B	0.20 ^B	0.45-0.65	...	0.30-0.60	...	...	0.20	0.4-1.0
Copper	0.30	0.30 ^B	0.30 ^B	...	...	...	...	...	0.30	...
Vanadium	0.03 ^B	0.03 ^B	0.03 ^B	...	...	...	...	...	0.03	...
Tensile Requirements: ^C										
Tensile strength, ksi [MPa]	60.0-85.0 [415-585]	65.0-90.0 [450-620]	70.0-95.0 [485-655]	65.0-90.0 [450-620]	70.0-95.0 [485-655]	105.0-130.0 [725-895]	70.0-95.0 [485-655]	70.0-95.0 [485-655]	85.0 [585]	110.0-135.0 [760-930]
Yield strength, ^D min, ksi [MPa]	30.0 [205]	35.0 [240]	40.0 [275]	35.0 [240]	40.0 [275]	80.0 [550]	40.0 [275]	40.0 [275]	75.0 [515]	80.0 [550]
Elongation in 2 in. or 50 mm, min, % ^E	24	24	22	24	24	18	24	24	20	15
Reduction of area, min, %	35	35	35	35	35	30	35	35	30	35
Impact Requirements Charpy V-Notch ^{C,F}										
Energy value, ft-lbf [J], min value for two specimens and min avg of three specimens	13 [18]	13 [18]	15 [20]	13 [18]	15 [20]	30 [41]	15 [20]	15 [20]	20 [27]	20 [27]
Energy value, ft-lbf [J], min for single specimen	10 [14]	10 [14]	12 [16]	10 [14]	12 [16]	25 [34]	12 [16]	12 [16]	15 [20]	15 [20]
Testing temperature, °F [°C]	-25 [-32]	-50 [-46]	-50 [-46]	-75 [-59]	-100 [-73]	-100 [-73]	-150 [-101]	-175 [-115]	-320 [-196]	-100 [-73]

^A For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 1.10 % for LCA, 1.28 % for LCB, and 1.40 % for LCC.

^B Specified Residual Elements—The total content of these elements is 1.00 % maximum.

^C See 1.2.

^D Determine by either 0.2 % offset method or 0.5 % extension-under-load method.

^E When ICI test bars are used in tensile testing as provided for in Specification A703/A703M, the gage length to reduced section diameter ratio shall be 4 to 1.

^F See Appendix X1.

TABLE 2 Minimum Preheat Temperatures

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
LCA	all	50 [10]
LCB	all	50 [10]
LCC	all	50 [10]
LC1	over ½ [15.9] % and under	250 [120] 50 [10]
LC2	all	300 [150]
LC2-1	all	300 [150]
LC3	all	300 [150]
LC4	all	300 [150]
CA6NM	all	50 [10]

10. Product Marking

10.1 All marking shall be on a raised pad using low-stress stamps.

10.2 In addition to the marking required by Specification A703/A703M, castings that have been liquid quenched and tempered shall be marked with the letters "QT".

11. Keywords

11.1 alloy steel; carbon steel; ferritic steel; low temperature applications; martensitic stainless steel; pressure containing parts; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A703/A703M. Those which are ordinarily considered suitable for use with this specification are given below together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in A703/A703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S9. Drop Weight Tests

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E709 or Practice E165.

S21. Heat Treatment

S21.1 Castings shall be liquid quenched and tempered.

S22. Impact Test Temperatures

S22.1 When an impact test temperature other than that listed in Table 1 is used, the lowest test temperature at which the material met the impact test requirements shall be stamped

with low-stress stamps on a raised pad located immediately ahead of the material symbol; for example, 25 LCB for +25°F [−4°C] and 025 LCB for −25°F [−32°C].

S22.2 Lateral expansion of V-notch specimens shall be measured in accordance with 23.2.3.1 of Test Methods and Definitions A370, and reported for information.

S23. Carbon Equivalent

S23.1 When specified on the order the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
LCA	0.50
LCB	0.50
LCC	0.55

S23.2 Determine carbon equivalent, CE , as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

APPENDIX

(Nonmandatory Information)

X1. EXPLANATION OF THE USE OF NOTCHED BAR IMPACT TESTS IN DETERMINING THE ACCEPTABILITY OF STEELS FOR LOW-TEMPERATURE SERVICE

X1.1 Years of experience and test work have shown that some materials, particularly ferritic steels, change from tough to brittle behavior with a decrease in temperature. The transition temperatures and the levels of notch toughness vary with different materials, depending on many factors. When materials are used under conditions where brittle behavior may occur, there is danger that flaws, which would be considered nonhazardous if the material were tough, may propagate to disastrous failure of the equipment.

X1.2 Accordingly, many varieties of tests have been developed in an effort to evaluate the toughness of materials and the conditions under which they will transform from tough to brittle behavior. There are many opinions and shadings of

opinion as to which test is most suitable for evaluating the suitability of materials for service at low temperatures; however, as yet, only the Charpy impact test has received sufficient general acceptance and has been used as a basis for purchasing for sufficient time to be included in ASTM standards. Furthermore, this test is required for low-temperature service vessels and piping constructed in accordance with ASME Code for Unfired Pressure Vessels and the American National Standard Code for Pressure Piping (ANSI B31), respectively. These ASTM specifications for materials for low-temperature service are primarily used in piping and pressure vessel construction that are subjected to temperatures lower than ambient; consequently, the notched bar impact test requirements are written to provide material that in quality and by its testing can be

validated for use under the construction codes.

X1.3 No assurance is offered that compliance with these requirements will provide a material that will resist brittle failure under all possible conditions of service to as low as the specified impact test temperature. It may eventually be possible that other types of tests will provide greater assurance of material suitability for low-temperature services, but at this time there is insufficient knowledge for agreement and general acceptance of some test other than the Charpy impact test.

X1.4 Attention is directed to the following subjects which have a bearing on the value of Charpy impact tests:

X1.4.1 Much of the original work in the field of notch toughness was done on wrought materials that had definite directional grain flow parallel to the axis of the bar, and the specimens were taken with the longitudinal axis of the specimen parallel to the axis of the bar. It has been well established that the results from impact testing of the same piece of steel may vary considerably, depending upon the orientation of the specimen to the direction of grain flow. Although it is known that specimens taken with their axis transverse to the direction of grain flow will have lower values depending on the amount of cross rolling or forging the material has received, there were insufficient test data to permit specific mandatory requirements on the impact properties of wrought materials determined in any direction other than parallel to the direction of grain flow. Except in special cases this limitation still exists.

X1.4.2 It is acknowledged that notched bar impact tests are of a qualitative rather than a quantitative nature. As yet, except possibly for ship steel, no satisfactory correlation has been possible between tests on small standardization specimens and the behavior of a structural part under any given conditions of

loading in service. The required values as determined by the Charpy V-notch impact test are arbitrary values which can be met by carbon and low-alloy constructional steels when tested at temperatures above that where their behavior changes from tough to brittle as judged by this test. The acceptability of this dividing line seems to be justified by service experience on carbon and certain low-alloy steels.

X1.4.3 The literature shows that notched bar impact strengths in constructional steels differ widely in accordance with many variables. Consequently, there is bound to be some discrepancy between an individual test bar and the entire part that it represents. No system of test bar selection can guarantee that every sample would meet minimum requirements. Test bar selection must be a compromise to generally represent the product.

X1.4.4 The committees responsible for these material specifications have had as an objective the selection of test specimens that will represent the properties of the materials, in the form in which they will be used. However, accomplishment of this objective has only partially been realized. At this time it is impossible to select samples for testing that will represent all parts and sizes of the product involved. Particularly in ferritic steels, it is impractical to remove the test bars from heavy sections over about 4 in. [100 mm] and expect them to show results as high as tests from light sections of the same material. The practical commercial limits on the amount of testing possible, as well as limits to knowledge of what results may be expected from testing in non-standard locations, have been considered in drafting these specifications. With time and increased knowledge, it may be possible to require more representative testing.

**SPECIFICATION FOR PRESSURE VESSEL PLATES,
ALLOY STEEL, DOUBLE-NORMALIZED AND TEMPERED
9% NICKEL**



SA-353/SA-353M



(Identical with ASTM Specification A353/A353M-17.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Double-Normalized and Tempered 9 % Nickel

1. Scope

1.1 This specification covers double-normalized and tempered 9 % nickel steel plates intended particularly for welded pressure vessels for cryogenic service.

1.2 Plates produced under this specification are subject to impact testing at -320°F [-195°C] or at such other temperatures as are agreed upon.

1.3 The maximum thickness of plates is limited only by the capacity of the material to meet the specific mechanical property requirements.

1.4 This material is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 All plates shall be heat treated in accordance with 5.2. Shell plates and other parts, including heads and reinforcing

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon, max ^A	0.13
Manganese, max	
Heat analysis	0.90
Product analysis	0.98
Phosphorus, max ^A	0.015
Sulfur, max ^A	0.015
Silicon:	
Heat analysis	0.15–0.40 ^B
Product analysis	0.13–0.45 ^B
Nickel:	
Heat analysis	8.50–9.50
Product analysis	8.40–9.60

^A Applies to both heat and product analyses.

^B The specified minimum limit does not apply if the total aluminum content is 0.030 % or more, or provided that acid soluble aluminum is 0.025 % or more.

TABLE 2 Tensile Requirements

Tensile strength, ksi [MPa]	100–120 [690–825]
Yield strength (0.2 % offset), min, ksi [MPa] ^A	75 [515]
Elongation in 2 in. [50 mm], min, % ^B	20.0

^A See 7.1.1.

^B See Specification A20/A20M for elongation adjustment.

pads that are heated for forming shall be heat treated after forming in accordance with 5.2.

5.2 Heat Treatment Procedure:

5.2.1 *First Normalizing Treatment*—Heat the plate to a uniform temperature of 1650 ± 25°F [900 ± 15°C], hold at that temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air.

5.2.2 *Second Normalizing Treatment*—Reheat the plate to a uniform temperature of 1450 ± 25°F [790 ± 15°C], hold at that temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air.

5.2.3 *Tempering Treatment*—Reheat the plate to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C], hold within that temperature range for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air or water quench at a rate not less than 300°F/h [165°C/h].

5.2.4 If hot forming is performed after heating to a temperature within the range from 1650 to 1750°F [900 to 955°C] the first normalizing treatment (5.2.1) may be omitted.

5.2.5 When the plates are heat treated by the fabricator, it shall be the fabricator's responsibility to apply the proper heat

treatment and to conduct tests it deems necessary to ensure that the specified properties are attained.

6. Chemical Requirements

6.1 The steel shall conform to the chemical composition requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements specified in Table 2.

7.1.1 Upon agreement between the purchaser and the manufacturer, yield strength may be determined by the extension under load method, using 0.005 in./in. [0.005 mm/mm] total extension.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and shows the greatest elongation.

7.1.3 One tension test shall be taken from each plate as heat treated.

7.2 Impact Test Requirements:

7.2.1 Charpy V-notch impact tests shall be made in accordance with Specification A20/A20M.

7.2.2 The longitudinal axis of the test specimens shall be transverse to the final rolling direction of the plate.

7.2.3 Unless otherwise agreed, tests shall be conducted at –320°F [–195°C].

7.2.4 Each test specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.381 mm].

8. Finish

8.1 Because retained scale may mask surface imperfections, as well as mar the plate surface, plates shall be descaled by the producer after heat treatment. In the case of material to be heat-treated by the purchaser, the plates shall be descaled by the producer prior to shipment.

9. Keywords

9.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

- | | |
|--|---|
| <p>S1. Vacuum Treatment,
 S2. Product Analysis,
 S4.1 Additional Tension Test,
 S6. Drop Weight Test,
 S8. Ultrasonic Examination in Accordance with Specification A435/A435M,</p> | <p>S11. Ultrasonic Examination in Accordance with Specification A577/A577M,
 S12. Ultrasonic Examination in Accordance with Specification A578/A578M, and
 S17. Vacuum Carbon-Deoxidized Steel.</p> |
|--|---|

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional Supplementary Requirements S55 and S56, which are suitable for this specification.

S55. Longitudinal Charpy Impact Energy Absorption Requirement

S55.1 The longitudinal Charpy V-notch impact properties shall not be less than 25 ft·lbf [34 J] at the specified temperature.

S55.2 Each impact-test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 25 ft·lbf [34 J], but in no case below 20 ft·lbf [27 J] for full size specimens.

S56. Transverse Charpy Impact Energy Absorption Requirement

S56.1 The transverse Charpy V-notch impact properties shall not be less than 20 ft·lbf [27 J] at the specified temperature.

S56.2 Each impact-test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 20 ft·lbf [27 J] but in no case below 15 ft·lbf [20 J] for full-size specimens.

SPECIFICATION FOR QUENCHED AND TEMPERED ALLOY STEEL BOLTS, STUDS, AND OTHER EXTERNALLY THREADED FASTENERS



SA-354

(Identical with ASTM Specification A354-11 except for the deletion of the term "private label distributor" in 15.1 and 15.3.5.)

Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

1. Scope

1.1 This specification covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners 4 in. and under in diameter for application at normal atmospheric temperatures, where high strength is required and for limited application at elevated temperature (Note 1). Any alloy steel capable of meeting the minimum mechanical and chemical properties set forth in this specification may be used.

NOTE 1—For bolts, studs, or other externally threaded fasteners, to be used at elevated temperatures, refer to Specification A193/A193M.

1.2 Two levels of bolting strength are covered, designated Grades BC and BD. Selection will depend upon design and the stresses and service for which the product is to be used.

NOTE 2—Quenched and tempered alloy steel bolts for structural steel joints up through 1½ in. in diameter are covered in Specification A490. Alloy steel bolts, studs, and other externally threaded fasteners (that is, heavy hex-structural bolts over 1½ in., hex bolts, anchor bolts, and countersunk bolts) exhibiting similar mechanical properties to bolts conforming to Specification A490 shall be covered by Grade BD of this specification.

When bolts of Grade BD of this specification are considered for pretensioned applications in excess of 50 % of the bolt tensile strength, the additional requirements of head size, maximum tensile strength, nut size and strength, washer hardness, tests, and inspections contained in Specification A490 should be carefully considered.

1.3 Nuts are covered in Specification A563. Unless otherwise specified, the grade and style of nut for each grade of fastener shall be as follows:

Grade of Fastener and Surface Finish	Nut Grade and Style ^A
BC, plain (or with a coating of insufficient thickness to require over-tapped nuts)	C, heavy hex
BC, zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex
BD, all finishes	DH, heavy hex

^A Nuts of other grades and styles having specified proof load stresses (Specification A563, Table 3) greater than the specified grade and style of nut are suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 Terms used in this specification are defined in Terminology F1789 unless otherwise defined herein.

2. Referenced Documents

2.1 *ASTM Standards:*

- A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
- A490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
- A563 Specification for Carbon and Alloy Steel Nuts
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- D3951 Practice for Commercial Packaging
- F436 Specification for Hardened Steel Washers
- F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
- F788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
 F1789 Terminology for F16 Mechanical Fasteners
 F2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 ASME Standards:

B1.1 Unified Screw Threads

B18.2.1 Square and Hex Bolts and Screws, Inch Series

B18.24 Part Identifying Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for bolts and studs (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue,

3.1.2 Name of product (that is, bolt or stud),

3.1.3 Grade (that is, BC or BD),

3.1.4 Quantities (number of pieces by size, including nuts),

3.1.5 Size and length,

3.1.6 Washers—Specify quantity and size (separate from bolts) (4.3),

3.1.7 *Zinc Coating*—When zinc-coated Grade BC fasteners are required, specify the zinc-coating process required, for example hot-dip, mechanically deposited, or no preference (see 4.4).

3.1.8 *Other Finishes*—Specify other protective finish, if required.

3.1.9 Specify if inspection at point of manufacture is required,

3.1.10 Specify if Certification (Section 14) is required, and

3.1.11 Specify additional testing (Section 9) or special requirements.

3.1.12 For establishment of a part identifying system, see ASME B18.24.

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen process.

4.2 All fasteners shall be heat-treated. At the option of the manufacturer, heat treatment may be performed on the raw material, during the manufacturing operations, or after final machining. Heat treatment shall consist of quenching in a liquid medium (except Grade BD sizes 1½ in. and smaller shall be quenched in oil) from above the transformation temperature and then tempering by reheating to a temperature of not less than 800°F (427°C) for Grade BC and for Grade BD.

4.3 When used, suitable hardened washers shall be quenched and tempered (non-carburized) in accordance with Specification F436.

4.4 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.4.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.4.2 When “hot-dip” is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Specification F2329.

4.4.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 55 of Specification B695.

4.4.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification F2329, or a mechanically deposited zinc coating in accordance with Specification B695, Class 55. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

NOTE 3—When the intended application requires that assembled tension exceeds 50 % of minimum bolt proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A563 and should be specified when required.

4.5 Zinc-coated bolts and nuts shall be shipped in the same container unless specifically requested otherwise by the purchaser.

NOTE 4—Research conducted on bolts of similar material and manufacture indicates that hydrogen-stress cracking or stress cracking corrosion may occur on hot-dip galvanized Grade BD bolts.

5. Chemical Composition

5.1 All fasteners shall be made from alloy steel conforming to the chemical composition requirements in accordance with Table 1. The steel shall contain sufficient alloying elements to qualify it as an alloy steel.

NOTE 5—Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

5.2 Product analysis may be made by the purchaser from finished material representing each lot of fasteners. The chemical composition thus determined shall conform to the requirements given in Table 1. Choice of alloy steel composition necessary to ensure meeting the specified mechanical requirements shall be made by the manufacturer and shall be reported to the purchaser for information purposes only.

5.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.4 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A751.

6. Mechanical Properties

6.1 Fasteners shall not exceed the maximum hardness specified in Table 2. Fasteners less than three diameters in length and studs less than four diameters in length shall have hardness

TABLE 1 Chemical Requirements

Alloy Steel		
Element	Heat Analysis, %	Product Analysis, %
Carbon:		
For sizes through 1 1/2 in.	0.30 to 0.53	0.28 to 0.55
For sizes larger than 1 1/2 in.	0.35 to 0.53	0.33 to 0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Alloying Elements	A	A
Alloy Steel with Boron Addition		
Element	Heat Analysis, %	Product Analysis, %
Carbon		
For sizes through 1 1/2 in.	0.30-0.48	0.28-0.50
For sizes larger than 1 1/2 in.	0.35-0.53	0.35-0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.045
Sulfur, max	0.040	0.045
Boron	0.0005-0.003	0.0005-0.003
Alloying Elements	A	A

^ASteel, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: Manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 % or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

TABLE 2 Hardness Requirements for Full-Size Fasteners

Size, in.	Grade	Hardness			
		Brinell		Rockwell C	
		Minimum	Maximum	Minimum	Maximum
1/4 to 2 1/2	BC	255	331	26	36
Over 2 1/2	BC	235	311	22	33
1/4 to 2 1/2	BD	311	363	33	39
Over 2 1/2	BD	293	363	31	39

values not less than the minimum nor more than the maximum hardness limits required in Table 2, as hardness is the only requirement.

6.2 Fasteners 1 3/8 in. in diameter or less for Grade BC and 1 1/4 in. in diameter or less for Grade BD, other than those excepted in 6.1, shall be tested full size and shall conform to the tensile strength and either the proof load or the yield strength requirements in accordance with Table 3.

6.3 Fasteners larger than 1 3/8 in. in diameter for Grade BC and fasteners larger than 1 1/4 in. in diameter for Grade BD, other than those excepted in 6.1, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements in accordance with Table 3. When equipment of sufficient capacity for full-size testing is not available, or when the length of the fastener makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements in accordance with Table 4. In the event that fasteners

are tested by both full-size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.4 For fasteners on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 *Bolts*—Unless otherwise specified, the bolts shall be Hex Head with dimensions conforming to the latest issue of ASME B18.2.1.

7.2 *Studs*—Studs shall have dimensions conforming to those specified by the purchaser.

7.3 Threads:

7.3.1 Unless otherwise specified, threads shall be the Unified National Coarse Thread Series as specified in B1.1, and shall have Class 2 A tolerances.

7.3.2 When specified, threads shall be the Unified National Fine Thread Series, 8-Pitch Thread Series for sizes over 1 in. or 14-Pitch UNS on 1 in. size as specified in ANSI B1.1 and shall have Class 2A tolerances.

7.3.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A563, shall have Class 2A threads before hot dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.	Oversize Limit, in. (mm) ^A
1/4	0.016
5/16, 3/8	0.017
7/16, 1/2	0.018
9/16 to 3/4, incl	0.020
7/8	0.022
1.0 to 1 1/4, incl	0.024
1 3/8, 1 1/2	0.027
1 3/4 to 4.0, incl	0.050

^A These values are the same as the overtapping required for zinc-coated nuts in Specification A563.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F788/F788M.

9. Number of Tests

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.6.

9.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party as defined in 12.1 shall be responsible for ensuring that all tests have been performed and the fasteners comply with the requirements of this specification.

9.2 *Purpose of Lot Inspection*—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully

TABLE 3 Tensile Requirements for All Full-Size Fasteners—Inch-Pound Units

Bolt Size, in.	Threads per inch	Stress Area, ^A in. ²	Grade BC			Grade BD		
			Tensile Strength, min, lbf ^B	Proof Load, min, lbf ^C	Yield Strength (0.2 % offset), min, lbf ^D	Tensile Strength, min, lbf ^E	Proof Load, min, lbf ^F	Yield Strength (0.2 % offset), min, lbf ^G
1	2	3	4	5	6	7	8	9
1/4	20	0.0318	4 000	3 350	3 450	4 750	3 800	4 100
1/4	28	0.0364	4 550	3 820	3 950	5 450	4 350	4 700
5/16	18	0.0524	6 550	5 500	5 700	7 850	6 300	6 800
5/16	24	0.0580	7 250	6 090	6 300	8 700	6 950	7 500
3/8	16	0.0775	9 700	8 150	8 450	11 650	9 300	10 075
3/8	24	0.0878	11 000	9 220	9 550	13 200	10 500	11 400
7/16	14	0.1063	13 300	11 150	11 600	15 950	12 750	13 850
7/16	20	0.1187	14 840	12 470	12 900	17 800	14 200	15 400
1/2	13	0.1419	17 750	14 900	15 450	21 300	17 050	18 500
1/2	20	0.1599	19 990	16 790	17 400	24 000	19 200	20 750
9/16	12	0.182	22 750	19 100	19 850	27 300	21 850	23 600
9/16	18	0.203	25 400	21 400	22 100	30 400	24 400	26 350
5/8	11	0.226	28 250	23 750	24 650	33 900	27 100	29 400
5/8	18	0.256	32 000	26 800	27 900	38 400	30 700	33 250
3/4	10	0.334	41 750	35 050	36 400	50 100	40 100	43 400
3/4	16	0.373	46 600	39 100	40 650	56 000	44 800	48 450
7/8	9	0.462	57 750	48 500	50 350	69 300	55 450	60 100
7/8	14	0.509	63 600	53 400	55 450	76 400	61 100	66 150
1	8	0.606	75 750	63 650	66 050	90 900	72 700	78 800
1	12	0.663	82 900	69 700	72 250	99 400	79 600	86 150
1	14 UNS	0.679	84 900	71 300	74 400	101 900	81 500	88 250
1 1/8	7	0.763	95 400	80 100	83 150	114 450	91 550	99 200
1 1/8	8	0.790	98 750	82 950	86 200	118 500	94 800	102 700
1 1/8	12	0.856	107 000	89 800	93 300	128 400	102 700	111 250
1 1/4	7	0.969	121 150	101 750	105 600	145 350	116 300	126 000
1 1/4	8	1.000	125 000	105 000	109 000	150 000	120 000	130 000
1 1/4	12	1.073	134 100	112 600	116 950	161 000	128 800	139 450
1 3/8	6	1.155	144 400	121 300	125 900	173 250	138 600	150 200
1 3/8	8	1.233	154 150	129 450	134 400	185 000	148 000	160 300
1 3/8	12	1.315	164 400	138 100	143 300	197 200	157 800	170 950
1 1/2	6	1.405	175 650	147 550	153 150	210 750	168 600	182 500
1 1/2	8	1.492	186 500	156 650	162 250	233 800	175 050	194 000
1 1/2	12	1.581	197 600	166 000	172 300	237 200	189 700	205 500
1 3/4	5	1.90	237 500	199 500	207 100	285 000	228 000	247 000
1 3/4	8	2.08	260 000	218 400	226 700	312 000	249 600	270 000
2	4 1/2	2.50	312 500	262 500	272 500	375 000	300 000	325 000
2	8	2.77	346 250	290 850	301 950	415 000	332 400	360 000
2 1/4	4 1/2	3.25	406 250	341 250	354 250	487 000	390 000	422 500
2 1/4	8	3.56	445 000	373 800	388 050	534 000	422 200	462 800
2 1/2	4	4.00	500 000	420 000	436 000	600 000	480 000	520 000
2 1/2	8	4.44	550 000	466 200	483 950	666 000	532 800	577 200
2 3/4	4	4.93	566 950	468 350	488 050	690 200	517 650	566 950
2 3/4	8	5.43	624 450	515 850	537 550	750 200	570 150	624 450
3	4	5.97	686 550	567 150	591 050	835 800	626 850	686 550
3	8	6.51	748 650	618 450	644 500	911 400	683 550	748 650
3 1/4	4	7.10	816 500	674 500	702 900	994 000	745 500	816 500
3 1/4	8	7.69	884 350	730 550	761 300	1 076 600	807 650	884 350
3 1/2	4	8.33	957 950	791 350	824 650	1 166 200	874 650	957 950
3 1/2	8	8.96	1 030 400	851 200	887 050	1 254 400	940 800	1 030 400
3 3/4	4	9.66	1 110 900	917 700	956 350	1 352 400	1 014 300	1 110 900
3 3/4	8	10.34	1 199 100	983 300	1 023 650	1 447 600	1 085 700	1 189 100
4	4	11.08	1 274 200	1 052 600	1 096 900	1 551 200	1 163 400	1 274 200
4	8	11.81	1 358 200	1 122 000	1 169 200	1 653 400	1 240 050	1 358 150

^A Stress Area, in.² = 0.7854 [D - 0.9743/n]² where D = nominal diameter, in., and n = threads/in.
^B Based on 125 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115 000 psi for sizes over 2 1/2 to 4 in., inclusive.
^C Based on 105 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 95 000 psi for sizes over 2 1/2 to 4 in., inclusive.
^D Based on 109 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 99 000 psi for sizes over 2 1/2 to 4 in., inclusive.
^E Based on 150 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 140 000 psi for sizes over 2 1/2 to 4 in., inclusive.
^F Based on 120 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 105 000 psi for sizes over 2 1/2 to 4 in., inclusive.
^G Based on 130 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115 000 psi for sizes over 2 1/2 to 4 in., inclusive.

TABLE 4 Mechanical Requirements for Machined Specimens

Grade	Size, in.	Tensile Strength min, psi	Yield Strength (0.2 % offset), min, psi	Elonga- tion in 2 in. min, %	Reduction of Area, min, %
BC	¼ to 2½, incl	125 000	109 000	16	50
BC	Over 2½	115 000	99 000	16	45
BD	¼ to 2½, incl	150 000	130 000	14	40
BD	Over 2½	140 000	115 000	14	40

effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 Lot Processing—All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of fasteners from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 Lot Definition—A lot is a quantity of a uniquely identified fastener product of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and heat treatment lot and processed at one time, by the same process, in the same manner so that statistical sampling is valid. The identity of the lot is maintained throughout all subsequent operations and packaging.

9.5 Number of Tests—The minimum number of tests from each production lot for the tests specified below shall be in accordance with Guide F1470.

Hardness Tensile	Coating Weight/Thickness Workmanship (Surface Discontinuities Section 8)
Proof Load	

9.5.1 The number of tests for dimensional and thread fit compliance shall be in accordance with the quality assurance provisions of the referenced dimensional standards.

9.6 If any test specimen shows defective machining it may be discarded and another specimen substituted.

10. Test Methods

10.1 Test methods shall be conducted in accordance with Test Methods F606.

10.2 Proof load, rather than yield strength determination is preferred and shall be the arbitration method for fasteners 1¼ in. and under in diameter.

10.3 Hexagon bolts shall be tested by the wedge tension method. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body.

10.3.1 At the option of the manufacturer, the yield strength test (Method 2, Yield Strength paragraph of Test Methods F606) and the wedge tension test (Wedge Tension Testing of Full-Size Product paragraph, both from the Test Method

section of Test Methods F606) may be accomplished concurrently to satisfy 10.2 and 10.3.

10.4 Studs and bolts other than those in 10.3 shall be tested by the axial tension method.

10.4.1 At the option of the manufacturer, the yield strength test and the axial tension test may be accomplished concurrently to satisfy 10.2 and 10.4.

10.5 The speed of testing determined with a free running crosshead shall be a maximum of ⅛ in. (3.2 mm)/min for the bolt proof load (or yield strength) determination and a maximum of 1 in. (25.4 mm)/min for the tensile strength determination.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or purchase order.

11.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

12. Responsibility

12.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party in accordance with Section 12, shall furnish the purchaser a test report which includes the following:

14.1.1 Product description, grade, quantity, ASTM Specification Number and issue date,

14.1.2 Alloy grade (AISI, SAE, UNS, etc.), heat analysis, and heat number, and type of quench,

14.1.3 Results of hardness, tensile, and proof load tests, as applicable,

14.1.4 Statement of compliance to Protective Coating Specification (if applicable),

14.1.5 Statement of compliance with the surface discontinuity requirements of Specification F788/F788M,

14.1.6 Statement of compliance dimensionally,

14.1.7 Report, describe, or illustrate manufacturer's markings and their location,

14.1.8 Lot number, purchase order number, and date shipped,

14.1.9 Country of origin, and

14.1.10 Title and signature of the individual assigned certification responsibility by the company officers, with complete mailing address.

14.2 Failure to include all the required information on the test report shall be cause for rejection.

15. Product Marking

15.1 *Manufacturers Identification* —All products shall be marked by the manufacturer with a unique identifier to identify the manufacturer.

15.2 *Grade Identification:*

15.2.1 All Grade BC products shall be marked “BC”.

15.2.2 All Grade BD products shall be marked “BD”. In addition to the “BD” marking, the product may be marked with 6 radial lines 60° apart if manufactured from alloy steel conforming to the requirements of this specification.

15.3 *Marking Location and Methods:*

15.3.1 Bolts shall be marked on the top of the bolt head.

15.3.2 Where studs have both coarse and fine threads, all markings shall appear on the coarse thread end or, if preferred, the manufacturer’s identification shall appear on the fine thread end and the grade marking on the coarse thread end.

15.3.3 Continuous thread studs may be marked on either end.

15.3.4 All markings may be raised or depressed at the manufacturer’s option.

15.3.5 Grade and manufacturer’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and when on the same level shall be separated by at least two spaces.

16. Packaging and Package Marking

16.1 *Packaging:*

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 *Package Marking:*

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and grade,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Purchase order number, and

16.2.1.6 Country of origin.

17. Keywords

17.1 alloy steel; bolts; steel; studs

SUPPLEMENTARY REQUIREMENTS

S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking in accordance with Section 15.

S1.2 Marking small sizes (customarily less than 0.375 in. (9.525 mm)) may not be practical. Consult the producer for the minimum size that can be marked.

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**SPECIFICATION FOR ELECTRIC-FUSION-WELDED
AUSTENITIC CHROMIUM-NICKEL STAINLESS STEEL
PIPE FOR HIGH-TEMPERATURE SERVICE AND
GENERAL APPLICATIONS**



SA-358/SA-358M

(Identical with ASTM Specification A358/A358M-15 except for the deletion of 6.3.2.2 for HT-0 pipe and 6.3.2.3 for HT-S0 pipe, and editorial correction in 1.4. For products ordered to Section III and Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S8 is mandatory.)

Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications

1. Scope

1.1 This specification covers electric-fusion-welded austenitic chromium-nickel stainless steel pipe suitable for corrosive or high-temperature service, or both, or for general applications.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.2 This specification covers the grades of alloy and stainless steel listed in Table 1. The selection of the proper grade and requirements for heat treatment shall be at the discretion of the purchaser, dependent on the service conditions to be encountered.

1.3 Five classes of pipe are covered as follows:

1.3.1 *Class 1*—Pipe shall be double welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.2 *Class 2*—Pipe shall be double welded by processes employing filler metal in all passes. No radiography is required.

1.3.3 *Class 3*—Pipe shall be single welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.4 *Class 4*—Same as Class 3 except that the weld pass exposed to the inside pipe surface may be made without the addition of filler metal (see 6.2.2.1 and 6.2.2.2).

1.3.5 *Class 5*—Pipe shall be double welded by processes employing filler metal in all passes and shall be spot radiographed.

1.4 Supplementary requirements covering provisions ranging from additional testing to formalized procedures for

manufacturing practice are provided. Supplementary Requirements S1 through S8 are included as options to be specified when desired.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ASME Boiler and Pressure Vessel Code:*

Section II

Section III

Section VIII

Section IX

TABLE 1 Plate and Filler Metal Specifications

Grade	UNS Designation	Material, Type	ASTM Plate Specification No. and Grade	Filler Metal Classification and UNS Designation ^A for Applicable ^B AWS Specification											
				A5.4/A5.4M		A5.9/A5.9M		A5.11/A5.11M		A5.14/A5.14M		A5.22/A5.22M		A5.30/A5.30M	
				Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
...	N08020	...	A240/A240M N08020	...	...	...	...	...	...	...	...	...	...	...	...
...	N08367	...	A240/A240M N08367	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	...	...	...	...
...	N08700	...	A240/A240M N08700	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	...	...	...	...
800 ^E	N08800	...	A240/A240M N08800	...	...	...	...	ENiCrFe-3	W86182	ERNiCr-3	N06082	...	...	...	...
800H ^E	N08810	...	A240/A240M N08810	...	...	...	...	ENiCrFe-3 ^F	W86182 ^F	ERNiCr-3 ^F	N06082 ^F	...	...	...	...
...	N08811	...	A240/A240M N08811	...	...	...	...	ENiCrFe-3 ^F	W86182 ^F	ERNiCr-3 ^F	N06082 ^F	...	...	...	...
...	N08904	...	A240/A240M N08904	...	...	...	...	...	...	...	...	...	...	...	...
...	N08926	...	A240/A240M N08926	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	...	...	...	...
201	S20100	201	A240/A240M Type 201	...	...	...	...	...	...	...	...	...	...	...	...
201LN	S20153	201LN	A240/A240M Type 201LN	...	...	...	...	...	...	...	...	...	...	...	...
...	S20400	...	A240/A240M S20400	E 209	W32210	ER209	S20980	...	...	...	...	...	...	...	...
XM-19	S20910	XM-19	A240/A240M Type XM-19	E209	W32210	ER209	S20980	...	...	...	...	...	...	...	...
XM-29	S24000	XM-29	A240/A240M Type XM-29	E240	W32410	ER240	S24080	...	...	...	...	...	...	...	...
304	S30400	304	A240/A240M Type 304	E308	W30810	ER308	S30880	...	...	...	...	E308T	W30831	IN308	S30880
304L	S30403	304L	A240/A240M Type 304	E308L	W30813	ER308L	S30883	...	...	...	...	E308LT	W30835	IN308L	S30883
304H	S30409	304H	A240/A240M Type 304H	E308H	W30810	ER308	S30880	...	...	...	...	E308T	W30831	IN308	S30880
...	S30415	...	A240/A240M S30415	...	...	...	...	...	...	...	...	...	...	...	...
304N	S30451	304N	A240/A240M Type 304N	E308	W30810	ER308	S30880	...	...	...	...	E308T	W30831	IN308	S30880
304LN	S30453	304LN	A240/A240M Type 304LN	E308L	W30813	ER308L	S30883	...	...	...	...	E308LTT	W30835	IN308L	S30883
...	S30600 ^P	...	A240/A240M S30600 ^P	...	...	...	...	...	...	...	...	...	...	...	...
...	S30815	...	A240/A240M S30815	...	...	...	...	...	...	...	...	...	...	...	...
309S	S30908	309S	A240/A240M Type 309S	...	...	...	...	...	...	...	...	...	...	...	...
309Cb	S30940	309Nb	A240/A240M Type 309Cb	E309Cb	W30917	...	...	...	...	...	...	...	...	...	...
310S	S31008	310S	A240/A240M Type 310S	...	...	...	...	...	...	...	...	...	...	...	...
310Cb	S31040	310Cb	A240/A240M Type 310Cb	E310NB	W31017	...	...	...	...	...	...	...	...	...	...
...	S31254	...	A240/A240M S31254	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	...	...	...	...
...	S31266	...	A240/A240M S31266	...	...	...	...	ENiCrMo-13	W86059	ERNiCrMo-13	N06059	...	...	...	...

TABLE 1 Continued

Grade	UNS Designation	Material, Type	ASTM Plate Specification No. and Grade	Filler Metal Classification and UNS Designation ^A for Applicable ^B AWS Specification											
				A5.4/A5.4M		A5.9/A5.9M		A5.11/A5.11M		A5.14/A5.14M		A5.22/A5.22M		A5.30/A5.30M	
				Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
...	S31266	...	A240/A240M S31266	...	...	...	...	ENiCrMo-10	W86022	ERNiCrMo-10	N06022	...	...	...	...
316	S31600	316	A240/A240M Type 316	E316	W31610	ER316	S31680 W31640	...	...	...	...	E316T	W31631	IN316	S31680
316L	S31603	316L	A240/A240M Type 316L	E316L	W31613	ER316L	S31683	...	...	...	...	E316LT	W31635	IN316L	S31683
316H	S31609	316H	A240/A240M Type 316H	E316H	W31610	ER316H	S31680	...	...	...	...	E316T	W31631	IN316	S31680
316N	S31651	316N	A240/A240M Type 316N	E316	W31610	ER316	S31680	...	...	...	...	E316T	W31631	IN316	S31680
316LN	S31653	316LN	A240/A240M Type 316LN	E316L	W31613	ER316L	S31683	...	...	...	...	E316LT	W31635	IN316L	S31683
...	S31655	...	A240/A240M S31655	...	...	...	...	...	...	...	...	...	...	...	...
317	S31700	317	A240/A240M Type 317	E317	W31710	ER 317	S31780	...	...	...	...	E317LT	W31735	...	...
317L	S31703	317L	A240/A240M Type 317L	E317L	W34713	ER317L	S31783	...	...	...	...	E317LT	W31735	...	...
...	S31725	...	A240/A240M S31725	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	...	...	...	...
...	S31726	...	A240/A240M S31726	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	...	...	...	...
...	S31727	...	A240/A240M S31727	...	...	...	...	...	...	...	...	...	...	...	...
...	S32050	...	A240/A240M S32050	...	...	...	...	...	...	...	...	...	...	...	...
...	S32053	...	A240/A240M S32053	...	...	...	...	...	...	...	...	...	...	...	...
321	S32100	321	A240/A240M Type 321	E347	W34710	ER321	S32180 S34780	...	...	...	...	E347T	W34731	IN348	S34780
321H ^C	S32109 ^C	321H ^C	A240/A240M Type 321H ^C		W34710	ER321 ER347	S32180 S34780					E347T	W34731	IN348	S34780
...	S32654	...	A240/A240M S32654	...	...	...	...	...	...	...	...	...	...	...	...
...	S34565	...	A240/A240M S34565	...	...	...	...	...	...	...	...	...	...	...	...
347	S34700	347	A240/A240M Type 347	E347	W34710	ER347	S34780	...	...	...	...	E347T	W34731	IN348	S34780
347H ^C	S34709 ^C	347H ^C	A240/A240M Type 347H ^C			ER347	S34780					E347T	W34731	IN348	S34780
347LN	S34751		A240/A240M Type 347LN	...	...	...	...	...	...	...	...	...	...	...	...
348	S34800	348	A240/A240M Type 348	E347	W34710	ER347	S34780	...	...	...	...	E347T	W34731	IN348	S34780

^A New designation established in accordance with Practice E527 and SAE J1086.

^B Choice of American Welding Society specification depends on the welding process used.

^C Minimum carbon content of the filler metal shall be 0.040 mass %.

^D In previous editions, S30600 was incorrectly shown as S01815.

^E Common name, not a trademark, widely used, not associated with any one producer.

^F These filler metals have a high nickel content and, therefore, lower creep strength than the parent metal at temperatures exceeding about 1470 °F [800 °C], and its resistance to sulphurous media is inferior in certain cases.

2.3 AWS Specifications:

- A5.4/A5.4M Stainless Steel Electrodes for Shielded Metal Arc Welding
- A5.9/A5.9M Bare Stainless Steel Welding Electrodes and Rods
- A5.11/A5.11M Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding
- A5.14/A5.14M Nickel and Nickel-Alloy Bare Welding Electrodes and Rods
- A5.22/A5.22M Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods
- A5.30/A5.30M Consumable Inserts

2.4 Other Standard:

- SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 Definitions:

- 3.1.1 The definitions in Specification A999/A999M and Terminology A941 are applicable to this specification.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for product under this specification. Such requirements to be considered include, but are not limited to, the following:

- 4.1.1 Quantity (feet, metres, or number of lengths),
- 4.1.2 Name of material (electric-fusion-welded pipe),
- 4.1.3 Grade (Table 1),
- 4.1.4 Class (see 1.3),
- 4.1.5 Size (outside diameter and nominal wall thickness),
- 4.1.6 Length (specific or random),
- 4.1.7 End finish (Section on Ends of Specification A999/A999M),
- 4.1.8 Authorization for repair of plate defects by welding and subsequent heat treatment without prior approval if such is intended (see 9.3),
- 4.1.9 Specification designation,
- 4.1.10 Special requirements,
- 4.1.11 Statement invoking requirements of 16.4 if such is intended.
- 4.1.12 Circumferential weld permissibility (see Section 16),
- 4.1.13 Supplementary Requirements (S1 through S8),
- 4.1.14 Applicable ASME Code if known,
- 4.1.15 For ASME Code Section III applications, the service classification intended, and
- 4.1.16 Certification requirements (see Section on Certification of Specification A999/A999M).

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 Materials:

- 6.1.1 The steel plate material shall conform to the require-

ments of one of the grades of Specification A240/A240M, listed in Table 1, except as provided in 6.3.2.3.

6.2 Welding:

6.2.1 The joints shall be full penetration double-welded or single-welded butt joints employing fusion welding processes as defined under "Definitions," ASME Boiler and Pressure Vessel Code, Section IX. This specification makes no provision for any difference in weld quality requirements regardless of the weld joint type employed (single or double) in making the weld. Where backing rings or strips are employed, the ring or strip material shall be of the same P-Number (Table QW-422 of Section IX) as the plate being joined. Backing rings or strips shall be completely removed after welding, prior to any required radiography, and the exposed weld surface shall be examined visually for conformance to the requirements of 6.2.3. Welds made by procedures employing backing strips or rings that remain in place are prohibited. Welding procedures, and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

6.2.2 Except as provided in 6.2.2.1 and 6.2.2.2, welds shall be made in their entirety by processes involving the deposition of filler metal.

6.2.2.1 For Class 4 pipe employing multiple passes, the root-pass may be without the addition of filler metal.

6.2.2.2 For Class 4 pipe, the weld surface exposed inside the pipe may result from a single pass made from the inside of the pipe without the addition of filler metal.

6.2.2.3 All single-welded pipe shall be completely radiographed.

6.2.3 The weld surface on either side of the weld is permitted to be flush with the base plate or to have a reasonably uniform crown, not to exceed $\frac{1}{8}$ in. [3 mm]. It is permitted at the option of the manufacturer or by agreement between the manufacturer and purchaser to remove any weld reinforcement. The contour of the reinforcement should be reasonably smooth and free from irregularities. The deposited metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

6.2.4 Weld defects shall be repaired by removal to sound metal and rewelding. Subsequent heat treatment and examination (that is, visual, radiographic, and dye penetrant) shall be as required on the original welds.

6.3 Heat Treatment:

6.3.1 All pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2.

6.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 6.3.1 is not desired by the purchaser:

6.3.2.1 A *final heat-treatment temperature under 1900 °F [1040 °C]*—Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix "HT." Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

TABLE 2 Annealing Requirements

Grade or UNS Designation ^A	Heat Treating Temperature ^B	Cooling/Testing Requirements
All grades not individually listed below:	1900 °F [1040 °C]	^C
304H, 309S, 309Cb, 310S, 310Cb,	1900 °F [1040 °C]	^D
321H, 347H, S22100, S28300,		
N08020	1800-1850 °F [980-1010 °C]	^D
N08367	2025 °F [1110 °C]	^D
N08700	2000 °F [1095 °C]	^D
N08810	2050 °F [1120 °C]	^D
N08811	2100 °F [1150 °C]	^D
N08904	2000 °F [1095 °C]	^D
N08926	2010 °F [1100 °C]	^D
S30600	2100 °F [1150 °C]	^D
S30815	1920 °F [1050 °C]	^D
S31254	2100 °F [1150 °C]	^D
S31266	2100 °F [1150 °C]	^D
S31727	1975–2175 °F [1080 to 1180 °C]	^D
S32050	2100 °F [1150 °C]	^D
S32053	1975–2175 °F [1080 to 1180 °C]	^D
S32654	2100 °F [1150 °C]	^D
S34565	2050 °F [1120 °C]	^D

^A New designation established in accordance with Practice E527 and SAE J1086.

^B Minimum, unless otherwise stated.

^C Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing Practices A262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S7). Note that Practices A262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.

^D Quenched in water or rapidly cooled by other means.

6.3.2.2 DELETED

6.3.2.3 DELETED

6.4 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in Grades 321, 321H, 347, 347H, and 348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

7. Chemical Composition

7.1 The chemical composition of the plate shall conform to the requirements of the applicable specification and grade listed in Specification A240/A240M.

7.2 Except for Grade S34751, the chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 1, or shall conform to the chemical composition specified for the plate in Specification A240/A240M, or shall, subject to purchaser approval, be a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties. Use of a filler metal other than that listed in Table 1 or conforming to the chemical composition specified for the plate in Specification A240/A240M shall be reported and the filler metal identified on the certificate of tests. When nitrogen and cerium are specified elements for the ordered grade, the method of analysis for these elements shall be a matter of agreement between the purchaser and the manufacturer.

7.3 The chemical composition of the welding filler metal for Grade S34751 shall conform to the chemical composition specified for the plate in Specification A240/A240M. The method for analysis for nitrogen shall be a matter of agreement between the purchaser and the manufacturer.

8. Permissible Variations in Dimensions

8.1 *Permissible Variations*—The dimensions at any point in a length of pipe shall not exceed the following:

8.1.1 *Outside Diameter*—Based on circumferential measurement, $\pm 0.5\%$ of the specified outside diameter.

8.1.2 *Out-of-Roundness*—Difference between major and minor outside diameters, 1 %.

8.1.3 *Alignment*—Using a 10-ft [3-m] straightedge placed so that both ends are in contact with the pipe, $\frac{1}{8}$ in. [3 mm] deviation from contact with the pipe.

8.1.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. [0.3 mm] under the nominal thickness.

9. Workmanship, Finish, and Appearance

9.1 The finished pipe shall have a workmanlike finish.

9.2 *Repair of Plate Defects by Machining or Grinding*—It is permitted to repair pipes showing slivers, or other surface defects, by machining or grinding inside or outside to a depth that ensures the removal of all included scale and slivers, provided that the wall thickness is not reduced below the specified minimum wall thickness. Machining or grinding shall

follow inspection of the pipe as rolled, and shall be followed by supplementary visual inspection.

9.3 *Repair of Plate Defects by Welding*—It is permitted to repair by welding defects that violate minimum wall thickness, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 6.3, shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than $\frac{1}{4}$ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable non-destructive examination techniques, including any techniques specifically required of the primary weld.

9.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to request that a passivating treatment be applied.

10. Heat Analysis

10.1 An analysis of each heat of steel shall be made by the plate manufacturer to determine the percentages of the elements prescribed in Specification A240/A240M. The chemical composition thus determined shall conform to the requirements prescribed in Specification A240/A240M.

11. Product Analysis

11.1 For each lot of 500 ft [150 m] of pipe or fraction thereof, analysis shall be made by the manufacturer from the finished pipe of the plate and of the weld deposit. Drillings for analysis may be taken from the mechanical test specimens. The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements of Section 7, subject to the product analysis tolerances of Table 1 in Specification A480/A480M.

11.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

12. Tensile Requirements

12.1 The plate used in making the pipe shall conform to the requirements as to tensile properties of the applicable specifications listed in Table 1. Tension tests made by the plate manufacturer shall qualify the plate material.

12.2 The transverse tension test taken across the welded joint specimen shall have a tensile strength not less than the specified minimum tensile strength of the plate.

13. Transverse Guided-Bend Weld Tests

13.1 Two bend test specimens shall be taken transversely from the pipe. Except as provided in 13.2, one shall be subject

to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

13.2 For wall thicknesses over $\frac{3}{8}$ in. [9.5 mm] but less than $\frac{3}{4}$ in. [19 mm] side-bend tests may be made instead of the face and root-bend tests. For specified wall thicknesses $\frac{3}{4}$ in. [19 mm] and over, both specimens shall be subjected to the side-bend tests. Side-bend specimens shall be bent so that one of the side surfaces becomes the convex surface of the bend specimen.

13.3 The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. [3 mm] in any direction is present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than $\frac{1}{4}$ in. [6.5 mm] measured in any direction shall not be considered.

14. Test Specimens and Methods of Testing

14.1 Transverse tension and bend test specimens shall be taken from the end of the finished pipe; the transverse tension and bend test specimens shall be flattened cold before final machining to size.

14.2 As an alternative to the requirements of 14.1, it is permitted to take the test specimens from a test plate of the same material as the pipe that is attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

14.3 Tension test specimens shall be made in accordance with Section IX, Part QW, Paragraph QW-150 of the ASME Boiler and Pressure Vessel Code and shall be one of the types shown in QW-462.1 of that code.

14.3.1 Reduced-section specimens conforming to the requirements given in QW-462.1(b) may be used for tension tests on all thicknesses of pipe having outside diameter greater than 3 in. [76 mm].

14.3.2 Turned specimens conforming to the requirements of QW-462.1(d) may be used for tension tests.

14.3.2.1 If turned specimens are used as given in 14.3.2.2 and 14.3.2.3, one complete set shall be made for each required tension test.

14.3.2.2 For thicknesses to and including $\frac{1}{4}$ in. [32 mm], it is permitted to use a single turned specimen.

14.3.2.3 For thicknesses over $\frac{1}{4}$ in. [32 mm], multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the material surface and not over 1 in. [25 mm] apart. The centers of the specimens adjacent to material surfaces shall not exceed $\frac{5}{8}$ in. [16 mm] from the surface.

14.4 The test specimens shall not be cut from the pipe or test plate until after final heat treatment.

15. Mechanical Tests Required

15.1 For the purposes of the tension and bend test requirements, the term "lot" shall mean all pipe of the same grade, permitted to include more than one heat of steel, within a $\frac{3}{16}$ -in [4.7-mm] range of thickness and welded to the same

weld procedure, and when heat treated, done so to the same heat-treating procedure and in the same furnace. The maximum lot size shall be 200 linear ft [60 m] of pipe.

15.1.1 *Transverse Tension Test*—One test shall be made to represent each lot of finished pipe.

15.1.2 *Transverse Guided-Bend Weld Test*—One test (two specimens) shall be made to represent each lot of finished pipe.

15.2 *Hydrostatic Test*—Each length of pipe shall be subjected to a hydrostatic test in accordance with Specification A999/A999M, unless specifically exempted under the provision of 15.3. Pressure shall be held for a sufficient time to permit the inspector to examine the entire length of the welded seam.

15.3 The purchaser, with the agreement of the manufacturer, is permitted to complete the hydrostatic test requirement with the system pressure test, performed at a pressure either lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH."

16. Radiographic Examination

16.1 For Classes 1, 3, and 4 pipe, all welded joints shall be completely examined by radiography.

16.2 For Class 5 pipe, the welded joints shall be spot radiographed to the extent of not less than 12 in. [300 mm] of radiograph per 50 ft [15 m] of weld.

16.3 For Classes 1, 3, and 4 pipe, radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, latest edition, Paragraph UW-51.

16.4 For Class 5 pipe, radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition, Paragraph UW-52.

16.5 Radiographic examination is permitted to be performed prior to heat treatment.

17. Lengths

17.1 Circumferentially welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A999/A999M, the markings on each length of pipe shall include the plate material designations as shown in Table 1, the marking requirements of 6.3 and 15.3, and Class 1, 2, 3, or 4, as appropriate (see 1.3).

18.2 *Bar Coding*—In addition to the requirements in 18.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

19. Keywords

19.1 arc welded steel pipe; austenitic stainless steel; chromium-nickel steel; fusion welded steel pipe; high temperature application; steel pipe; temperature service applications; high; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser is permitted to specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, it is permitted to modify the retest and retreatment provisions of these supplementary requirements.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Tension and Bend Tests

S2.1 Tension tests (Section 12) and bend tests (Section 13) shall be made on specimens to represent each length of pipe. Failure of any test specimen to meet the requirements shall be cause for the rejection of the pipe length represented.

S3. Penetrant Oil and Powder Examination

S3.1 All welded joints shall be subjected to examination by a penetrant oil and powder method. The details of the method and the disposition of flaws detected shall be a matter for agreement between the purchaser and the manufacturer.

S4. Ferrite Control in Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe shall be determined. The procedural details pertaining to this subject (that is, welding; plate and weld

deposit chemistry; testing equipment and method; number and location of test sites; and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 6.3, Grades 321, 321H, 347, 347H, and 348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and manufacturer.

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

NOTE S1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

S7. In-Process Heat Treatments

S7.1 For H grades, separate solution treatments are required for solution annealing. In-process heat treatments are not permitted as a substitute for separate solution annealing.

S8. ASME Section III or Section VIII, Division 1, Construction

S8.1 Products furnished under this specification that are intended for application under the rules of Section III or Section VIII, Division 1, of the ASME Boiler and Pressure

Vessel Code shall be manufactured by holders of the appropriate ASME Certificate of Authorization and Certification Mark. The product is subject to all applicable requirements of Section III or Section VIII, Division 1, including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

S8.2 The applicable ASME Partial Data Report form, signed by an Authorized Inspector or Authorized Nuclear Inspector and a material test report shall be furnished for each lot of pipe.

S8.3 The welded joints shall be full penetration butt welds as obtained by double welding or by other means that will obtain the same quality of deposited weld metal on the inside and outside. Welds using metal backing strips that remain in place are prohibited.

S8.4 In addition to the requirements of 15.1, for pipe that is not heat treated, or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft [60 m] or fraction thereof, of all pipe of the same heat of plate starting material of the same thickness, subjected to the same heat treatment. For pipe that is heat treated in a batch-type furnace that is automatically controlled within a 50 °F [25 °C] range and is equipped with recording pyrometers so that the heating records are available, a lot shall be defined as for continuous furnace heat treatment. Each length of pipe shall be so marked as to identify each such piece of pipe with the lot and the material test report.

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SPECIFICATION FOR CARBON AND FERRITIC ALLOY STEEL FORGED AND BORED PIPE FOR HIGH-TEMPERATURE SERVICE



SA-369/SA-369M



(Identical with ASTM Specification A369/A369M-18.)

Standard Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service

1. Scope

1.1 This specification covers heavy-wall carbon and alloy steel pipe (Note 1) made from turned and bored forgings and is intended for high-temperature service. Pipe ordered under this specification shall be suitable for bending and other forming operations and for fusion welding. Selection will depend on design, service conditions, mechanical properties and high-temperature characteristics.

NOTE 1—The use of the word “pipe” throughout the several sections of this specification is used in the broad sense and intended to mean pipe headers, or leads.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (S1 to S6) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired shall be so stated in the order, together with the number of such tests required.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E290 Test Methods for Bend Testing of Material for Ductility

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

2.2 *ASME Boiler and Pressure Vessel Code:*
Section IX

2.3 ANSI Standard:

B 46.1 Surface Texture

2.4 AWS Specifications:

A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3. Ordering Information

3.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (forged and bored pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (inside diameter and minimum wall thickness),

3.1.5 Length (Permissible Variations in Length Section of Specification A999/A999M),

TABLE 1 Chemical Requirements

Grade	Composition, %				
	FPA	FPB	FP1	FP2	
Carbon	0.25 max	0.30 max	0.10–0.20		0.10–0.20
Manganese	0.27–0.93	0.29–1.06	0.30–0.80		0.30–0.61
Phosphorus, max	0.035	0.035	0.025		0.025
Sulfur, max	0.035	0.035	0.025		0.025
Silicon	0.10 min	0.10 min	0.10–0.50		0.10–0.30
Chromium	...	...	...		0.50–0.81
Molybdenum	...	...	0.44–0.65		0.44–0.65
Grade	FP5	FP9	FP11		FP12
Carbon	0.15 max	0.15 max	0.05–0.15		0.05–0.15
Manganese	0.30–0.60	0.30–0.60	0.30–0.60		0.30–0.61
Phosphorus, max	0.025	0.030	0.025		0.025
Sulfur, max	0.025	0.030	0.025		0.025
Silicon	0.50 max	0.50–1.00	0.50–1.00		0.50 max
Chromium	4.00–6.00	8.00–10.00	1.00–1.50		0.80–1.25
Molybdenum	0.45–0.65	0.90–1.10	0.44–0.65		0.44–0.65
Grade	FP21	FP22	Type 1	Type 2	FP92
Carbon					0.07–0.13
Heat	0.05–0.15	0.05–0.15	0.08–0.12	0.08–0.12	
Product	...	...	...	0.07–0.13	
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.50 ^A	0.30–0.60
Phosphorus, max	0.025	0.025	0.025	0.020 ^A	0.020
Sulfur, max	0.025	0.025	0.025	0.005 ^A	0.010
Silicon	0.50 max	0.50 max	0.20–0.50	0.20–0.40 ^A	0.50 max
Chromium	2.65–3.35	1.90–2.60	8.00–9.50	8.0–9.50 ^A	8.50–9.50
Molybdenum					0.30–0.60
Heat	0.80–1.06	0.87–1.13	0.85–1.05	0.85–1.05	
Product	...	...	...	0.80–1.05	
			Ni 0.40 max	Others: 0.20 max ^A	W 1.50–2.00 V 0.15–0.25 Cb 0.04–0.09
			Heat 0.18–0.25 Product ...	V 0.18–0.25 0.16–0.27	
			Heat 0.06–0.10 Product ...	Cb 0.06–0.10 0.05–0.11	N 0.030–0.070
			N 0.03–0.07	0.035–0.070 ^A	Ni 0.40 max
			Al 0.02 max	0.020 max ^A	Al 0.02 max
			Ti 0.01 max	0.01 max ^A	Ti 0.01 max
			Zr 0.01 max	0.01 max ^A	Zr 0.01 max
			Sn ...	0.010 max ^A	B 0.001–0.006
			Sb ...	0.003 max ^A	
			B ...	0.001 max ^A	
			Cu ...	0.10 max ^A	
			W ...	0.05 max ^A	
			As ...	0.010 max ^A	
			N/Al ...	≥ 4.0	

^AApplies to both heat and product analyses.

3.1.6 Verification of tensile and hardness properties at mid-thickness for Grade FP91 Type 1 and Type 2 (9.2),

3.1.7 End finish (13),

3.1.8 Optional requirements (Sections 8, Supplementary Requirements S1 to S6; 13.2),

3.1.9 Test report required (Certification Section of Specification A999/A999M),

3.1.10 Specification designation, and

3.1.11 Special requirements or exceptions to this specification.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 *Discard:*

5.1.1 A sufficient discard shall be made from each ingot to secure freedom from injurious defects. The steel shall have a homogeneous structure.

5.2 *Manufacture:*

5.2.1 Material for forging shall consist of ingots or of blooms, billets, or solid-rolled bars forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

5.2.2 The material shall be forged (Note 3) by hammering or pressing, and shall be brought as nearly as practicable to the finished shape and size by hot working.

NOTE 3—The cross-sectional area of the solid forging shall have a reduction by forging or by rolling and forging from that of the ingot in the ratio of not less than 3 to 1.

5.2.3 Unless otherwise specified, the final forging operation shall be followed by a treatment suitable to the grade as specified in 5.4.

5.3 Machining:

5.3.1 All forgings shall have both the inner and outer surfaces machined.

5.3.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250- μ in. [6.4- μ m] arithmetical average deviation (AA), terms as defined in ANSI B 46.1-1962, unless otherwise specified.

5.4 Heat Treatment:

5.4.1 All pipe of the grades shown in Table 1 other than FPA, FPB, FP1, FP2, FP12, FP91 Type 1 and Type 2, and FP92 shall be reheated and furnished in the full-annealed or normalized and tempered condition. If furnished in the normalized and tempered condition (Note 4), the temperature for tempering shall be 1250 °F [680 °C] or higher for Grades FP5, FP9, FP21, and FP22, and 1200 °F [650 °C] or higher for Grades FP36 and FP11.

NOTE 4—It is recommended that the temperature for tempering should be at least 100 °F [50 °C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100 °F [600 °C].

5.4.2 Pipe in Grades FPA and FPB as a final heat treatment shall be either normalized or shall be given a stress relieving treatment at 1200 to 1300 °F [650 to 705 °C]. Pipe in Grades FP1, FP2, and FP12, as a final heat treatment shall be given a stress-relieving treatment at 1200 to 1300 °F [650 to 705 °C].

NOTE 5—Certain of the ferritic steels covered by this specification tend to harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, hot-bending and other forming operations, should be followed by suitable heat treatment.

5.4.3 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP91 Type 1 and Type 2 shall be normalized and tempered by reheating within the temperature range from 1900 to 1975 °F [1040 to 1080 °C], followed by air cooling and tempering in the temperature range of 1350 to 1470 °F [730 to 800 °C].

5.4.4 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP92 shall be normalized and tempered by reheating within the temperature range of 1900 to 1975 °F [1040 to 1080 °C], followed by air cooling and tempering in the temperature range of 1350 to 1470 °F [730 to 800 °C].

5.5 Repair by Welding:

5.5.1 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A999/A999M.

5.5.2 All repair welds in FP91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni + Mn content of all welding consumables used to weld repair FP91 Type 1 and Type 2 shall not exceed 1.0 %.

5.5.3 All repair welds in FP92 shall be made using welding consumables meeting the chemical requirements for the grade in Table 1.

5.5.4 After weld repair, Grades FP91 Type 1 and Type 2 and FP92 shall be heat treated at 1350–1470 °F [730–800 °C].

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified.

7.2 In the case of large ingots poured from two or more heats, the weighted average of the chemical determinations of the several heats, made in accordance with 7.1, shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, a product analysis shall be made by the manufacturer on every heat.

8.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

8.3 If the analysis of one of the tests specified in Section 7 or Section 8 does not conform to the requirements specified in Section 6 an analysis of each billet or pipe from the same heat may be made, and all billets or pipes conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2. Tests for acceptance shall be made after final heat treatment of the forging.

9.2 For Grade FP91 Type 1 and Type 2, when requested by the purchaser, the tensile and hardness properties shall be met and verified on material taken from the half-thickness location.

10. Mechanical Tests Required

10.1 *Transverse or Longitudinal Tension Test*—One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

10.2 *Flattening Test*—For pipe NPS 14 or less, and diameter to wall thickness ratios of more than 7.0, a flattening test shall be carried out in accordance with Specification A999/A999M. A test shall be carried out on a specimen taken from one end of each length of pipe.

10.3 *Bend Test*—For pipe larger than NPS 14 or NPS where diameters to wall thickness ratio is 7.0 or less, a bend test shall be carried out in accordance with Test Methods E290. Unless otherwise specified, the test specimens shall be taken in a transverse direction. The diameter of the pin shall be $\frac{2}{3}t$ for longitudinal specimens or $\frac{1}{3}t$ for transverse specimens,

TABLE 2 Tensile Requirements

Grade	FPA	FPB	FP1, FP2	FP12	FP91 Type 1 and Type 2	FP92	All Others
Tensile strength, min; ksi [MPa]	48 [330]	60 [415]	55 [380]	60 [415]	85 [585]	90 [620]	60 [415]
Yield strength, min; ksi [MPa]	30 [210]	35 [240]	30 [210]	32 [220]	60 [415]	64 [440]	30 [210]

Grade	Elongation Requirements							
	FPA		FPB		FP91 Type 1 and Type 2 and FP92		All Others	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %:								
Basic minimum elongation for wall $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full-section	35	25	30	17	27	18	30	20
When standard round 2-in. or 50-mm gage length test specimen is used	28	20	22	12	20	13	22	14

where t is the specimen thickness. The bend test specimens shall be bent at room temperature through 180° without cracking. One bend test shall be taken from one end of each length of pipe.

11. Workmanship

11.1 The pipe shall conform to the sizes and shapes specified by the purchaser.

12. Ends

12.1 Pipe ends shall be machined as specified in the purchase order.

13. Finish

13.1 The finished pipe shall be reasonably straight and shall have a workmanlike finish.

13.2 Repair of defects by welding shall be permitted only subject to the approval of the purchaser. Defects shall be thoroughly chipped or ground out before welding. Only quali-

fied operators and procedures in accordance with the ASME Boiler and Pressure Vessel Code, Section IX, shall be used. Local or full heat treatment in accordance with 5.4 shall follow welding. Local grinding following welding and retreating shall be considered as meeting the requirements of 5.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A999/A999M, the marking shall include the wall thickness, piece mark, length, and additional symbol "S" if the pipe conforms to the supplementary requirements specified in Supplementary Requirements S1 to S5, and the heat number or the manufacturer's number by which the heat can be identified. Indentation stamping, instead of stenciling, will be permitted only with the written approval of the purchaser.

14.2 For FP91, additional marking shall include the appropriate Type.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Additional Tension Test

S1.1 An additional tension test shall be made on a specimen from one or each end of each pipe. If this supplementary requirement is specified, the number of tests per pipe required shall be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation),

that length shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest.

S2. Additional Flattening or Bend Tests

S2.1 The appropriate flattening or bend test may be made on specimens from both ends of each length of pipe. Crop ends may be used. If the specimen from either end of any length fails to conform to the specific requirement, that length shall be rejected.

S3. Ultrasonic Tests

S3.1 Each pipe shall be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Until suitable standards are established, the basis for rejection of material shall be a matter of agreement between the manufacturer and purchaser.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied as agreed upon by the manufacturer and purchaser.

S5. Metal Structure and Etching Tests

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section

from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Alternative Heat Treatment—Grades FP91 Type 1 and Type 2 and FP92

S6.1 Grades FP91 Type 1 and Type 2 and FP92 shall be normalized in accordance with 5.4.3 or 5.4.4, respectively, and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper in the range of 1350 to 1470 °F [730 to 800 °C]. All mechanical tests shall be made on material heat treated in accordance with 5.4.3 or 5.4.4, respectively. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S6" shall be included with the required marking of the pipe.

TEST METHODS AND DEFINITIONS FOR MECHANICAL TESTING OF STEEL PRODUCTS



SA-370



(Identical with ASTM Specification A370-05.)

TEST METHODS AND DEFINITIONS FOR MECHANICAL TESTING OF STEEL PRODUCTS



SA-370



(Identical with ASTM Specification A 370-05)

1. Scope

1.1 These test methods cover procedures and definitions for the mechanical testing of wrought and cast steels, stainless steels, and related alloys. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided, and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases in which the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.

1.2 The following mechanical tests are described:

	Sections
Tension	5 to 13
Bend	14
Hardness	15
Brinell	16
Rockwell	17
Portable	18
Impact	19 to 28
Keywords	29

1.3 Annexes covering details peculiar to certain products are appended to these test methods as follows:

	Annex
Bar Products	A1.1
Tubular Products	Annex A2
Fasteners	Annex A3
Round Wire Products	Annex A4
Significance of Notched-Bar Impact Testing	Annex A5
Converting Percentage Elongation of Round Specimens to Equivalents for Flat Specimens	Annex A6
Testing Multi-Wire Strand	Annex A7
Rounding of Test Data	Annex A8
Methods for Testing Steel Reinforcing Bars	Annex A9
Procedure for Use and Control of Heat-Cycle Simulation	Annex A10

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 When this document is referenced in a metric product specification, the yield and tensile values may be determined in inch-pound (ksi) units then converted into SI (MPa) units. The elongation determined in inch-pound gage lengths of 2 or 8 in. may be reported in SI unit gage lengths of 50 or 200 mm, respectively, as applicable. Conversely, when this document is referenced in an inch-pound product specification, the yield and tensile values may be determined in SI units then converted into inch-pound units. The elongation determined in SI unit gage lengths of 50 or 200 mm may be reported in inch-pound gage lengths of 2 or 8 in., respectively, as applicable.

1.6 Attention is directed to Practices A 880 and E 1595 when there may be a need for information on criteria for evaluation of testing laboratories.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
- A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use
- A 833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers
- A 880 Practice for Criteria for Use in Evaluation of Testing Laboratories and Organizations for Examination and Inspection of Steel, Stainless Steel, and Related Alloys
- E 4 Practices for Force Verification of Testing Machines
- E 6 Terminology Relating to Methods of Mechanical Testing
- E 8 Test Methods for Tension Testing of Metallic Materials

- E 8M Test Methods for Tension Testing of Metallic Materials [Metric]
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 83 Practice for Verification and Classification of Extensometer System
- E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers
- E 190 Test Method for Guided Bend Test for Ductility of Welds
- E 290 Test Method for Bend Testing of Material for Ductility
- E 1595 Practice for Evaluating the Performance of Mechanical Testing Laboratories

2.2 ASME Document:

ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Part UG-8

3. General Precautions

3.1 Certain methods of fabrication, such as bending, forming, and welding, or operations involving heating, may affect the properties of the material under test. Therefore, the product specifications cover the stage of manufacture at which mechanical testing is to be performed. The properties shown by testing prior to fabrication may not necessarily be representative of the product after it has been completely fabricated.

3.2 Improper machining or preparation of test specimens may give erroneous results. Care should be exercised to assure good workmanship in machining. Improperly machined specimens should be discarded and other specimens substituted.

3.3 Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.

3.4 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

4. Orientation of Test Specimens

4.1 The terms “longitudinal test” and “transverse test” are used only in material specifications for wrought products and are not applicable to castings. When such reference

is made to a test coupon or test specimen, the following definitions apply:

4.1.1 Longitudinal Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension (Fig. 1, Fig. 2a, and 2b).

4.1.2 Transverse Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension (Fig. 1).

4.2 The terms “radial test” and “tangential test” are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.2.1 Radial Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center (Fig. 2a).

4.2.2 Tangential Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center (Fig. 2a, 2b, 2c, and 2d).

TENSION TEST

5. Description

5.1 The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in Terminology E 6.

5.2 In general, the testing equipment and methods are given in Test Methods E 8. However, there are certain exceptions to Test Methods E 8 practices in the testing of steel, and these are covered in these test methods.

6. Terminology

6.1 For definitions of terms pertaining to tension testing, including tensile strength, yield point, yield strength,

elongation, and reduction of area, reference should be made to Terminology E 6.

7. Testing Apparatus and Operations

7.1 Loading Systems — There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free running crosshead speeds. Some modern screw power machines, and all hydraulic machines permit stepless variation throughout the range of speeds.

7.2 The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of Practices E 4.

NOTE 1 — Many machines are equipped with stress-strain recorders for autographic plotting of stress-strain curves. It should be noted that some recorders have a load measuring component entirely separate from the load indicator of the testing machine. Such recorders are calibrated separately.

7.3 Loading — It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test and that bending or twisting be held to a minimum. For specimens with a reduced section, gripping of the specimen shall be restricted to the grip section. In the case of certain sections tested in full size, nonaxial loading is unavoidable and in such cases shall be permissible.

7.4 Speed of Testing — The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed: (1) in terms of free running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), (2) in terms of rate of separation of the two heads of the testing machine under load, (3) in terms of rate of stressing the specimen, or (4) in terms of rate of straining the specimen. The following limitations on the speed of testing are recommended as adequate for most steel products:

NOTE 2 — Tension tests using closed-loop machines (with feedback control of rate) should not be performed using load control, as this mode of testing will result in acceleration of the crosshead upon yielding and elevation of the measured yield strength.

7.4.1 Any convenient speed of testing may be used up to one half the specified yield point or yield strength.

When this point is reached, the free-running rate of separation of the crossheads shall be adjusted so as not to exceed $\frac{1}{16}$ in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the free-running rate of separation of the heads shall not exceed $\frac{1}{2}$ in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. In any event, the minimum speed of testing shall not be less than $\frac{1}{10}$ the specified maximum rates for determining yield point or yield strength and tensile strength.

7.4.2 It shall be permissible to set the speed of the testing machine by adjusting the free running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free running crosshead speed.

7.4.3 As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 100 000 psi (690 MPa)/min. However, the minimum rate of stressing shall not be less than 10 000 psi (70 MPa)/min.

8. Test Specimen Parameters

8.1 Selection — Test coupons shall be selected in accordance with the applicable product specifications.

8.1.1 Wrought Steels — Wrought steel products are usually tested in the longitudinal direction, but in some cases, where size permits and the service justifies it, testing is in the transverse, radial, or tangential directions (see Fig. 1 and Fig. 2).

8.1.2 Forged Steels — For open die forgings, the metal for tension testing is usually provided by allowing extensions or prolongations on one or both ends of the forgings, either on all or a representative number as provided by the applicable product specifications. Test specimens are normally taken at mid-radius. Certain product specifications permit the use of a representative bar or the destruction of a production part for test purposes. For ring or disk-like forgings test metal is provided by increasing the diameter, thickness, or length of the forging. Upset disk or ring forgings, which are worked or extended by forging in a direction perpendicular to the axis of the forging, usually have their principal extension along concentric circles and for such forgings tangential tension specimens are obtained from extra metal on the periphery or end of the forging. For some forgings, such as rotors, radial tension tests are required. In such cases the specimens are cut or trepanned from specified locations.

8.1.3 Cast Steels — Test coupons for castings from which tension test specimens are prepared shall be in accordance with the requirements of Specifications A 703/A 703M or A 781/A 781M, as applicable.

8.2 Size and Tolerances — Test specimens shall be the full thickness or section of material as-rolled, or may be machined to the form and dimensions shown in Figs. 3–6, inclusive. The selection of size and type of specimen is prescribed by the applicable product specification. Full section specimens shall be tested in 8 in. (200 mm) gage length unless otherwise specified in the product specification.

8.3 Procurement of Test Specimens — Specimens shall be sheared, blanked, sawed, trepanned, or oxygen-cut from portions of the material. They are usually machined so as to have a reduced cross section at mid-length in order to obtain uniform distribution of the stress over the cross section and to localize the zone of fracture. When test coupons are sheared, blanked, sawed, or oxygen-cut, care shall be taken to remove by machining all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the test.

8.4 Aging of Test Specimens — Unless otherwise specified, it shall be permissible to age tension test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil or in an oven.

8.5 Measurement of Dimensions of Test Specimens:

8.5.1 Standard Rectangular Tension Test Specimens — These forms of specimens are shown in Fig. 3. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.005 in. (0.13 mm) for the 8 in. (200 mm) gage length specimen and 0.001 in. (0.025 mm) for the 2 in. (50 mm) gage length specimen in Fig. 3. The center thickness dimension shall be measured to the nearest 0.001 in. for both specimens.

8.5.2 Standard Round Tension Test Specimens — These forms of specimens are shown in Fig. 4 and Fig. 5. To determine the cross-sectional area, the diameter shall be measured at the center of the gage length to the nearest 0.001 in. (0.025 mm) (see Table 1).

8.6 General — Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.

8.6.1 Improperly prepared test specimens often cause unsatisfactory test results. It is important, therefore, that care be exercised in the preparation of specimens, particularly in the machining, to assure good workmanship.

8.6.2 It is desirable to have the cross-sectional area of the specimen smallest at the center of the gage length to ensure fracture within the gage length. This is provided for by the taper in the gage length permitted for each of the specimens described in the following sections.

8.6.3 For brittle materials it is desirable to have fillets of large radius at the ends of the gage length.

9. Plate-Type Specimen

9.1 The standard plate-type test specimen is shown in Fig. 3. This specimen is used for testing metallic materials in the form of plate, structural and bar-size shapes, and flat material having a nominal thickness of $\frac{3}{16}$ in. (5 mm) or over. When product specifications so permit, other types of specimens may be used.

NOTE 3 — When called for in the product specification, the 8 in. gage length specimen of Fig. 3 may be used for sheet and strip material.

10. Sheet-Type Specimen

10.1 The standard sheet-type test specimen is shown in Fig. 3. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.005 to $\frac{3}{4}$ in. (0.13 to 19 mm). When product specifications so permit, other types of specimens may be used, as provided in Section 9 (see Note 3).

11. Round Specimens

11.1 The standard 0.500 in. (12.5 mm) diameter round test specimen shown in Fig. 4 is used quite generally for testing metallic materials, both cast and wrought.

11.2 Fig. 4 also shows small size specimens proportional to the standard specimen. These may be used when it is necessary to test material from which the standard specimen or specimens shown in Fig. 3 cannot be prepared. Other sizes of small round specimens may be used. In any such small size specimen it is important that the gage length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4).

11.3 The shape of the ends of the specimens outside of the gage length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads are applied axially. Fig. 5 shows specimens with various types of ends that have given satisfactory results.

12. Gage Marks

12.1 The specimens shown in Figs. 3–6 shall be gage marked with a center punch, scribe marks, multiple device,

or drawn with ink. The purpose of these gage marks is to determine the percent elongation. Punch marks shall be light, sharp, and accurately spaced. The localization of stress at the marks makes a hard specimen susceptible to starting fracture at the punch marks. The gage marks for measuring elongation after fracture shall be made on the flat or on the edge of the flat tension test specimen and within the parallel section; for the 8 in. gage length specimen, Fig. 3, one or more sets of 8 in. gage marks may be used, intermediate marks within the gage length being optional. Rectangular 2-in. gage length specimens, Fig. 3, and round specimens, Fig. 4, are gage marked with a double-pointed center punch or scribe marks. One or more sets of gage marks may be used; however, one set must be approximately centered in the reduced section. These same precautions shall be observed when the test specimen is full section.

13. Determination of Tensile Properties

13.1 Yield Point — Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:

13.1.1 Drop of the Beam or Halt of the Pointer Method — In this method, apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief but appreciable interval of time. When a machine equipped with a load-indicating dial is used there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the “drop of the beam” or the “halt of the pointer” and record the corresponding stress as the yield point.

13.1.2 Autographic Diagram Method — When a sharp-kneed stress-strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Fig. 7), or the stress at which the curve drops as the yield point.

13.1.3 Total Extension Under Load Method — When testing material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt of the pointer, or autographic

diagram methods described in 13.1.1 and 13.1.2, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better extensometer (Note 4 and Note 5) to the specimen. When the load producing a specified extension (Note 6) is reached record the stress corresponding to the load as the yield point (Fig. 8).

NOTE 4 — Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

NOTE 5 — Reference should be made to Practice E 83.

NOTE 6 — For steel with a yield point specified not over 80 000 psi (550 MPa), an appropriate value is 0.005 in./in. of gage length. For values above 80 000 psi, this method is not valid unless the limiting total extension is increased.

NOTE 7 — The shape of the initial portion of an autographically determined stress-strain (or a load-elongation) curve may be influenced by numerous factors such as the seating of the specimen in the grips, the straightening of a specimen bent due to residual stresses, and the rapid loading permitted in 7.4.1. Generally, the aberrations in this portion of the curve should be ignored when fitting a modulus line, such as that used to determine the extension-under-load yield, to the curve.

13.2 Yield Strength — Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent offset, total extension under load, etc. Determine yield strength by one of the following methods:

13.2.1 Offset Method — To determine the yield strength by the “offset method,” it is necessary to secure data (autographic or numerical) from which a stress-strain diagram with a distinct modulus characteristic of the material being tested may be drawn. Then on the stress-strain diagram (Fig. 9) lay off O_m equal to the specified value of the offset, draw mn parallel to OA , and thus locate r , the intersection of mn with the stress-strain curve corresponding to load R , which is the yield-strength load. In recording values of yield strength obtained by this method, the value of offset specified or used, or both, shall be stated in parentheses after the term yield strength, for example:

$$\text{Yield strength (0.2\% offset)} = 52\,000 \text{ psi (360 MPa)} \quad (1)$$

When the offset is 0.2% or larger, the extensometer used shall qualify as a Class B2 device over a strain range of 0.05 to 1.0%. If a smaller offset is specified, it may be necessary to specify a more accurate device (that is, a Class B1 device) or reduce the lower limit of the strain range (for example, to 0.01%) or both. See also Note 9 for automatic devices.

NOTE 8 — For stress-strain diagrams not containing a distinct modulus, such as for some cold-worked materials, it is recommended that the extension under load method be utilized. If the offset method is used for materials without a distinct modulus, a modulus value appropriate for the material being tested should be used: 30 000 000 psi (207 000 MPa) for carbon steel; 29 000 000 psi (200 000 MPa) for ferritic stainless steel; 28 000 000 psi (193 000 MPa) for austenitic stainless steel. For special alloys, the producer should be contacted to discuss appropriate modulus values.

13.2.2 Extension Under Load Method — For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (see Note 9 and Note 10) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is the value of the yield strength. In recording values of yield strength obtained by this method, the value of “extension” specified or used, or both, shall be stated in parentheses after the term yield strength, for example:

$$\text{Yield strength (0.5\% EUL)} = 52\,000 \text{ psi (360 MPa)} \quad (2)$$

The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Note 4, Note 5, and Note 7).

NOTE 9 — Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated.

NOTE 10 — The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular steel under test. In general, the value of extension under load applicable to steel at any strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation is used:

$$\text{Extension under load, in./in. of gage length} = (YS/E) + r \quad (3)$$

where:

- YS = specified yield strength, psi or MPa,
- E = modulus of elasticity, psi or MPa, and
- r = limiting plastic strain, in./in.

13.3 Tensile Strength — Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

13.4 Elongation:

13.4.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. (0.25 mm) for gage lengths of 2 in. and under, and to the nearest 0.5% of the gage length for gage lengths over 2 in. A percentage scale reading to 0.5% of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In recording elongation values, give both the percentage increase and the original gage length.

13.4.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

13.4.3 Automated tensile testing methods using extensometers allow for the measurement of elongation in a method described below. Elongation may be measured and reported either this way, or as in the method described above, fitting the broken ends together. Either result is valid.

13.4.4 Elongation at fracture is defined as the elongation measured just prior to the sudden decrease in force associated with fracture. For many ductile materials not exhibiting a sudden decrease in force, the elongation at fracture can be taken as the strain measured just prior to when the force falls below 10% of the maximum force encountered during the test.

13.4.4.1 Elongation at fracture shall include elastic and plastic elongation and may be determined with autographic or automated methods using extensometers verified over the strain range of interest. Use a class B2 or better extensometer for materials having less than 5% elongation; a class C or better extensometer for materials having elongation greater than or equal to 5% but less than 50%; and a class D or better extensometer for materials having 50% or greater elongation. In all cases, the extensometer gage length shall be the nominal gage length required for the specimen being tested. Due to the lack of precision in fitting fractured ends together, the elongation after fracture using the manual methods of the preceding paragraphs may differ from the elongation at fracture determined with extensometers.

13.4.4.2 Percent elongation at fracture may be calculated directly from elongation at fracture data and be reported instead of percent elongation as calculated in 13.4.1. However, these two parameters are not interchangeable. Use of the elongation at fracture method generally provides more repeatable results.

13.5 Reduction of Area — Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area is the reduction of area.

BEND TEST

14. Description

14.1 The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in bending operations. The severity of the bend test is primarily a function of the angle of bend and inside diameter to which the specimen is bent, and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified. Test Method E 190 and Test Method E 290 may be consulted for methods of performing the test.

14.2 Unless otherwise specified, it shall be permissible to age bend test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water or by heating in oil or in an oven.

14.3 Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specifications, to the extent specified without major cracking on the outside of the bent portion. The speed of bending is ordinarily not an important factor.

HARDNESS TEST

15. General

15.1 A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Table 2, Table 3, Table 4, and Table 5 are for the conversion of hardness measurements from one scale to another or to approximate tensile strength. These conversion values have been obtained from computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.

15.2 Hardness Testing:

15.2.1 If the product specification permits alternative hardness testing to determine conformance to a specified hardness requirement, the conversions listed in Table 2, Table 3, Table 4, and Table 5 shall be used.

15.2.2 When recording converted hardness numbers, the measured hardness and test scale shall be indicated in parentheses, for example: 353 HB (38 HRC). This means that a hardness value of 38 was obtained using the Rockwell C scale and converted to a Brinell hardness of 353.

16. Brinell Test

16.1 Description:

16.1.1 A specified load is applied to a flat surface of the specimen to be tested, through a hard ball of specified diameter. The average diameter of the indentation is used as a basis for calculation of the Brinell hardness number. The quotient of the applied load divided by the area of the surface of the indentation, which is assumed to be spherical, is termed the Brinell hardness number (HB) in accordance with the following equation:

$$HB = P/[(\pi D/2)(D - \sqrt{D^2 - d^2})] \quad (4)$$

where:

HB = Brinell hardness number,

P = applied load, kgf,

D = diameter of the steel ball, mm, and

d = average diameter of the indentation, mm.

NOTE 11 — The Brinell hardness number is more conveniently secured from standard tables such as Table 6, which show numbers corresponding to the various indentation diameters, usually in increments of 0.05 mm.

NOTE 12 — In Test Method E 10 the values are stated in SI units, whereas in this section kg/m units are used.

16.1.2 The standard Brinell test using a 10 mm ball employs a 3000 kgf load for hard materials and a 1500 or 500 kgf load for thin sections or soft materials (see Annex A2 on Steel Tubular Products). Other loads and different size indentors may be used when specified. In recording hardness values, the diameter of the ball and the load must be stated except when a 10 mm ball and 3000 kgf load are used.

16.1.3 A range of hardness can properly be specified only for quenched and tempered or normalized and tempered material. For annealed material a maximum figure only should be specified. For normalized material a minimum or a maximum hardness may be specified by agreement. In general, no hardness requirements should be applied to untreated material.

16.1.4 Brinell hardness may be required when tensile properties are not specified.

16.2 Apparatus — Equipment shall meet the following requirements:

16.2.1 Testing Machine — A Brinell hardness testing machine is acceptable for use over a loading range within which its load measuring device is accurate to $\pm 1\%$.

16.2.2 Measuring Microscope — The divisions of the micrometer scale of the microscope or other measuring devices used for the measurement of the diameter of the indentations shall be such as to permit the direct measurement of the diameter to 0.1 mm and the estimation of the diameter to 0.05 mm.

NOTE 13 — This requirement applies to the construction of the microscope only and is not a requirement for measurement of the indentation, see 16.4.3.

16.2.3 Standard Ball — The standard ball for Brinell hardness testing is 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.005 mm (0.0004 in.) in any diameter. A ball suitable for use must not show a permanent change in diameter greater than 0.01 mm (0.0004 in.) when pressed with a force of 3000 kgf against the test specimen.

16.3 Test Specimen — Brinell hardness tests are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.

16.4 Procedure:

16.4.1 It is essential that the applicable product specifications state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least two and one-half times the diameter of the indentation.

16.4.2 Apply the load for a minimum of 15 s.

16.4.3 Measure two diameters of the indentation at right angles to the nearest 0.1 mm, estimate to the nearest 0.05 mm, and average to the nearest 0.05 mm. If the two diameters differ by more than 0.1 mm, discard the readings and make a new indentation.

16.4.4 Do not use a steel ball on steels having a hardness over 450 HB nor a carbide ball on steels having a hardness over 650 HB. The Brinell hardness test is not recommended for materials having a hardness over 650 HB.

16.4.4.1 If a ball is used in a test of a specimen which shows a Brinell hardness number greater than the limit for the ball as detailed in 16.4.4, the ball shall be either discarded and replaced with a new ball or remeasured to ensure conformance with the requirements of Test Method E 10.

16.5 Detailed Procedure — For detailed requirements of this test, reference shall be made to the latest revision of Test Method E 10.

17. Rockwell Test

17.1 Description:

17.1.1 In this test a hardness value is obtained by determining the depth of penetration of a diamond point

or a steel ball into the specimen under certain arbitrarily fixed conditions. A minor load of 10 kgf is first applied which causes an initial penetration, sets the penetrator on the material and holds it in position. A major load which depends on the scale being used is applied increasing the depth of indentation. The major load is removed and, with the minor load still acting, the Rockwell number, which is proportional to the difference in penetration between the major and minor loads is determined; this is usually done by the machine and shows on a dial, digital display, printer, or other device. This is an arbitrary number which increases with increasing hardness. The scales most frequently used are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
B	1/16 in. steel ball	100	10
C	Diamond brale	150	10

17.1.2 Rockwell superficial hardness machines are used for the testing of very thin steel or thin surface layers. Loads of 15, 30, or 45 kgf are applied on a hardened steel ball or diamond penetrator, to cover the same range of hardness values as for the heavier loads. The superficial hardness scales are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
15T	1/16 in. steel ball	15	3
30T	1/16 in. steel ball	30	3
45T	1/16 in. steel ball	45	3
15N	Diamond brale	15	3
30N	Diamond brale	30	3
45N	Diamond brale	45	3

17.2 Reporting Hardness — In recording hardness values, the hardness number shall always precede the scale symbol, for example: 96 HRB, 40 HRC, 75 HR15N, or 77 HR30T.

17.3 Test Blocks — Machines should be checked to make certain they are in good order by means of standardized Rockwell test blocks.

17.4 Detailed Procedure — For detailed requirements of this test, reference shall be made to the latest revision of Test Methods E 18.

18. Portable Hardness Test

18.1 Although the use of the standard, stationary Brinell or Rockwell hardness tester is generally preferred, it is not always possible to perform the hardness test using such equipment due to the part size or location. In this event, hardness testing using portable equipment as described in Practice A 833 or Test Method E 110 shall be used.

CHARPY IMPACT TESTING

19. Summary

19.1 A Charpy V-notch impact test is a dynamic test in which a notched specimen is struck and broken by a single blow in a specially designed testing machine. The measured test values may be the energy absorbed, the percentage shear fracture, the lateral expansion opposite the notch, or a combination thereof.

19.2 Testing temperatures other than room (ambient) temperature often are specified in product or general requirement specifications (hereinafter referred to as the specification). Although the testing temperature is sometimes related to the expected service temperature, the two temperatures need not be identical.

20. Significance and Use

20.1 Ductile vs. Brittle Behavior — Body-centered-cubic or ferritic alloys exhibit a significant transition in behavior when impact tested over a range of temperatures. At temperatures above transition, impact specimens fracture by a ductile (usually microvoid coalescence) mechanism, absorbing relatively large amounts of energy. At lower temperatures, they fracture in a brittle (usually cleavage) manner absorbing less energy. Within the transition range, the fracture will generally be a mixture of areas of ductile fracture and brittle fracture.

20.2 The temperature range of the transition from one type of behavior to the other varies according to the material being tested. This transition behavior may be defined in various ways for specification purposes.

20.2.1 The specification may require a minimum test result for absorbed energy, fracture appearance, lateral expansion, or a combination thereof, at a specified test temperature.

20.2.2 The specification may require the determination of the transition temperature at which either the absorbed energy or fracture appearance attains a specified level when testing is performed over a range of temperatures.

20.3 Further information on the significance of impact testing appears in Annex A5.

21. Apparatus

21.1 Testing Machines:

21.1.1 A Charpy impact machine is one in which a notched specimen is broken by a single blow of a freely swinging pendulum. The pendulum is released from a fixed height. Since the height to which the pendulum is raised prior to its swing, and the mass of the pendulum are known,

the energy of the blow is predetermined. A means is provided to indicate the energy absorbed in breaking the specimen.

21.1.2 The other principal feature of the machine is a fixture (See Fig. 10) designed to support a test specimen as a simple beam at a precise location. The fixture is arranged so that the notched face of the specimen is vertical. The pendulum strikes the other vertical face directly opposite the notch. The dimensions of the specimen supports and striking edge shall conform to Fig. 10.

21.1.3 Charpy machines used for testing steel generally have capacities in the 220 to 300 ft•lbf (300 to 400 J) energy range. Sometimes machines of lesser capacity are used; however, the capacity of the machine should be substantially in excess of the absorbed energy of the specimens (see Test Methods E 23). The linear velocity at the point of impact should be in the range of 16 to 19 ft/s (4.9 to 5.8 m/s).

21.2 Temperature Media:

21.2.1 For testing at other than room temperature, it is necessary to condition the Charpy specimens in media at controlled temperatures.

21.2.2 Low temperature media usually are chilled fluids (such as water, ice plus water, dry ice plus organic solvents, or liquid nitrogen) or chilled gases.

21.2.3 Elevated temperature media are usually heated liquids such as mineral or silicone oils. Circulating air ovens may be used.

21.3 Handling Equipment — Tongs, especially adapted to fit the notch in the impact specimen, normally are used for removing the specimens from the medium and placing them on the anvil (refer to Test Methods E 23). In cases where the machine fixture does not provide for automatic centering of the test specimen, the tongs may be precision machined to provide centering.

22. Sampling and Number of Specimens

22.1 Sampling:

22.1.1 Test location and orientation should be addressed by the specifications. If not, for wrought products, the test location shall be the same as that for the tensile specimen and the orientation shall be longitudinal with the notch perpendicular to the major surface of the product being tested.

22.1.2 Number of Specimens.

22.1.2.1 A Charpy impact test consists of all specimens taken from a single test coupon or test location.

22.1.2.2 When the specification calls for a minimum average test result, three specimens shall be tested.

22.1.2.3 When the specification requires determination of a transition temperature, eight to twelve specimens are usually needed.

22.2 Type and Size:

22.2.1 Use a standard full size Charpy V-notch specimen (Type A) as shown in Fig. 11, except as allowed in 22.2.2.

22.2.2 Subsize Specimens.

22.2.2.1 For flat material less than $\frac{7}{16}$ in. (11 mm) thick, or when the absorbed energy is expected to exceed 80% of full scale, use standard subsize test specimens.

22.2.2.2 For tubular materials tested in the transverse direction, where the relationship between diameter and wall thickness does not permit a standard full size specimen, use standard subsize test specimens or standard size specimens containing outer diameter (OD) curvature as follows:

(1) Standard size specimens and subsize specimens may contain the original OD surface of the tubular product as shown in Fig. 12. All other dimensions shall comply with the requirements of Fig. 11.

NOTE 14 — For materials with toughness levels in excess of about 50 ft-lbs, specimens containing the original OD surface may yield values in excess of those resulting from the use of conventional Charpy specimens.

22.2.2.3 If a standard full-size specimen cannot be prepared, the largest feasible standard subsize specimen shall be prepared. The specimens shall be machined so that the specimen does not include material nearer to the surface than 0.020 in. (0.5 mm).

22.2.2.4 Tolerances for standard subsize specimens are shown in Fig. 11. Standard subsize test specimen sizes are: 10 × 7.5 mm, 10 × 6.7 mm, 10 × 5 mm, 10 × 3.3 mm, and 10 × 2.5 mm.

22.2.2.5 Notch the narrow face of the standard subsize specimens so that the notch is perpendicular to the 10 mm wide face.

22.3 Notch Preparation — The machining of the notch is critical, as it has been demonstrated that extremely minor variations in notch radius and profile, or tool marks at the bottom of the notch may result in erratic test data. (See Annex A5).

23. Calibration

23.1 Accuracy and Sensitivity — Calibrate and adjust Charpy impact machines in accordance with the requirements of Test Methods E 23.

24. Conditioning — Temperature Control

24.1 When a specific test temperature is required by the specification or purchaser, control the temperature of

the heating or cooling medium within $\pm 2^\circ\text{F}$ (1°C) because the effect of variations in temperature on Charpy test results can be very great.

NOTE 15 — For some steels there may not be a need for this restricted temperature, for example, austenitic steels.

NOTE 16 — Because the temperature of a testing laboratory often varies from 60 to 90°F (15 to 32°C) a test conducted at “room temperature” might be conducted at any temperature in this range.

25. Procedure

25.1 Temperature:

25.1.1 Condition the specimens to be broken by holding them in the medium at test temperature for at least 5 min in liquid media and 30 min in gaseous media.

25.1.2 Prior to each test, maintain the tongs for handling test specimens at the same temperature as the specimen so as not to affect the temperature at the notch.

25.2 Positioning and Breaking Specimens:

25.2.1 Carefully center the test specimen in the anvil and release the pendulum to break the specimen.

25.2.2 If the pendulum is not released within 5 s after removing the specimen from the conditioning medium, do not break the specimen. Return the specimen to the conditioning medium for the period required in 25.1.1.

25.3 Recovering Specimens — In the event that fracture appearance or lateral expansion must be determined, recover the matched pieces of each broken specimen before breaking the next specimen.

25.4 Individual Test Values:

25.4.1 Impact energy — Record the impact energy absorbed to the nearest ft•lbf (J).

25.4.2 Fracture Appearance:

25.4.2.1 Determine the percentage of shear fracture area by any of the following methods:

(1) Measure the length and width of the brittle portion of the fracture surface, as shown in Fig. 13 and determine the percent shear area from either Table 7 or Table 8 depending on the units of measurement.

(2) Compare the appearance of the fracture of the specimen with a fracture appearance chart as shown in Fig. 14.

(3) Magnify the fracture surface and compare it to a precalibrated overlay chart or measure the percent shear fracture area by means of a planimeter.

(4) Photograph the fractured surface at a suitable magnification and measure the percent shear fracture area by means of a planimeter.

25.4.2.2 Determine the individual fracture appearance values to the nearest 5% shear fracture and record the value.

25.4.3 Lateral Expansion:

25.4.3.1 Lateral expansion is the increase in specimen width, measured in thousandths of an inch (mils), on the compression side, opposite the notch of the fractured Charpy V-notch specimen as shown in Fig. 15.

25.4.3.2 Examine each specimen half to ascertain that the protrusions have not been damaged by contacting the anvil, machine mounting surface, and so forth. Discard such samples since they may cause erroneous readings.

25.4.3.3 Check the sides of the specimens perpendicular to the notch to ensure that no burrs were formed on the sides during impact testing. If burrs exist, remove them carefully by rubbing on emery cloth or similar abrasive surface, making sure that the protrusions being measured are not rubbed during the removal of the burr.

25.4.3.4 Measure the amount of expansion on each side of each half relative to the plane defined by the undeformed portion of the side of the specimen using a gage similar to that shown in Fig. 16 and Fig. 17.

25.4.3.5 Since the fracture path seldom bisects the point of maximum expansion on both sides of a specimen, the sum of the larger values measured for each side is the value of the test. Arrange the halves of one specimen so that compression sides are facing each other. Using the gage, measure the protrusion on each half specimen, ensuring that the same side of the specimen is measured. Measure the two broken halves individually. Repeat the procedure to measure the protrusions on the opposite side of the specimen halves. The larger of the two values for each side is the expansion of that side of the specimen.

25.4.3.6 Measure the individual lateral expansion values to the nearest mil (0.025 mm) and record the values.

25.4.3.7 With the exception described as follows, any specimen that does not separate into two pieces when struck by a single blow shall be reported as unbroken. If the specimen can be separated by force applied by bare hands, the specimen may be considered as having been separated by the blow.

26. Interpretation of Test Result

26.1 When the acceptance criterion of any impact test is specified to be a minimum average value at a given temperature, the test result shall be the average (arithmetic mean) of the individual test values of three specimens from one test location.

26.1.1 When a minimum average test result is specified:

26.1.1.1 The test result is acceptable when all of the below are met:

(1) The test result equals or exceeds the specified minimum average (given in the specification),

(2) The individual test value for not more than one specimen measures less than the specified minimum average, and

(3) The individual test value for any specimen measures not less than two-thirds of the specified minimum average.

26.1.1.2 If the acceptance requirements of 26.1.1.1 are not met, perform one retest of three additional specimens from the same test location. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.

26.2 Test Specifying a Minimum Transition Temperature:

26.2.1 Definition of Transition Temperature — For specification purposes, the transition temperature is the temperature at which the designated material test value equals or exceeds a specified minimum test value.

26.2.2 Determination of Transition Temperature:

26.2.2.1 Break one specimen at each of a series of temperatures above and below the anticipated transition temperature using the procedures in Section 25. Record each test temperature to the nearest 1°F (0.5°C).

26.2.2.2 Plot the individual test results (ft•lbf or percent shear) as the ordinate versus the corresponding test temperature as the abscissa and construct a best-fit curve through the plotted data points.

26.2.2.3 If transition temperature is specified as the temperature at which a test value is achieved, determine the temperature at which the plotted curve intersects the specified test value by graphical interpolation (extrapolation is not permitted). Record this transition temperature to the nearest 5°F (3°C). If the tabulated test results clearly indicate a transition temperature lower than specified, it is not necessary to plot the data. Report the lowest test temperature for which test value exceeds the specified value.

26.2.2.4 Accept the test result if the determined transition temperature is equal to or lower than the specified value.

26.2.2.5 If the determined transition temperature is higher than the specified value, but not more than 20°F (12°C) higher than the specified value, test sufficient samples in accordance with Section 25 to plot two additional curves. Accept the test results if the temperatures determined from both additional tests are equal to or lower than the specified value.

26.3 When subsize specimens are permitted or necessary, or both, modify the specified test requirement according to Table 9 or test temperature according to ASME Boiler and Pressure Vessel Code, Table UG-84.2, or both. Greater energies or lower test temperatures may be agreed upon by purchaser and supplier.

27. Records

27.1 The test record should contain the following information as appropriate:

27.1.1 Full description of material tested (that is, specification number, grade, class or type, size, heat number).

27.1.2 Specimen orientation with respect to the material axis.

27.1.3 Specimen size.

27.1.4 Test temperature and individual test value for each specimen broken, including initial tests and retests.

27.1.5 Test results.

27.1.6 Transition temperature and criterion for its determination, including initial tests and retests.

28. Report

28.1 The specification should designate the information to be reported.

29. Keywords

29.1 bend test; Brinell hardness; Charpy impact test; elongation; FATT (Fracture Appearance Transition Temperature); hardness test; portable hardness; reduction of area; Rockwell hardness; tensile strength; tension test; yield strength

FIG. 1 THE RELATION OF TEST COUPONS AND TEST SPECIMENS TO ROLLING DIRECTION OR EXTENSION (APPLICABLE TO GENERAL WROUGHT PRODUCTS)

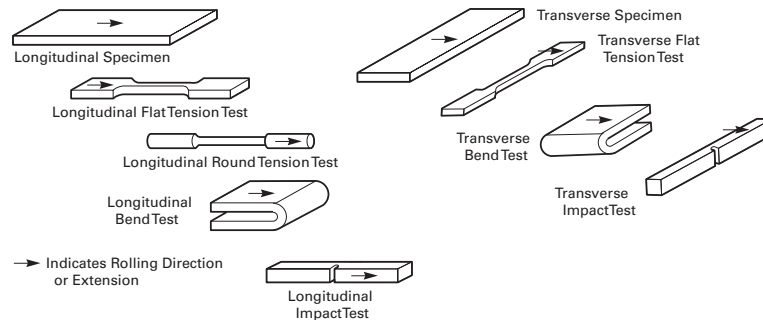


FIG. 2 LOCATION OF LONGITUDINAL TENSION TEST SPECIMENS IN RINGS CUT FROM TUBULAR PRODUCTS

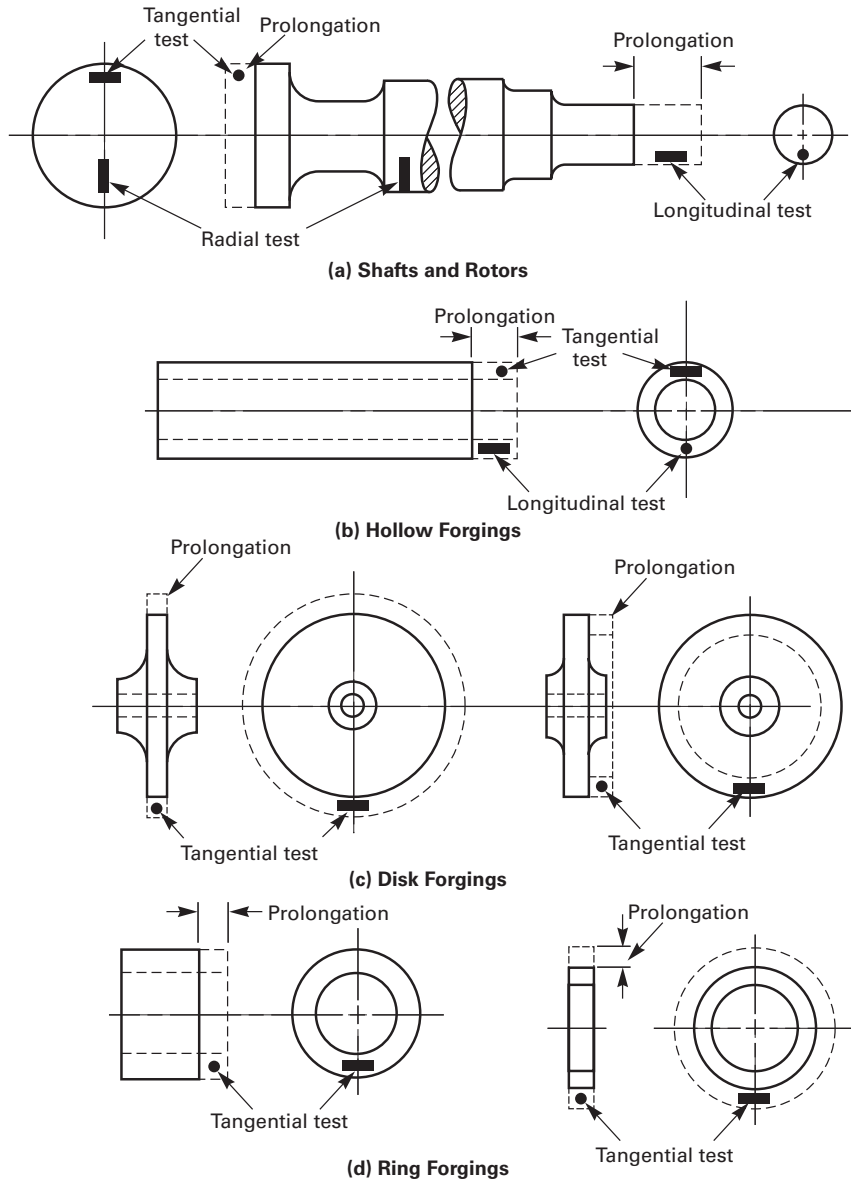
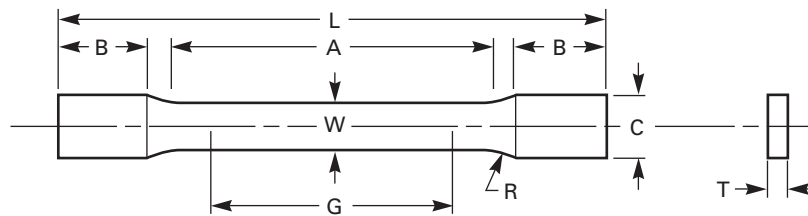


FIG. 3 RECTANGULAR TENSION TEST SPECIMENS



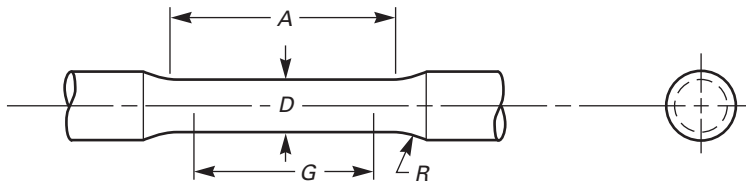
DIMENSIONS

	Standard Specimens				Subsize Specimen	
	Plate-Type, 1½ in. Wide		Sheet-Type, ½ in. Wide		¼ in. Wide	
	in.	mm	in.	mm	in.	mm
<i>G</i> —Gage length (Notes 1 and 2)	8.00 ± 0.01	200 ± 0.25	2.000 ± 0.005	50.0 ± 0.10	1.000 ± 0.003	25.0 ± 0.08
<i>W</i> —Width (Notes 3, 5, and 6)	1½ + ⅛ – ¼	40 + 3 – 6	0.500 ± 0.010	12.5 ± 0.25	0.250 ± 0.002	6.25 ± 0.05
<i>T</i> —Thickness (Note 7)			thickness of material			
<i>R</i> —Radius of fillet, min (Note 4)	½	13	½	13	¼	6
<i>L</i> —Over-all length, min (Notes 2 and 8)	18	450	8	200	4	100
<i>A</i> —Length of reduced section, min	9	225	2¼	60	1¼	32
<i>B</i> —Length of grip section, min (Note 9)	3	75	2	50	1¼	32
<i>C</i> —Width of grip section, approximate (Notes 4, 10, and 11)	2	50	¾	20	⅜	10

NOTES:

- For the 1½ in. (40 mm) wide specimen, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. Either a set of nine or more punch marks 1 in. (25 mm) apart, or one or more pairs of punch marks 8 in. (200 mm) apart may be used.
- For the ½ in. (12.5 mm) wide specimen, gage marks for measuring the elongation after fracture shall be made on the ½ in. (12.5 mm) face or on the edge of the specimen and within the reduced section. Either a set of three or more marks 1.0 in. (25 mm) apart or one or more pairs of marks 2 in. (50 mm) apart may be used.
- For the three sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.004, 0.002 or 0.001 in. (0.10, 0.05 or 0.025 mm), respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at either end shall not be more than 0.015 in., 0.005 in., or 0.003 in. (0.40, 0.10 or 0.08 mm), respectively, larger than the width at the center.
- For each specimen type, the radii of all fillets shall be equal to each other with a tolerance of 0.05 in. (1.25 mm), and the centers of curvature of the two fillets at a particular end shall be located across from each other (on a line perpendicular to the centerline) within a tolerance of 0.10 in. (2.5 mm).
- For each of the three sizes of specimens, narrower widths (*W* and *C*) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than *W*, the sides may be parallel throughout the length of the specimen.
- The specimen may be modified by making the sides parallel throughout the length of the specimen, the width and tolerances being the same as those specified above. When necessary a narrower specimen may be used, in which case the width should be as great as the width of the material being tested permits. If the width is 1½ in. (38 mm) or less, the sides may be parallel throughout the length of the specimen.
- The dimension *T* is the thickness of the test specimen as provided for in the applicable material specifications. Minimum nominal thickness of 1½ in. (40 mm) wide specimens shall be ⅜ in. (5 mm), except as permitted by the product specification. Maximum nominal thickness of ½ in. (12.5 mm) and ¼ in. (6 mm) wide specimens shall be ¾ in. (19 mm) and ¼ in. (6 mm), respectively.
- To aid in obtaining axial loading during testing of ¼ in. (6 mm) wide specimens, the overall length should be as the material will permit.
- It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of ½ in. (13 mm) wide specimens is over ⅜ in. (10 mm), longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.
- For standard sheet-type specimens and subsize specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.01 and 0.005 in. (0.25 and 0.13 mm), respectively. However, for steel if the ends of the ½ in. (12.5 mm) wide specimen are symmetrical within 0.05 in. (1.0 mm) a specimen may be considered satisfactory for all but referee testing.
- For standard plate-type specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.25 in. (6.35 mm) except for referee testing in which case the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in. (2.5 mm).

FIG. 4 STANDARD 0.500 IN. (12.5 MM) ROUND TENSION TEST SPECIMEN WITH 2 IN. (50 MM) GAGE LENGTH AND EXAMPLES OF SMALL-SIZE SPECIMENS PROPORTIONAL TO THE STANDARD SPECIMENS



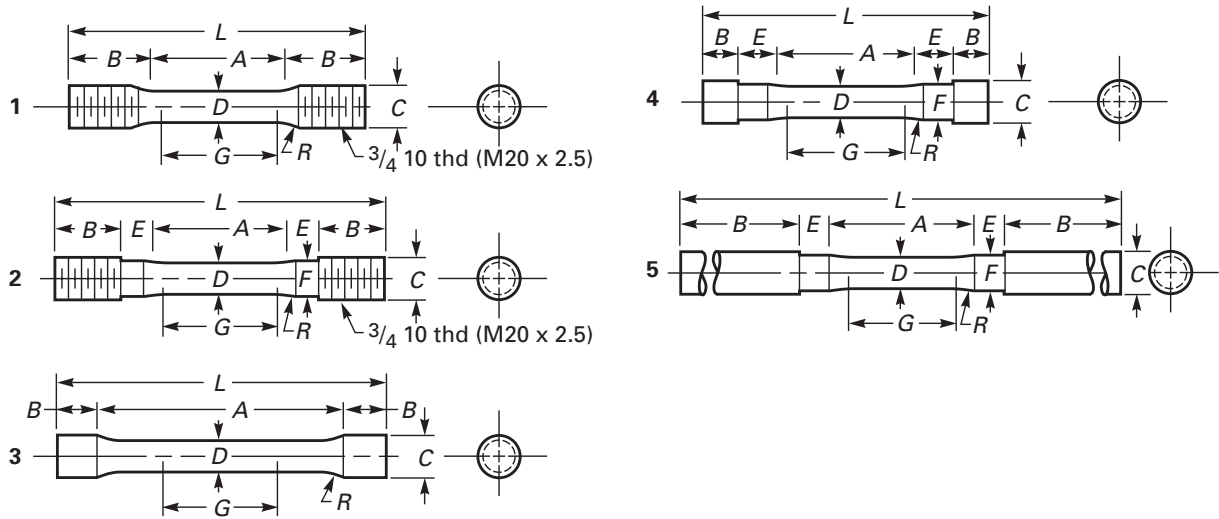
DIMENSIONS

	Standard Specimen		Small-Size Specimens Proportional to Standard							
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
Nominal Diameter	0.500	12.5	0.350	8.75	0.250	6.25	0.160	4.00	0.113	2.50
<i>G</i> —Gage length	2.00± 0.005	50.0± 0.10	1.400± 0.005	35.0± 0.10	1.000± 0.005	25.0± 0.10	0.640± 0.005	16.0± 0.10	0.450± 0.005	10.0± 0.10
<i>D</i> —Diameter (Note 1)	0.500± 0.010	12.5± 0.25	0.350± 0.007	8.75± 0.18	0.250± 0.005	6.25± 0.12	0.160± 0.003	4.00± 0.08	0.113± 0.002	2.50± 0.05
<i>R</i> —Radius of fillet, min	$\frac{3}{8}$	10	$\frac{1}{4}$	6	$\frac{3}{16}$	5	$\frac{5}{32}$	4	$\frac{3}{32}$	2
<i>A</i> —Length of reduced section, min (Note 2)	$2\frac{1}{4}$	60	$1\frac{3}{4}$	45	$1\frac{1}{4}$	32	$\frac{3}{4}$	20	$\frac{5}{8}$	16

NOTES:

- (1) The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 percent larger in diameter than the center (controlling dimension).
- (2) If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gage length.
- (3) The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial (see Fig. 9). If the ends are to be held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.
- (4) On the round specimens in Fig. 5 and Fig. 6, the gage lengths are equal to four times the nominal diameter. In some product specifications other specimens may be provided for, but unless the 4-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.
- (5) The use of specimens smaller than 0.250 in. (6.25 mm) diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.
- (6) Five sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, 0.160, and 0.113 in., the reason being to permit easy calculations of stress from loads, since the corresponding cross sectional areas are equal or close to 0.200, 0.100, 0.0500, 0.0200, and 0.0100 in.², respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20, 50, and 100, respectively. (The metric equivalents of these fixed diameters do not result in correspondingly convenient cross sectional area and multiplying factors.)

FIG. 5 SUGGESTED TYPES OF ENDS FOR STANDARD ROUND TENSION TEST SPECIMENS



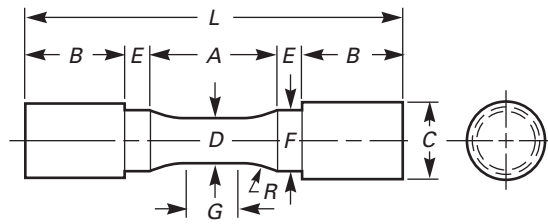
DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
<i>G</i> —Gage length	2.000± 0.005	50.0± 0.10	2.000± 0.005	50.0± 0.10	2.000± 0.005	50.0± 0.10	2.000± 0.005	50.0± 0.10	2.00± 0.005	50.0± 0.10
<i>D</i> —Diameter (Note 1)	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25
<i>R</i> —Radius of fillet, min	$\frac{3}{8}$	10	$\frac{3}{8}$	10	$\frac{1}{16}$	2	$\frac{3}{8}$	10	$\frac{3}{8}$	10
<i>A</i> —Length of reduced section	2 $\frac{1}{4}$, min	60, min	2 $\frac{1}{4}$, min	60, min	4, ap- proxi- mately	100, ap- proxi- mately	2 $\frac{1}{4}$, min	60, min	2 $\frac{1}{4}$, min	60, min
<i>L</i> —Overall length, approximate	5	125	5 $\frac{1}{2}$	140	5 $\frac{1}{2}$	140	4 $\frac{3}{4}$	120	9 $\frac{1}{2}$	240
<i>B</i> —Grip section (Note 2)	1 $\frac{3}{8}$, ap- proxi- mately	35, ap- proxi- mately	1, ap- proxi- mately	25, ap- proxi- mately	3 $\frac{3}{4}$, ap- proxi- mately	20, ap- proxi- mately	1 $\frac{1}{2}$, ap- proxi- mately	13, ap- proxi- mately	3, min	75, min
<i>C</i> —Diameter of end section	$\frac{3}{4}$	20	$\frac{3}{4}$	20	2 $\frac{3}{32}$	18	$\frac{7}{8}$	22	$\frac{3}{4}$	20
<i>E</i> —Length of shoulder and fillet section, approximate	...	...	$\frac{5}{8}$	16	...	...	$\frac{3}{4}$	20	$\frac{5}{8}$	16
<i>F</i> —Diameter of shoulder	...	...	$\frac{5}{8}$	16	...	...	$\frac{5}{8}$	16	1 $\frac{9}{32}$	15

NOTES:

- (1) The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.10 mm) larger in diameter than the center.
- (2) On Specimen 5 it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.
- (3) The types of ends shown are applicable for the standard 0.500 in. round tension test specimen; similar types can be used for subsize specimens. The use of UNF series of threads ($\frac{3}{4}$ by 16, $\frac{1}{2}$ by 20, $\frac{3}{8}$ by 24, and $\frac{1}{4}$ by 28) is suggested for high-strength brittle materials to avoid fracture in the thread portion.

FIG. 6 STANDARD TENSION TEST SPECIMENS FOR CAST IRON



DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3	
	in.	mm	in.	mm	in.	mm
<i>G</i> —Length of parallel	Shall be equal to or greater than diameter <i>D</i>					
<i>D</i> —Diameter	0.500±0.010	12.5±0.25	0.750±0.015	20.0±0.40	1.25±0.025	30.0±0.60
<i>R</i> —Radius of fillet, min	1	25	1	25	2	50
<i>A</i> —Length of reduced section, min	1¼	32	1½	38	2¼	60
<i>L</i> —Over-all length, min	¾	95	4	100	6⅜	160
<i>B</i> —Grip section, approximate	1	25	1	25	¾	45
<i>C</i> —Diameter of end section, approximate	¾	20	1⅛	30	1⅞	48
<i>E</i> —Length of shoulder, min	¼	6	¼	6	5/16	8
<i>F</i> —Diameter of shoulder	5/8±1/64	16.0±0.40	15/16±1/64	24.0±0.40	17/16±1/64	36.5±0.40

GENERAL NOTE: The reduced section and shoulders (dimensions *A*, *D*, *E*, *F*, *G*, and *R*) shall be shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. Commonly the ends are threaded and have the dimensions *B* and *C* given above.

FIG. 7 STRESS-STRAIN DIAGRAM SHOWING YIELD POINT CORRESPONDING WITH TOP OF KNEE

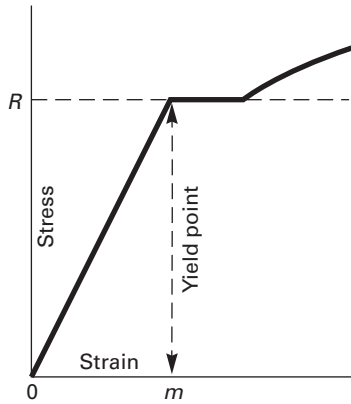


FIG. 8 STRESS-STRAIN DIAGRAM SHOWING YIELD POINT OR YIELD STRENGTH BY EXTENSION UNDER LOAD METHOD

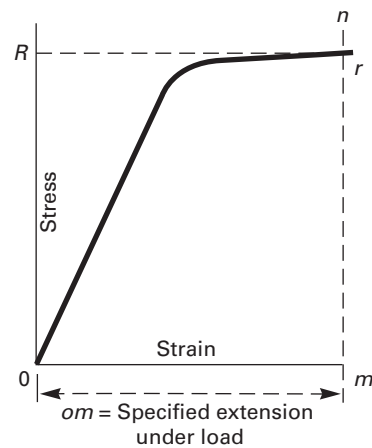
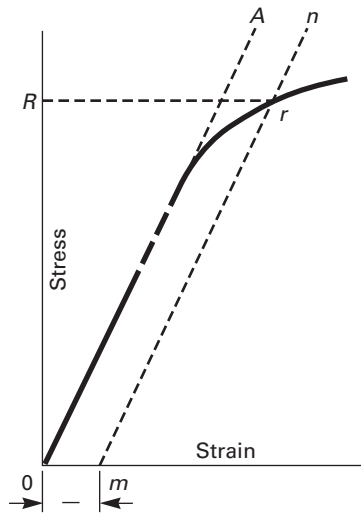
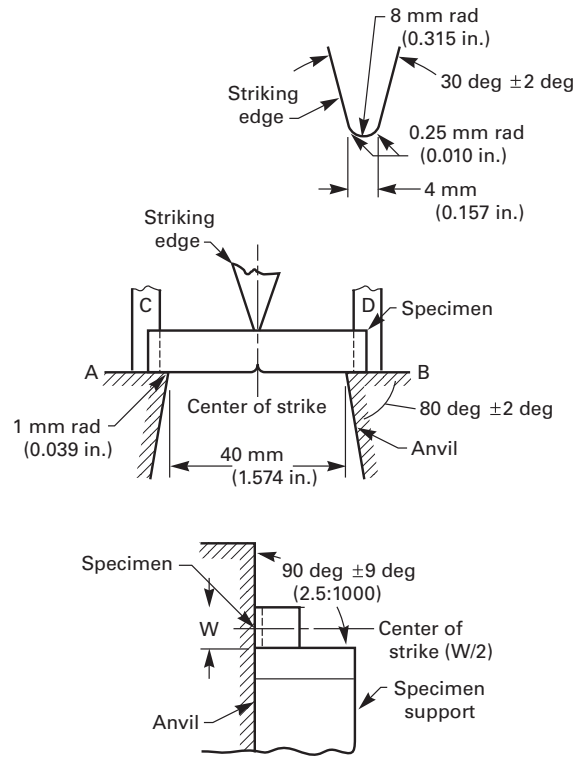


FIG. 9 STRESS-STRAIN DIAGRAM FOR DETERMINATION OF YIELD STRENGTH BY THE OFFSET METHOD



$om = \text{Specified Offset}$

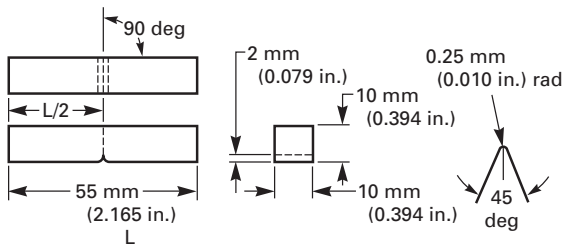
FIG. 10 CHARPY (SIMPLE-BEAM) IMPACT TEST



GENERAL NOTES:

- (a) All dimensional tolerances shall be $\pm 0.05 \text{ mm}$ (0.002 in.) unless otherwise specified.
- (b) A shall be parallel to B within 2:1000 and coplanar with B within 0.05 mm (0.002 in.)
- (c) C shall be parallel to D within 20:1000 and coplanar with D within 0.125 mm (0.005 in.)
- (d) Finish on unmarked parts shall be $4 \mu\text{m}$ (125 $\mu\text{in.}$).

FIG. 11 CHARPY (SIMPLE-BEAM) IMPACT TEST SPECIMENS

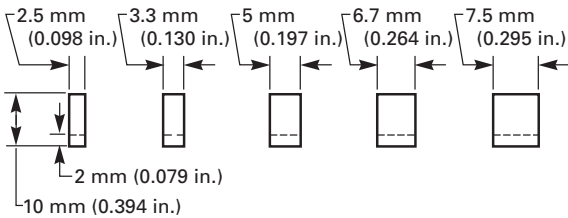


GENERAL NOTES:

(a) Permissible variations shall be as follows:

Notch length to edge	90 deg ±2 deg
Adjacent sides shall be at	90 deg ±10 min
Cross-section dimensions	±0.075 mm (±0.003 in.)
Length of specimen (L)	+0, -2.5 mm (+0, -0.100 in.)
Centering of notch (L/2)	±1 mm (±0.039 in.)
Angle of notch	±1 deg
Radius of notch	±0.025 mm (±0.001 in.)
Notch depth	±0.025 mm (±0.001 in.)
Finish requirements	2 μm (63 μin.) on notched surface and opposite face; 4 μm (125 μin.) on other two surfaces

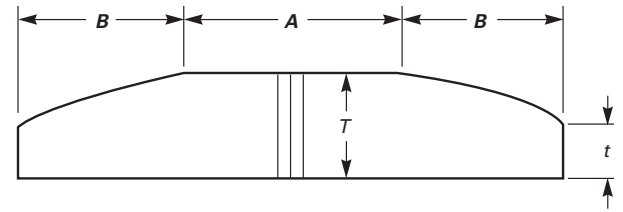
(a) Standard Full Size Specimen



(b) On subsized specimens, all dimensions and tolerances of the standard specimen remain constant with the exception of the width, which varies as shown above and for which the tolerance shall be ±1%.

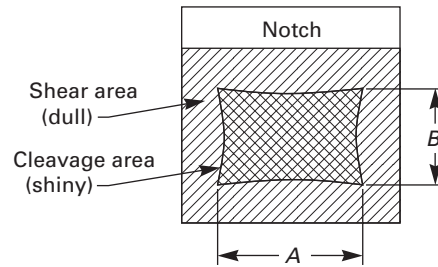
(b) Standard Subsize Specimen

FIG. 12 TUBULAR IMPACT SPECIMEN CONTAINING ORIGINAL OD SURFACE



Dimension	Description	Requirement
A	Machined surface	28 mm minimum
B	Original OD surface	13.5 mm maximum
T	Specimen thickness	Figure 11
t	End thickness	1/2 T minimum

FIG. 13 DETERMINATION OF PERCENT SHEAR FRACTURE



GENERAL NOTES:

- (a) Measure average dimensions A and B to the nearest 0.02 in. or 0.5 mm.
- (b) Determine the percent shear fracture using Table 7 or Table 8.

FIG. 14 FRACTURE APPEARANCE CHARTS AND PERCENT SHEAR FRACTURE COMPARATOR

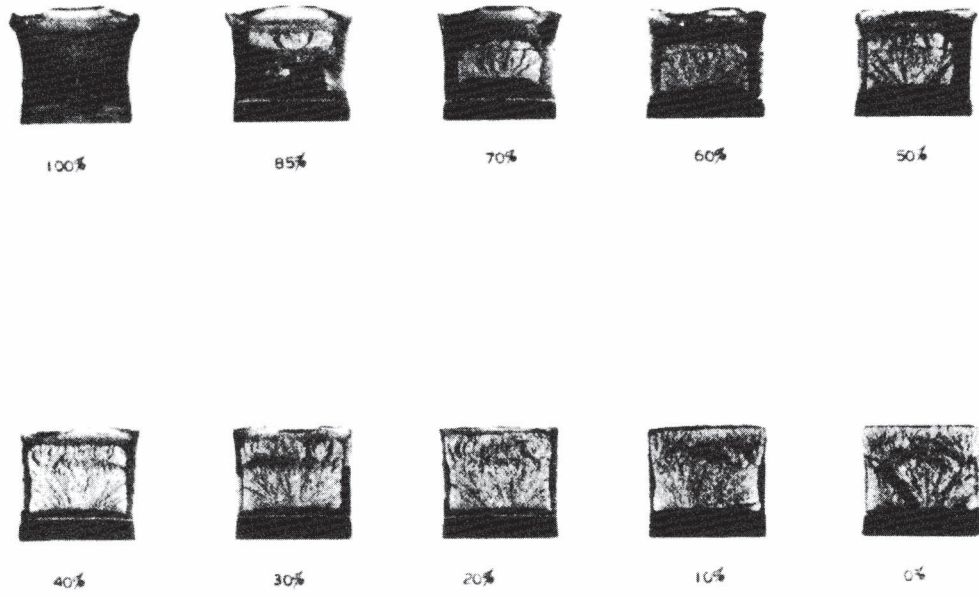


FIG. 15 HALVES OF BROKEN CHARPY V-NOTCH IMPACT SPECIMEN JOINED FOR THE MEASUREMENT OF LATERAL EXPANSION, DIMENSION A

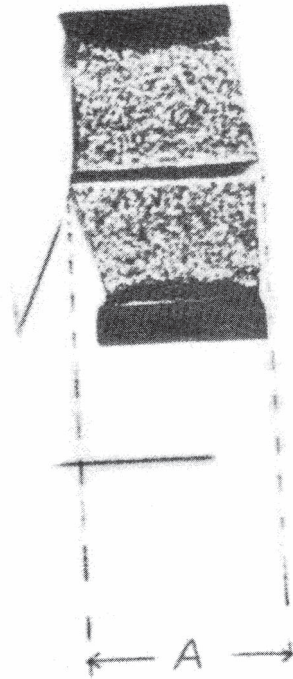


FIG. 16 LATERAL EXPANSION GAGE FOR CHARPY IMPACT SPECIMENS

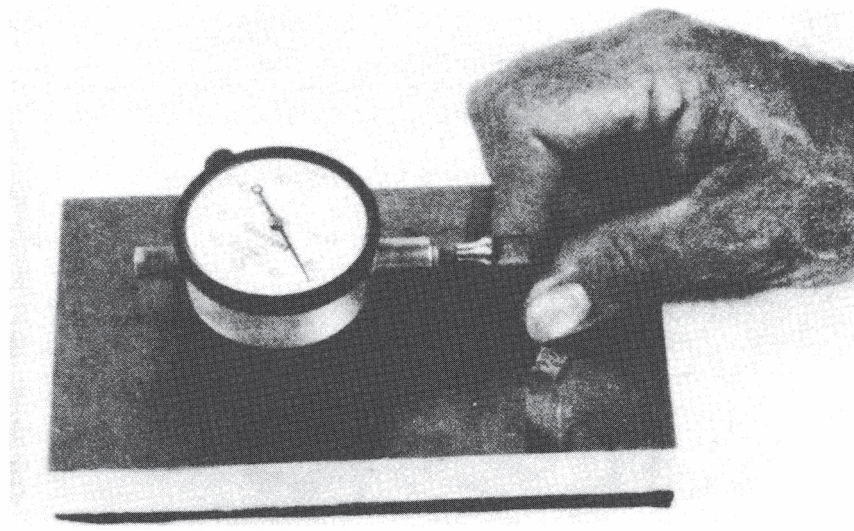
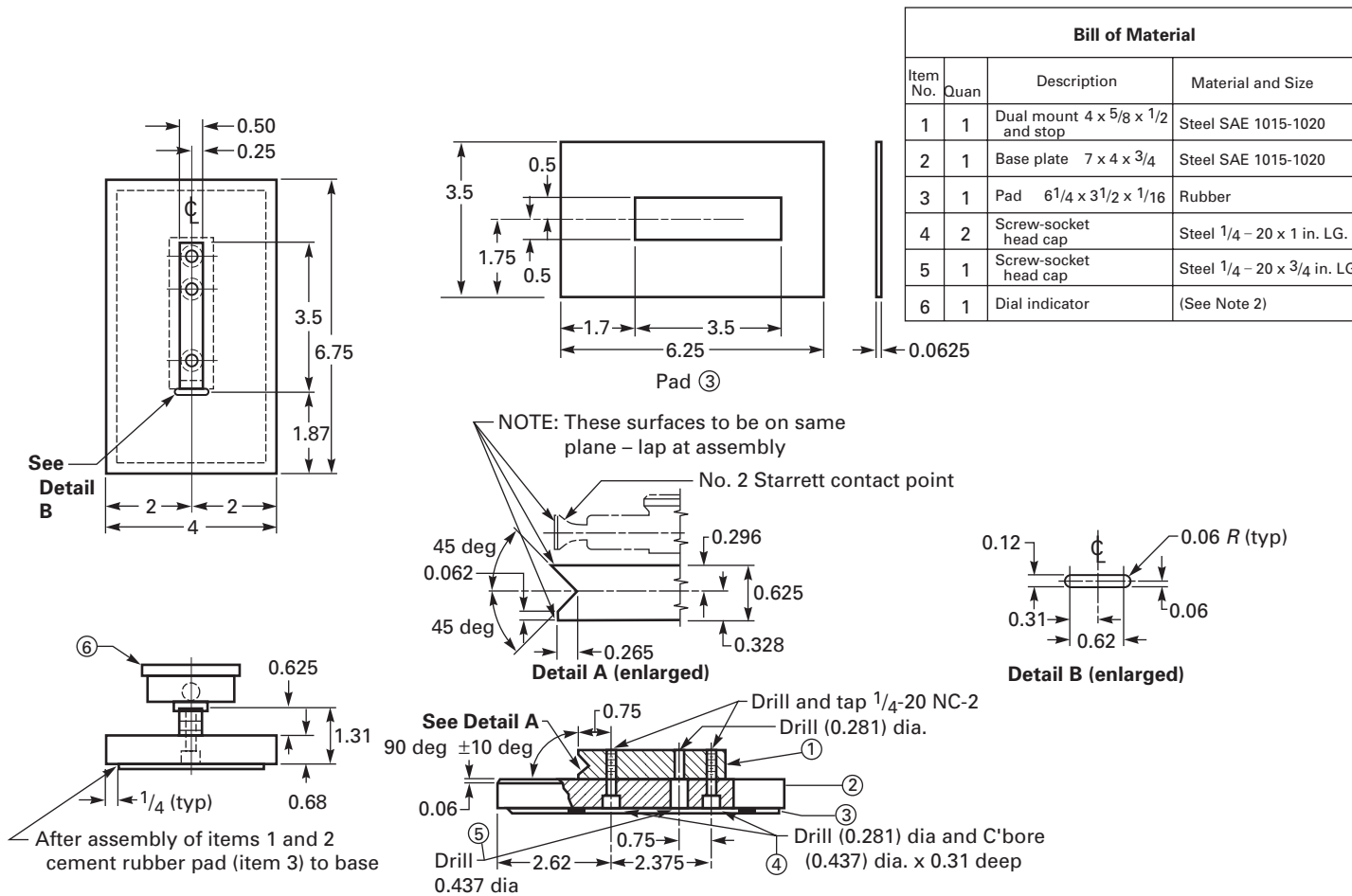


FIG. 17 ASSEMBLY AND DETAILS FOR LATERAL EXPANSION GAGE



NOTES:

- (1) Flash chrome plate items 1 and 2.
- (2) Dial indicator - Starrett No. 25-241 range 0.001 - 0.250 back - adjustable bracket contact point No. 2.

TABLE 1
MULTIPLYING FACTORS TO BE USED FOR VARIOUS DIAMETERS OF ROUND TEST SPECIMENS

Standard Specimen			Small Size Specimens Proportional to Standard					
0.500 in. Round			0.350 in. Round			0.250 in. Round		
Actual Diameter, in.	Area, in. ²	Multiplying Factor	Actual Diameter, in.	Area, in. ²	Multiplying Factor	Actual Diameter, in.	Area, in. ²	Multiplying Factor
0.490	0.1886	5.30	0.343	0.0924	10.82	0.245	0.0471	21.21
0.491	0.1893	5.28	0.344	0.0929	10.76	0.246	0.0475	21.04
0.492	0.1901	5.26	0.345	0.0935	10.70	0.247	0.0479	20.87
0.493	0.1909	5.24	0.346	0.0940	10.64	0.248	0.0483	20.70
0.494	0.1917	5.22	0.347	0.0946	10.57	0.249	0.0487	20.54
0.495	0.1924	5.20	0.348	0.0951	10.51	0.250	0.0491	20.37
0.496	0.1932	5.18	0.349	0.0957	10.45	0.251	0.0495	20.21
0.497	0.1940	5.15	0.350	0.0962	10.39	0.252	(0.05) (A)	(20.0) (A)
0.498	0.1948	5.13	0.351	0.0968	10.33	0.253	0.0499	20.05
0.499	0.1956	5.11	0.352	0.0973	10.28	0.254	(0.05) (A)	(20.0) (A)
0.500	0.1963	5.09	0.353	0.0979	10.22	0.255	0.0503	19.89
0.501	0.1971	5.07	0.354	0.0984	10.16	...	0.0507	19.74
0.502	0.1979	5.05	0.355	0.0990	10.10	...	0.0511	19.58
0.503	0.1987	5.03	0.356	0.0995	10.05	...	...	...
0.504	0.1995	5.01	0.357	(0.1) (A)	(10.0) (A)	...	...	...
0.505	(0.2) (A)	(5.0) (A)	...	0.1001	9.99	...	...	...
0.506	0.2003	4.99	...	(0.1) (A)	(10.0) (A)	...	...	...
0.507	(0.2) (A)	(5.0) (A)	...	...	...	...	...	...
0.508	0.2011	4.97	...	...	...	...	...	...
0.509	(0.2) (A)	(5.0) (A)	...	...	...	...	...	...
0.510	0.2019	4.95	...	...	...	...	...	...
	0.2027	4.93	...	...	...	...	...	...
	0.2035	4.91	...	...	...	...	...	...
	0.2043	4.90	...	...	...	...	...	...

NOTE:

(A) The values in parentheses may be used for ease in calculation of stresses, in pounds per square inch, as permitted in 5 of Fig. 4.

TABLE 2
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS (A) (ROCKWELL C TO OTHER
HARDNESS NUMBERS)

Rockwell C Scale, 150 kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Knoop Hardness, 500 gf Load and Over	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell Superficial Hardness			Approximate Tensile Strength, ksi (MPa)
					15N Scale, 15 kgf Load, Diamond Penetrator	30N Scale 30 kgf Load, Diamond Penetrator	45N Scale, 45 kgf Load, Diamond Penetrator	
68	940	...	920	85.6	93.2	84.4	75.4	...
67	900	...	895	85.0	92.9	83.6	74.2	...
66	865	...	870	84.5	92.5	82.8	73.3	...
65	832	739	846	83.9	92.2	81.9	72.0	...
64	800	722	822	83.4	91.8	81.1	71.0	...
63	772	706	799	82.8	91.4	80.1	69.9	...
62	746	688	776	82.3	91.1	79.3	68.8	...
61	720	670	754	81.8	90.7	78.4	67.7	...
60	697	654	732	81.2	90.2	77.5	66.6	...
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

NOTE:

(A) This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 3
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS (A) (ROCKWELL B TO OTHER
HARDNESS NUMBERS)

Rockwell B Scale, 100 kgf Load $\frac{1}{16}$ in. (1.588 mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Knoop Hardness, 500 gf Load and Over	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell F Scale, 60 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	30T Scale, 30 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	45T Scale, 45 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	
100	240	240	251	61.5	...	93.1	83.1	72.9	116 (800)
99	234	234	246	60.9	...	92.8	82.5	71.9	114 (785)
98	228	228	241	60.2	...	92.5	81.8	70.9	109 (750)
97	222	222	236	59.5	...	92.1	81.1	69.9	104 (715)
96	216	216	231	58.9	...	91.8	80.4	68.9	102 (705)
95	210	210	226	58.3	...	91.5	79.8	67.9	100 (690)
94	205	205	221	57.6	...	91.2	79.1	66.9	98 (675)
93	200	200	216	57.0	...	90.8	78.4	65.9	94 (650)
92	195	195	211	56.4	...	90.5	77.8	64.8	92 (635)
91	190	190	206	55.8	...	90.2	77.1	63.8	90 (620)
90	185	185	201	55.2	...	89.9	76.4	62.8	89 (615)
89	180	180	196	54.6	...	89.5	75.8	61.8	88 (605)
88	176	176	192	54.0	...	89.2	75.1	60.8	86 (590)
87	172	172	188	53.4	...	88.9	74.4	59.8	84 (580)
86	169	169	184	52.8	...	88.6	73.8	58.8	83 (570)
85	165	165	180	52.3	...	88.2	73.1	57.8	82 (565)
84	162	162	176	51.7	...	87.9	72.4	56.8	81 (560)
83	159	159	173	51.1	...	87.6	71.8	55.8	80 (550)
82	156	156	170	50.6	...	87.3	71.1	54.8	77 (530)
81	153	153	167	50.0	...	86.9	70.4	53.8	73 (505)
80	150	150	164	49.5	...	86.6	69.7	52.8	72 (495)
79	147	147	161	48.9	...	86.3	69.1	51.8	70 (485)
78	144	144	158	48.4	...	86.0	68.4	50.8	69 (475)
77	141	141	155	47.9	...	85.6	67.7	49.8	68 (470)
76	139	139	152	47.3	...	85.3	67.1	48.8	67 (460)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	...
63	112	112	125	40.9	92.8	81.1	58.4	35.7	...
62	110	110	124	40.4	92.2	80.8	57.7	34.7	...
61	108	108	122	40.0	91.7	80.5	57.0	33.7	...
60	107	107	120	39.5	91.1	80.1	56.4	32.7	...
59	106	106	118	39.0	90.5	79.8	55.7	31.7	...
58	104	104	117	38.6	90.0	79.5	55.0	30.7	...
57	103	103	115	38.1	89.4	79.2	54.4	29.7	...
56	101	101	114	37.7	88.8	78.8	53.7	28.7	...
55	100	100	112	37.2	88.2	78.5	53.0	27.7	...
54	...	...	111	36.8	87.7	78.2	52.4	26.7	...
53	...	...	110	36.3	87.1	77.9	51.7	25.7	...
52	...	...	109	35.9	86.5	77.5	51.0	24.7	...
51	...	...	108	35.5	86.0	77.2	50.3	23.7	...
50	...	...	107	35.0	85.4	76.9	49.7	22.7	...
49	...	...	106	34.6	84.8	76.6	49.0	21.7	...

TABLE 3
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS (A) (ROCKWELL B TO OTHER
HARDNESS NUMBERS) (CONT'D)

Rockwell B Scale, 100- kgf Load $\frac{1}{16}$ -in. (1.588 mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Knoop Hardness, 500 gf Load and Over	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell F Scale, 60 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	30T Scale, 30 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	45T Scale, 45 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	
48	105	34.1	84.3	76.2	48.3	20.7	...
47	104	33.7	83.7	75.9	47.7	19.7	...
46	103	33.3	83.1	75.6	47.0	18.7	...
45	102	32.9	82.6	75.3	46.3	17.7	...
44	101	32.4	82.0	74.9	45.7	16.7	...
43	100	32.0	81.4	74.6	45.0	15.7	...
42	99	31.6	80.8	74.3	44.3	14.7	...
41	98	31.2	80.3	74.0	43.7	13.6	...
40	97	30.7	79.7	73.6	43.0	12.6	...
39	96	30.3	79.1	73.3	42.3	11.6	...
38	95	29.9	78.6	73.0	41.6	10.6	...
37	94	29.5	78.0	72.7	41.0	9.6	...
36	93	29.1	77.4	72.3	40.3	8.6	...
35	92	28.7	76.9	72.0	39.6	7.6	...
34	91	28.2	76.3	71.7	39.0	6.6	...
33	90	27.8	75.7	71.4	38.3	5.6	...
32	89	27.4	75.2	71.0	37.6	4.6	...
31	88	27.0	74.6	70.7	37.0	3.6	...
30	87	26.6	74.0	70.4	36.3	2.6	...

NOTE:

(A) This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 4
 APPROXIMATE HARDNESS CONVERSION NUMBERS FOR AUSTENITIC STEELS (ROCKWELL C TO OTHER
 HARDNESS NUMBERS)

Rockwell C Scale, 150 kgf Load, Diamond Penetrator	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
		15N Scale, 15 kgf Load, Diamond Penetrator	30N Scale, 30 kgf Load, Diamond Penetrator	45N Scale, 45 kgf Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

TABLE 5
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR AUSTENITIC STEELS (ROCKWELL B TO OTHER
HARDNESS NUMBERS)

Rockwell B Scale, 100 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	Brinell Indentation Diameter, mm	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15T Scale, 15 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	30T Scale, 30 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	45T Scale, 45 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

TABLE 6
BRINELL HARDNESS NUMBERS (A)
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load
2.00	158	473	945	2.60	92.6	278	555	3.20	60.5	182	363	3.80	42.4	127	255
2.01	156	468	936	2.61	91.8	276	551	3.21	60.1	180	361	3.81	42.2	127	253
2.02	154	463	926	2.62	91.1	273	547	3.22	59.8	179	359	3.82	42.0	126	252
2.03	153	459	917	2.63	90.4	271	543	3.23	59.4	178	356	3.83	41.7	125	250
2.04	151	454	908	2.64	89.7	269	538	3.24	59.0	177	354	3.84	41.5	125	249
2.05	150	450	899	2.65	89.0	267	534	3.25	58.6	176	352	3.85	41.3	124	248
2.06	148	445	890	2.66	88.4	265	530	3.26	58.3	175	350	3.86	41.1	123	246
2.07	147	441	882	2.67	87.7	263	526	3.27	57.9	174	347	3.87	40.9	123	245
2.08	146	437	873	2.68	87.0	261	522	3.28	57.5	173	345	3.88	40.6	122	244
2.09	144	432	865	2.69	86.4	259	518	3.29	57.2	172	343	3.89	40.4	121	242
2.10	143	428	856	2.70	85.7	257	514	3.30	56.8	170	341	3.90	40.2	121	241
2.11	141	424	848	2.71	85.1	255	510	3.31	56.5	169	339	3.91	40.0	120	240
2.12	140	420	840	2.72	84.4	253	507	3.32	56.1	168	337	3.92	39.8	119	239
2.13	139	416	832	2.73	83.8	251	503	3.33	55.8	167	335	3.93	39.6	119	237
2.14	137	412	824	2.74	83.2	250	499	3.34	55.4	166	333	3.94	39.4	118	236
2.15	136	408	817	2.75	82.6	248	495	3.35	55.1	165	331	3.95	39.1	117	235
2.16	135	404	809	2.76	81.9	246	492	3.36	54.8	164	329	3.96	38.9	117	234
2.17	134	401	802	2.77	81.3	244	488	3.37	54.4	163	326	3.97	38.7	116	232
2.18	132	397	794	2.78	80.8	242	485	3.38	54.1	162	325	3.98	38.5	116	231
2.19	131	393	787	2.79	80.2	240	481	3.39	53.8	161	323	3.99	38.3	115	230
2.20	130	390	780	2.80	79.6	239	477	3.40	53.4	160	321	4.00	38.1	114	229
2.21	129	386	772	2.81	79.0	237	474	3.41	53.1	159	319	4.01	37.9	114	228
2.22	128	383	765	2.82	78.4	235	471	3.42	52.8	158	317	4.02	37.7	113	226
2.23	126	379	758	2.83	77.9	234	467	3.43	52.5	157	315	4.03	37.5	113	225
2.24	125	376	752	2.84	77.3	232	464	3.44	52.2	156	313	4.04	37.3	112	224
2.25	124	372	745	2.85	76.8	230	461	3.45	51.8	156	311	4.05	37.1	111	223
2.26	123	369	738	2.86	76.2	229	457	3.46	51.5	155	309	4.06	37.0	111	222
2.27	122	366	732	2.87	75.7	227	454	3.47	51.2	154	307	4.07	36.8	110	221
2.28	121	363	725	2.88	75.1	225	451	3.48	50.9	153	306	4.08	36.6	110	219
2.29	120	359	719	2.89	74.6	224	448	3.49	50.6	152	304	4.09	36.4	109	218
2.30	119	356	712	2.90	74.1	222	444	3.50	50.3	151	302	4.10	36.2	109	217
2.31	118	353	706	2.91	73.6	221	441	3.51	50.0	150	300	4.11	36.0	108	216
2.32	117	350	700	2.92	73.0	219	438	3.52	49.7	149	298	4.12	35.8	108	215
2.33	116	347	694	2.93	72.5	218	435	3.53	49.4	148	297	4.13	35.7	107	214
2.34	115	344	688	2.94	72.0	216	432	3.54	49.2	147	295	4.14	35.5	106	213
2.35	114	341	682	2.95	71.5	215	429	3.55	48.9	147	293	4.15	35.3	106	212
2.36	113	338	676	2.96	71.0	213	426	3.56	48.6	146	292	4.16	35.1	105	211
2.37	112	335	670	2.97	70.5	212	423	3.57	48.3	145	290	4.17	34.9	105	210
2.38	111	332	665	2.98	70.1	210	420	3.58	48.0	144	288	4.18	34.8	104	209
2.39	110	330	659	2.99	69.6	209	417	3.59	47.7	143	286	4.19	34.6	104	208
2.40	109	327	653	3.00	69.1	207	415	3.60	47.5	142	285	4.20	34.4	103	207
2.41	108	324	648	3.01	68.6	206	412	3.61	47.2	142	283	4.21	34.2	103	205
2.42	107	322	643	3.02	68.2	205	409	3.62	46.9	141	282	4.22	34.1	102	204
2.43	106	319	637	3.03	67.7	203	406	3.63	46.7	140	280	4.23	33.9	102	203
2.44	105	316	632	3.04	67.3	202	404	3.64	46.4	139	278	4.24	33.7	101	202
2.45	104	313	627	3.05	66.8	200	401	3.65	46.1	138	277	4.25	33.6	101	201
2.46	104	311	621	3.06	66.4	199	398	3.66	45.9	138	275	4.26	33.4	100	200
2.47	103	308	616	3.07	65.9	198	395	3.67	45.6	137	274	4.27	33.2	99.7	199
2.48	102	306	611	3.08	65.5	196	393	3.68	45.4	136	272	4.28	33.1	99.2	198
2.49	101	303	606	3.09	65.0	195	390	3.69	45.1	135	271	4.29	32.9	98.8	198

TABLE 6
BRINELL HARDNESS NUMBERS (A) (CONT'D)
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load
2.50	100	301	601	3.10	64.6	194	388	3.70	44.9	135	269	4.30	32.8	98.3	197
2.51	99.4	298	597	3.11	64.2	193	385	3.71	44.6	134	268	4.31	32.6	97.8	196
2.52	98.6	296	592	3.12	63.8	191	383	3.72	44.4	133	266	4.32	32.4	97.3	195
2.53	97.8	294	587	3.13	63.3	190	380	3.73	44.1	132	265	4.33	32.3	96.8	194
2.54	97.1	291	582	3.14	62.9	189	378	3.74	43.9	132	263	4.34	32.1	96.4	193
2.55	96.3	289	578	3.15	62.5	188	375	3.75	43.6	131	262	4.35	32.0	95.9	192
2.56	95.5	287	573	3.16	62.1	186	373	3.76	43.4	130	260	4.36	31.8	95.5	191
2.57	94.8	284	569	3.17	61.7	185	370	3.77	43.1	129	259	4.37	31.7	95.0	190
2.58	94.0	282	564	3.18	61.3	184	368	3.78	42.9	129	257	4.38	31.5	94.5	189
2.59	93.3	280	560	3.19	60.9	183	366	3.79	42.7	128	256	4.39	31.4	94.1	188
4.40	31.2	93.6	187	5.05	23.3	69.8	140	5.70	17.8	53.5	107	6.35	14.0	42.0	84.0
4.41	31.1	93.2	186	5.06	23.2	69.5	139	5.71	17.8	53.3	107	6.36	13.9	41.8	83.7
4.42	30.9	92.7	185	5.07	23.1	69.2	138	5.72	17.7	53.1	106	6.37	13.9	41.7	83.4
4.43	30.8	92.3	185	5.08	23.0	68.9	138	5.73	17.6	52.9	106	6.38	13.8	41.5	83.1
4.44	30.6	91.8	184	5.09	22.9	68.6	137	5.74	17.6	52.7	105	6.39	13.8	41.4	82.8
4.45	30.5	91.4	183	5.10	22.8	68.3	137	5.75	17.5	52.5	105	6.40	13.7	41.2	82.5
4.46	30.3	91.0	182	5.11	22.7	68.0	136	5.76	17.4	52.3	105	6.41	13.7	41.1	82.2
4.47	30.2	90.5	181	5.12	22.6	67.7	135	5.77	17.4	52.1	104	6.42	13.6	40.9	81.9
4.48	30.0	90.1	180	5.13	22.5	67.4	135	5.78	17.3	51.9	104	6.43	13.6	40.8	81.6
4.49	29.9	89.7	179	5.14	22.4	67.1	134	5.79	17.2	51.7	103	6.44	13.5	40.6	81.3
4.50	29.8	89.3	179	5.15	22.3	66.9	134	5.80	17.2	51.5	103	6.45	13.5	40.5	81.0
4.51	29.6	88.8	178	5.16	22.2	66.6	133	5.81	17.1	51.3	103	6.46	13.4	40.4	80.7
4.52	29.5	88.4	177	5.17	22.1	66.3	133	5.82	17.0	51.1	102	6.47	13.4	40.2	80.4
4.53	29.3	88.0	176	5.18	22.0	66.0	132	5.83	17.0	50.9	102	6.48	13.4	40.1	80.1
4.54	29.2	87.6	175	5.19	21.9	65.8	132	5.84	16.9	50.7	101	6.49	13.3	39.9	79.8
4.55	29.1	87.2	174	5.20	21.8	65.5	131	5.85	16.8	50.5	101	6.50	13.3	39.8	79.6
4.56	28.9	86.8	174	5.21	21.7	65.2	130	5.86	16.8	50.3	101	6.51	13.2	39.6	79.3
4.57	28.8	86.4	173	5.22	21.6	64.9	130	5.87	16.7	50.2	100	6.52	13.2	39.5	79.0
4.58	28.7	86.0	172	5.23	21.6	64.7	129	5.88	16.7	50.0	99.9	6.53	13.1	39.4	78.7
4.59	28.5	85.6	171	5.24	21.5	64.4	129	5.89	16.6	49.8	99.5	6.54	13.1	39.2	78.4
4.60	28.4	85.4	170	5.25	21.4	64.1	128	5.90	16.5	49.6	99.2	6.55	13.0	39.1	78.2
4.61	28.3	84.8	170	5.26	21.3	63.9	128	5.91	16.5	49.4	98.8	6.56	13.0	38.9	78.0
4.62	28.1	84.4	169	5.27	21.2	63.6	127	5.92	16.4	49.2	98.4	6.57	12.9	38.8	77.6
4.63	28.0	84.0	168	5.28	21.1	63.3	127	5.93	16.3	49.0	98.0	6.58	12.9	38.7	77.3
4.64	27.9	83.6	167	5.29	21.0	63.1	126	5.94	16.3	48.8	97.7	6.59	12.8	38.5	77.1
4.65	27.8	83.3	167	5.30	20.9	62.8	126	5.95	16.2	48.7	97.3	6.60	12.8	38.4	76.8
4.66	27.6	82.9	166	5.31	20.9	62.6	125	5.96	16.2	48.5	96.9	6.61	12.8	38.3	76.5
4.67	27.5	82.5	165	5.32	20.8	62.3	125	5.97	16.1	48.3	96.6	6.62	12.7	38.1	76.2
4.68	27.4	82.1	164	5.33	20.7	62.1	124	5.98	16.0	48.1	96.2	6.63	12.7	38.0	76.0
4.69	27.3	81.8	164	5.34	20.6	61.8	124	5.99	16.0	47.9	95.9	6.64	12.6	37.9	75.7
4.70	27.1	81.4	163	5.35	20.5	61.5	123	6.00	15.9	47.7	95.5	6.65	12.6	37.7	75.4
4.71	27.0	81.0	162	5.36	20.4	61.3	123	6.01	15.9	47.6	95.1	6.66	12.5	37.6	75.2
4.72	26.9	80.7	161	5.37	20.3	61.0	122	6.02	15.8	47.4	94.8	6.67	12.5	37.5	74.9
4.73	26.8	80.3	161	5.38	20.3	60.8	122	6.03	15.7	47.2	94.4	6.68	12.4	37.3	74.7
4.74	26.6	79.9	160	5.39	20.2	60.6	121	6.04	15.7	47.0	94.1	6.69	12.4	37.2	74.4
4.75	26.5	79.6	159	5.40	20.1	60.3	121	6.05	15.6	46.8	93.7	6.70	12.4	37.1	74.1
4.76	26.4	79.2	158	5.41	20.0	60.1	120	6.06	15.6	46.7	93.4	6.71	12.3	36.9	73.9
4.77	26.3	78.9	158	5.42	19.9	59.8	120	6.07	15.5	46.5	93.0	6.72	12.3	36.8	73.6
4.78	26.2	78.5	157	5.43	19.9	59.6	119	6.08	15.4	46.3	92.7	6.73	12.2	36.7	73.4
4.79	26.1	78.2	156	5.44	19.8	59.3	119	6.09	15.4	46.2	92.3	6.74	12.2	36.6	73.1

TABLE 6
BRINELL HARDNESS NUMBERS (A) (CONT'D)
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load
4.80	25.9	77.8	156	5.45	19.7	59.1	118	6.10	15.3	46.0	92.0	6.75	12.1	36.4	72.8
4.81	25.8	77.5	155	5.46	19.6	58.9	118	6.11	15.3	45.8	91.7	6.76	12.1	36.3	72.6
4.82	25.7	77.1	154	5.47	19.5	58.6	117	6.12	15.2	45.7	91.3	6.77	12.1	36.2	72.3
4.83	25.6	76.8	154	5.48	19.5	58.4	117	6.13	15.2	45.5	91.0	6.78	12.0	36.0	72.1
4.84	25.5	76.4	153	5.49	19.4	58.2	116	6.14	15.1	45.3	90.6	6.79	12.0	35.9	71.8
4.85	25.4	76.1	152	5.50	19.3	57.9	116	6.15	15.1	45.2	90.3	6.80	11.9	35.8	71.6
4.86	25.3	75.8	152	5.51	19.2	57.7	115	6.16	15.0	45.0	90.0	6.81	11.9	35.7	71.3
4.87	25.1	75.4	151	5.52	19.2	57.5	115	6.17	14.9	44.8	89.6	6.82	11.8	35.5	71.1
4.88	25.0	75.1	150	5.53	19.1	57.2	114	6.18	14.9	44.7	89.3	6.83	11.8	35.4	70.8
4.89	24.9	74.8	150	5.54	19.0	57.0	114	6.19	14.8	44.5	89.0	6.84	11.8	35.3	70.6
4.90	24.8	74.4	149	5.55	18.9	56.8	114	6.20	14.7	44.3	88.7	6.86	11.7	35.2	70.4
4.91	24.7	74.1	148	5.56	18.9	56.6	113	6.21	14.7	44.2	88.3	6.86	11.7	35.1	70.1
4.92	24.6	73.8	148	5.57	18.8	56.3	113	6.22	14.7	44.0	88.0	6.87	11.6	34.9	69.9
4.93	24.5	73.5	147	5.58	18.7	56.1	112	6.23	14.6	43.8	87.7	6.88	11.6	34.8	69.6
4.94	24.4	73.2	146	5.59	18.6	55.9	112	6.24	14.6	43.7	87.4	6.89	11.6	34.7	69.4
4.95	24.3	72.8	146	5.60	18.6	55.7	111	6.25	14.5	43.5	87.1	6.90	11.5	34.6	69.2
4.96	24.2	72.5	145	5.61	18.5	55.5	111	6.26	14.5	43.4	86.7	6.91	11.5	34.5	68.9
4.97	24.1	72.2	144	5.62	18.4	55.2	110	6.27	14.4	43.2	86.4	6.92	11.4	34.3	68.7
4.98	24.0	71.9	144	5.63	18.3	55.0	110	6.28	14.4	43.1	86.1	6.93	11.4	34.2	68.4
4.99	23.9	71.6	143	5.64	18.3	54.8	110	6.29	14.3	42.9	85.8	6.94	11.4	34.1	68.2
5.00	23.8	71.3	143	5.65	18.2	54.6	109	6.30	14.2	42.7	85.5	6.95	11.3	34.0	68.0
5.01	23.7	71.0	142	5.66	18.1	54.4	109	6.31	14.2	42.6	85.2	6.96	11.3	33.9	67.7
5.02	23.6	70.7	141	5.67	18.1	54.2	108	6.32	14.1	42.4	84.9	6.97	11.3	33.8	67.5
5.03	23.5	70.4	141	5.68	18.0	54.0	108	6.33	14.1	42.3	84.6	6.98	11.2	33.6	67.3
5.04	23.4	70.1	140	5.69	17.9	53.7	107	6.34	14.0	42.1	84.3	6.99	11.2	33.5	67.0

NOTE:

(A) Prepared by the Engineering Mechanics Section, Institute for Standards Technology.

TABLE 7
PERCENT SHEAR FOR MEASUREMENTS MADE IN INCHES

Dimension B_i , in.	Dimension A_i , in.																
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.05	98	96	95	94	94	93	92	91	90	90	89	88	87	86	85	85	84
0.10	96	92	90	89	87	85	84	82	81	79	77	76	74	73	71	69	68
0.12	95	90	88	86	85	83	81	79	77	75	73	71	69	67	65	63	61
0.14	94	89	86	84	82	80	77	75	73	71	68	66	64	62	59	57	55
0.16	94	87	85	82	79	77	74	72	69	67	64	61	59	56	53	51	48
0.18	93	85	83	80	77	74	72	68	65	62	59	56	54	51	48	45	42
0.20	92	84	81	77	74	72	68	65	61	58	55	52	48	45	42	39	36
0.22	91	82	79	75	72	68	65	61	57	54	50	47	43	40	36	33	29
0.24	90	81	77	73	69	65	61	57	54	50	46	42	38	34	30	27	23
0.26	90	79	75	71	67	62	58	54	50	46	41	37	33	29	25	20	16
0.28	89	77	73	68	64	59	55	50	46	41	37	32	28	23	18	14	10
0.30	88	76	71	66	61	56	52	47	42	37	32	27	23	18	13	9	3
0.31	88	75	70	65	60	55	50	45	40	35	30	25	20	18	10	5	0

GENERAL NOTE: Since this table is set up for finite measurements or dimensions A and B , 100% shear is to be reported when either A or B is zero.

TABLE 8
PERCENT SHEAR FOR MEASUREMENTS MADE IN MILLIMETRES

Dimension <i>B</i> , mm	Dimension <i>A</i> , mm																		
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
1.0	99	98	98	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	88
1.5	98	97	96	95	94	93	92	92	91	90	89	88	87	86	85	84	83	82	81
2.0	98	96	95	94	92	91	90	89	88	86	85	84	82	81	80	79	77	76	75
2.5	97	95	94	92	91	89	88	86	84	83	81	80	78	77	75	73	72	70	69
3.0	96	94	92	91	89	87	85	83	81	79	77	76	74	72	70	68	66	64	62
3.5	96	93	91	89	87	85	82	80	78	76	74	72	69	67	65	63	61	58	56
4.0	95	92	90	88	85	82	80	77	75	72	70	67	65	62	60	57	55	52	50
4.5	94	92	89	86	83	80	77	75	72	69	66	63	61	58	55	52	49	46	44
5.0	94	91	88	85	81	78	75	72	69	66	62	59	56	53	50	47	44	41	37
5.5	93	90	86	83	79	76	72	69	66	62	59	55	52	48	45	42	38	35	31
6.0	92	89	85	81	77	74	70	66	62	59	55	51	47	44	40	36	33	29	25
6.5	92	88	84	80	76	72	67	63	59	55	51	47	43	39	35	31	27	23	19
7.0	91	87	82	78	74	69	65	61	56	52	47	43	39	34	30	26	21	17	12
7.5	91	86	81	77	72	67	62	58	53	48	44	39	34	30	25	20	16	11	6
8.0	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0

GENERAL NOTE: Since this table is set up for finite measurements or dimensions *A* and *B*, 100% shear is to be reported when either *A* or *B* is zero.

TABLE 9
CHARPY V-NOTCH TEST ACCEPTANCE CRITERIA FOR VARIOUS SUB-SIZE SPECIMENS

Full Size, 10 by 10 mm		$\frac{3}{4}$ Size, 10 by 7.5 mm		$\frac{2}{3}$ Size, 10 by 6.7 mm		$\frac{1}{2}$ Size, 10 by 5 mm		$\frac{1}{3}$ Size, 10 by 3.3 mm		$\frac{1}{4}$ Size, 10 by 2.5 mm	
ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]
40	[54]	30	[41]	27	[37]	20	[27]	13	[18]	10	[14]
35	[48]	26	[35]	23	[31]	18	[24]	12	[16]	9	[12]
30	[41]	22	[30]	20	[27]	15	[20]	10	[14]	8	[11]
25	[34]	19	[26]	17	[23]	12	[16]	8	[11]	6	[8]
20	[27]	15	[20]	13	[18]	10	[14]	7	[10]	5	[7]
16	[22]	12	[16]	11	[15]	8	[11]	5	[7]	4	[5]
15	[20]	11	[15]	10	[14]	8	[11]	5	[7]	4	[5]
13	[18]	10	[14]	9	[12]	6	[8]	4	[5]	3	[4]
12	[16]	9	[12]	8	[11]	6	[8]	4	[5]	3	[4]
10	[14]	8	[11]	7	[10]	5	[7]	3	[4]	2	[3]
7	[10]	5	[7]	5	[7]	4	[5]	2	[3]	2	[3]

ANNEXES

(Mandatory Information)

A1. STEEL BAR PRODUCTS**A1.1 Scope**

A1.1.1 This supplement delineates only those details which are peculiar to hot-rolled and cold-finished steel bars and are not covered in the general section of these test methods.

A1.2 Orientation of Test Specimens

A1.2.1 Carbon and alloy steel bars and bar-size shapes, due to their relatively small cross-sectional dimensions, are customarily tested in the longitudinal direction. In special cases where size permits and the fabrication or service of a part justifies testing in a transverse direction, the selection and location of test or tests are a matter of agreement between the manufacturer and the purchaser.

A1.3 Tension Test

A1.3.1 Carbon Steel Bars — Carbon steel bars are not commonly specified to tensile requirements in the as-rolled condition for sizes of rounds, squares, hexagons, and octagons under $\frac{1}{2}$ in. (13 mm) in diameter or distance between parallel faces nor for other bar-size sections, other than flats, less than 1 in.² (645 mm²) in cross-sectional area.

A1.3.2 Alloy Steel Bars — Alloy steel bars are usually not tested in the as-rolled condition.

A1.3.3 When tension tests are specified, the practice for selecting test specimens for hot-rolled and cold-finished steel bars of various sizes shall be in accordance with Table A1.1, unless otherwise specified in the product specification.

A1.4 Bend Test

A1.4.1 When bend tests are specified, the recommended practice for hot-rolled and cold-finished steel bars shall be in accordance with Table A1.2.

A1.5 Hardness Test

A1.5.1 Hardness Tests on Bar Products — flats, rounds, squares, hexagons and octagons — is conducted on the surface after a minimum removal of 0.015 in. to provide for accurate hardness penetration.

A2. STEEL TUBULAR PRODUCTS**A2.1 Scope**

A2.1.1 This supplement covers test specimens and test methods that are applicable to tubular products and

are not covered in the general section of Test Methods and Definitions A 370.

A2.1.2 Tubular shapes covered by this specification include, round, square, rectangular, and special shapes.

A2.2 Tension Test**A2.2.1 Full-Size Longitudinal Test Specimens:**

A2.2.1.1 As an alternative to the use of longitudinal strip test specimens or longitudinal round test specimens, tension test specimens of full-size tubular sections are used, provided that the testing equipment has sufficient capacity. Snug-fitting metal plugs should be inserted far enough in the end of such tubular specimens to permit the testing machine jaws to grip the specimens properly without crushing. A design that may be used for such plugs is shown in Fig. A2.1. The plugs shall not extend into that part of the specimen on which the elongation is measured (Fig. A2.1). Care should be exercised to see that insofar as practicable, the load in such cases is applied axially. The length of the full-section specimen depends on the gage length prescribed for measuring the elongation.

A2.2.1.2 Unless otherwise required by the product specification, the gage length is 2 in. or 50 mm, except that for tubing having an outside diameter of $\frac{3}{8}$ in. (9.5 mm) or less, it is customary for a gage length equal to four times the outside diameter to be used when elongation comparable to that obtainable with larger test specimens is required.

A2.2.1.3 To determine the cross-sectional area of the full-section specimen, measurements shall be recorded as the average or mean between the greatest and least measurements of the outside diameter and the average or mean wall thickness, to the nearest 0.001 in. (0.025 mm) and the cross-sectional area is determined by the following equation:

$$A = 3.1416t(D - t) \quad (\text{A2.1})$$

where:

- A = sectional area, in.²
- D = outside diameter, in., and
- t = thickness of tube wall, in.

NOTE A2.1 — There exist other methods of cross-sectional area determination, such as by weighing of the specimens, which are equally accurate or appropriate for the purpose.

A2.2.2 Longitudinal Strip Test Specimens:

A2.2.2.1 As an alternative to the use of full-size longitudinal test specimens or longitudinal round test specimens, longitudinal strip test specimens, obtained from strips cut from the tubular product as shown in Fig. A2.2 and machined to the dimensions shown in Fig. A2.3 are used. For welded structural tubing, such test specimens shall be from a location at least 90° from the weld; for other welded tubular products, such test specimens shall be from a location approximately 90° from the weld. Unless otherwise required by the product specification, the gage length is 2 in. or 50 mm. The test specimens shall be tested using grips that are flat or have a surface contour corresponding to the curvature of the tubular product, or the ends of the test specimens shall be flattened without heating prior to the test specimens being tested using flat grips. The test specimen shown as specimen no. 4 in Fig. 3 shall be used, unless the capacity of the testing equipment or the dimensions and nature of the tubular product to be tested makes the use of specimen nos. 1, 2, or 3 necessary.

NOTE A2.2 — An exact formula for calculating the cross-sectional area of specimens of the type shown in Fig. A2.3 taken from a circular tube is given in Test Methods E 8 or E 8M.

A2.2.2.2 The width should be measured at each end of the gage length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in.

A2.2.3 *Transverse Strip Test Specimens:*

A2.2.3.1 In general, transverse tension tests are not recommended for tubular products, in sizes smaller than 8 in. in nominal diameter. When required, transverse tension test specimens may be taken from rings cut from ends of tubes or pipe as shown in Fig. A2.4. Flattening of the specimen may be done either after separating it from the tube as in Fig. A2.4 (a), or before separating it as in Fig. A2.4 (b), and may be done hot or cold; but if the flattening is done cold, the specimen may subsequently be normalized. Specimens from tubes or pipe for which heat treatment is specified, after being flattened either hot or cold, shall be given the same treatment as the tubes or pipe. For tubes or pipe having a wall thickness of less than $\frac{3}{4}$ in. (19 mm), the transverse test specimen shall be of the form and dimensions shown in Fig. A2.5 and either or both surfaces may be machined to secure uniform thickness. Specimens for transverse tension tests on welded steel tubes or pipe to determine strength of welds, shall be located perpendicular to the welded seams with the weld at about the middle of their length.

A2.2.3.2 The width should be measured at each end of the gage length to determine parallelism and also

at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in. (0.025 mm).

A2.2.4 *Round Test Specimens:*

A2.2.4.1 When provided for in the product specification, the round test specimen shown in Fig. 4 may be used.

A2.2.4.2 The diameter of the round test specimen is measured at the center of the specimen to the nearest 0.001 in. (0.025 mm).

A2.2.4.3 Small-size specimens proportional to standard, as shown in Fig. 4, may be used when it is necessary to test material from which the standard specimen cannot be prepared. Other sizes of small-size specimens may be used. In any such small-size specimen, it is important that the gage length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4). The elongation requirements for the round specimen 2-in. gage length in the product specification shall apply to the small-size specimens.

A2.2.4.4 For transverse specimens, the section from which the specimen is taken shall not be flattened or otherwise deformed.

A2.2.4.5 Longitudinal test specimens are obtained from strips cut from the tubular product as shown in Fig. A2.2.

A2.3 *Determination of Transverse Yield Strength, Hydraulic Ring-Expansion Method*

A2.3.1 Hardness tests are made on the outside surface, inside surface, or wall cross-section depending upon product-specification limitation. Surface preparation may be necessary to obtain accurate hardness values.

A2.3.2 A testing machine and method for determining the transverse yield strength from an annular ring specimen, have been developed and described in A2.3.3–8.1.2.

A2.3.3 A diagrammatic vertical cross-sectional sketch of the testing machine is shown in Fig. A2.6.

A2.3.4 In determining the transverse yield strength on this machine, a short ring (commonly 3 in. (76 mm) in length) test specimen is used. After the large circular nut is removed from the machine, the wall thickness of the ring specimen is determined and the specimen is telescoped over the oil resistant rubber gasket. The nut is then replaced, but is not turned down tight against the specimen. A slight clearance is left between the nut and specimen for the purpose of permitting free radial movement of the specimen as it is being tested. Oil under pressure is then admitted to the interior of the rubber gasket through the pressure

line under the control of a suitable valve. An accurately calibrated pressure gage serves to measure oil pressure. Any air in the system is removed through the bleeder line. As the oil pressure is increased, the rubber gasket expands which in turn stresses the specimen circumferentially. As the pressure builds up, the lips of the rubber gasket act as a seal to prevent oil leakage. With continued increase in pressure, the ring specimen is subjected to a tension stress and elongates accordingly. The entire outside circumference of the ring specimen is considered as the gage length and the strain is measured with a suitable extensometer which will be described later. When the desired total strain or extension under load is reached on the extensometer, the oil pressure in pounds per square inch is read and by employing Barlow's formula, the unit yield strength is calculated. The yield strength, thus determined, is a true result since the test specimen has not been cold worked by flattening and closely approximates the same condition as the tubular section from which it is cut. Further, the test closely simulates service conditions in pipe lines. One testing machine unit may be used for several different sizes of pipe by the use of suitable rubber gaskets and adapters.

NOTE A2.3 — Barlow's formula may be stated two ways:

$$(1) \quad P = 2St/D \quad (A2.2)$$

$$(2) \quad S = PD/2t \quad (A2.3)$$

where:

- P = internal hydrostatic pressure, psi,
- S = unit circumferential stress in the wall of the tube produced by the internal hydrostatic pressure, psi,
- t = thickness of the tube wall, in., and
- D = outside diameter of the tube, in.

A2.3.5 A roller chain type extensometer which has been found satisfactory for measuring the elongation of the ring specimen is shown in Fig. A2.7 and Fig. A2.8. Fig. A2.7 shows the extensometer in position, but unclamped, on a ring specimen. A small pin, through which the strain is transmitted to and measured by the dial gage, extends through the hollow threaded stud. When the extensometer is clamped, as shown in Fig. A2.8, the desired tension which is necessary to hold the instrument in place and to remove any slack, is exerted on the roller chain by the spring. Tension on the spring may be regulated as desired by the knurled thumb screw. By removing or adding rollers, the roller chain may be adapted for different sizes of tubular sections.

A2.4 Hardness Tests

A2.4.1 Hardness tests are made either on the outside or the inside surfaces on the end of the tube as appropriate.

A2.4.2 The standard 3000 kgf Brinell load may cause too much deformation in a thin-walled tubular specimen. In this case the 500 kgf load shall be applied, or inside stiffening by means of an internal anvil should be used.

Brinell testing shall not be applicable to tubular products less than 2 in. (51 mm) in outside diameter, or less than 0.200 in. (5.1 mm) in wall thickness.

A2.4.3 The Rockwell hardness tests are normally made on the inside surface, a flat on the outside surface, or on the wall cross-section depending upon the product limitation. Rockwell hardness tests are not performed on tubes smaller than $\frac{5}{16}$ in. (7.9 mm) in outside diameter, nor are they performed on the inside surface of tubes with less than $\frac{1}{4}$ in. (6.4 mm) inside diameter. Rockwell hardness tests are not performed on annealed tubes with walls less than 0.065 in. (1.65 mm) thick or cold worked or heat treated tubes with walls less than 0.049 in. (1.24 mm) thick. For tubes with wall thicknesses less than those permitting the regular Rockwell hardness test, the Superficial Rockwell test is sometimes substituted. Transverse Rockwell hardness readings can be made on tubes with a wall thickness of 0.187 in. (4.75 mm) or greater. The curvature and the wall thickness of the specimen impose limitations on the Rockwell hardness test. When a comparison is made between Rockwell determinations made on the outside surface and determinations made on the inside surface, adjustment of the readings will be required to compensate for the effect of curvature. The Rockwell B scale is used on all materials having an expected hardness range of B0 to B100. The Rockwell C scale is used on material having an expected hardness range of C20 to C68.

A2.4.4 Superficial Rockwell hardness tests are normally performed on the outside surface whenever possible and whenever excessive spring back is not encountered. Otherwise, the tests may be performed on the inside. Superficial Rockwell hardness tests shall not be performed on tubes with an inside diameter of less than $\frac{1}{4}$ in. (6.4 mm). The wall thickness limitations for the Superficial Rockwell hardness test are given in Table A2.1 and Table A2.2.

A2.4.5 When the outside diameter, inside diameter, or wall thickness precludes the obtaining of accurate hardness values, tubular products shall be specified to tensile properties and so tested.

A2.5 Manipulating Tests

A2.5.1 The following tests are made to prove ductility of certain tubular products:

A2.5.1.1 Flattening Test — The flattening test as commonly made on specimens cut from tubular products is conducted by subjecting rings from the tube or pipe to a prescribed degree of flattening between parallel plates (Fig. A2.4). The severity of the flattening test is measured by the distance between the parallel plates and is varied according to the dimensions of the tube or pipe. The flattening test specimen should not be less than $2\frac{1}{2}$ in. (63.5 mm) in length and should be flattened cold to the extent required by the applicable material specifications.

A2.5.1.2 Reverse Flattening Test — The reverse flattening test is designed primarily for application to electric-welded tubing for the detection of lack of penetration or overlaps resulting from flash removal in the weld. The specimen consists of a length of tubing approximately 4 in. (102 mm) long which is split longitudinally 90° on each side of the weld. The sample is then opened and flattened with the weld at the point of maximum bend (Fig. A2.9).

A2.5.1.3 Crush Test — The crush test, sometimes referred to as an upsetting test, is usually made on boiler and other pressure tubes, for evaluating ductility (Fig. A2.10). The specimen is a ring cut from the tube, usually about 2½ in. (63.5 mm) long. It is placed on end and crushed endwise by hammer or press to the distance prescribed by the applicable material specifications.

A2.5.1.4 Flange Test — The flange test is intended to determine the ductility of boiler tubes and their ability to withstand the operation of bending into a tube sheet. The test is made on a ring cut from a tube, usually not less than 4 in. (100 mm) long and consists of having a flange turned over at right angles to the body of the tube to the width required by the applicable material specifications. The flaring tool and die block shown in Fig. A2.11 are recommended for use in making this test.

A2.5.1.5 Flaring Test — For certain types of pressure tubes, an alternate to the flange test is made. This test consists of driving a tapered mandrel having a slope of 1 in 10 as shown in Fig. A2.12 (a) or a 60° included angle as shown in Fig. A2.12 (b) into a section cut from the tube, approximately 4 in. (100 mm) in length, and thus expanding the specimen until the inside diameter has been increased to the extent required by the applicable material specifications.

A2.5.1.6 Bend Test — For pipe used for coiling in sizes 2 in. and under a bend test is made to determine its ductility and the soundness of weld. In this test a sufficient length of full-size pipe is bent cold through 90° around a cylindrical mandrel having a diameter 12 times the nominal diameter of the pipe. For close coiling, the pipe is bent cold through 180° around a mandrel having a diameter 8 times the nominal diameter of the pipe.

A2.5.1.7 Transverse Guided Bend Test of Welds — This bend test is used to determine the ductility of fusion welds. The specimens used are approximately 1½ in. (38 mm) wide, at least 6 in. (152 mm) in length with the weld at the center, and are machined in accordance with Fig. A2.13 for face and root bend tests and in accordance with Fig. A2.14 for side bend tests. The dimensions of the plunger shall be as shown in Fig. A2.15 and the other dimensions of the bending jig shall be substantially as given in this same figure. A test shall consist of a face bend specimen and a root bend specimen or two side bend specimens. A face bend test requires bending with the

inside surface of the pipe against the plunger; a root bend test requires bending with the outside surface of the pipe against the plunger; and a side bend test requires bending so that one of the side surfaces becomes the convex surface of the bend specimen.

(a) Failure of the bend test depends upon the appearance of cracks in the area of the bend, of the nature and extent described in the product specifications.

A3. STEEL FASTENERS

A3.1 Scope

A3.1.1 This supplement covers definitions and methods of testing peculiar to steel fasteners which are not covered in the general section of Test Methods and Definitions A 370. Standard tests required by the individual product specifications are to be performed as outlined in the general section of these methods.

A3.1.2 These tests are set up to facilitate production control testing and acceptance testing with certain more precise tests to be used for arbitration in case of disagreement over test results.

A3.2 Tension Tests

A3.2.1 It is preferred that bolts be tested full size, and it is customary, when so testing bolts to specify a minimum ultimate load in pounds, rather than a minimum ultimate strength in pounds per square inch. Three times the bolt nominal diameter has been established as the minimum bolt length subject to the tests described in the remainder of this section. Sections A3.2.1.1–A3.2.1.3 apply when testing bolts full size. Section A3.2.1.4 shall apply where the individual product specifications permit the use of machined specimens.

A3.2.1.1 Proof Load — Due to particular uses of certain classes of bolts it is desirable to be able to stress them, while in use, to a specified value without obtaining any permanent set. To be certain of obtaining this quality the proof load is specified. The proof load test consists of stressing the bolt with a specified load which the bolt must withstand without permanent set. An alternate test which determines yield strength of a full size bolt is also allowed. Either of the following Methods, 1 or 2, may be used but Method 1 shall be the arbitration method in case of any dispute as to acceptance of the bolts.

A3.2.1.2 Proof Load Testing Long Bolts — When full size tests are required, proof load Method 1 is to be limited in application to bolts whose length does not exceed 8 in. (203 mm) or 8 times the nominal diameter, whichever is greater. For bolts longer than 8 in. or 8 times the nominal diameter, whichever is greater, proof load Method 2 shall be used.

(a) *Method 1, Length Measurement* — The overall length of a straight bolt shall be measured at its true center

line with an instrument capable of measuring changes in length of 0.0001 in. (0.0025 mm) with an accuracy of 0.0001 in. in any 0.001 in. (0.025 mm) range. The preferred method of measuring the length shall be between conical centers machined on the center line of the bolt, with mating centers on the measuring anvils. The head or body of the bolt shall be marked so that it can be placed in the same position for all measurements. The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4, and the proof load specified in the product specification shall be applied. Upon release of this load the length of the bolt shall be again measured and shall show no permanent elongation. A tolerance of ± 0.0005 in. (0.0127 mm) shall be allowed between the measurement made before loading and that made after loading. Variables, such as straightness and thread alignment (plus measurement error), may result in apparent elongation of the fasteners when the proof load is initially applied. In such cases, the fastener may be retested using a 3 percent greater load, and may be considered satisfactory if the length after this loading is the same as before this loading (within the 0.0005 in. tolerance for measurement error).

A3.2.1.3 Proof Load-Time of Loading — The proof load is to be maintained for a period of 10 s before release of load, when using Method 1.

(1) *Method 2, Yield Strength* — The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4. As the load is applied, the total elongation of the bolt or any part of the bolt which includes the exposed six threads shall be measured and recorded to produce a load-strain or a stress-strain diagram. The load or stress at an offset equal to 0.2 percent of the length of bolt occupied by 6 full threads shall be determined by the method described in 13.2.1 of these methods, A 370. This load or stress shall not be less than that prescribed in the product specification.

A3.2.1.4 Axial Tension Testing of Full Size Bolts — Bolts are to be tested in a holder with the load axially applied between the head and a nut or suitable fixture (Fig. A3.1), either of which shall have sufficient thread engagement to develop the full strength of the bolt. The nut or fixture shall be assembled on the bolt leaving six complete bolt threads unengaged between the grips, except for heavy hexagon structural bolts which shall have four complete threads unengaged between the grips. To meet the requirements of this test there shall be a tensile failure in the body or threaded section with no failure at the junction of the body, and head. If it is necessary to record or report the tensile strength of bolts as psi values the stress area shall be calculated from the mean of the mean root and pitch diameters of Class 3 external threads as follows:

$$A_s = 0.7854 [D - (0.9743/n)]^2 \quad (\text{A3.1})$$

where:

A_s = stress area, in.²

D = nominal diameter, in., and

n = number of threads per inch

A3.2.1.5 Tension Testing of Full-Size Bolts with a Wedge — The purpose of this test is to obtain the tensile strength and demonstrate the “head quality” and ductility of a bolt with a standard head by subjecting it to eccentric loading. The ultimate load on the bolt shall be determined as described in A3.2.1.4, except that a 10° wedge shall be placed under the same bolt previously tested for the proof load (see A3.2.1.1). The bolt head shall be so placed that no corner of the hexagon or square takes a bearing load, that is, a flat of the head shall be aligned with the direction of uniform thickness of the wedge (Fig. A3.2). The wedge shall have an included angle of 10° between its faces and shall have a thickness of one-half of the nominal bolt diameter at the short side of the hole. The hole in the wedge shall have the following clearance over the nominal size of the bolt, and its edges, top and bottom, shall be rounded to the following radius:

Nominal Bolt Size, in.	Clearance in Hole, in. (mm)	Radius on Corners of Hole, in. (mm)
$\frac{1}{4}$ to $\frac{1}{2}$	0.030 (0.76)	0.030 (0.76)
$\frac{9}{16}$ to $\frac{3}{4}$	0.050 (1.3)	0.060 (1.5)
$\frac{7}{8}$ to 1	0.063 (1.5)	0.060 (1.5)
$1\frac{1}{8}$ to $1\frac{1}{4}$	0.063 (1.5)	0.125 (3.2)
$1\frac{3}{8}$ to $1\frac{1}{2}$	0.094 (2.4)	0.125 (3.2)

A3.2.1.6 Wedge Testing of HT Bolts Threaded to Head — For heat-treated bolts over 100 000 psi (690 MPa) minimum tensile strength and that are threaded 1 diameter and closer to the underside of the head, the wedge angle shall be 6° for sizes $\frac{1}{4}$ through $\frac{3}{4}$ in. (6.35 to 19.0 mm) and 4° for sizes over $\frac{3}{4}$ in.

A3.2.1.7 Tension Testing of Bolts Machined to Round Test Specimens:

(1) Bolts under $1\frac{1}{2}$ in. (38 mm) in diameter which require machined tests shall preferably use a standard $\frac{1}{2}$ in., (13 mm) round 2 in. (50 mm) gage length test specimen (Fig. 4); however, bolts of small cross-section that will not permit the taking of this standard test specimen shall use one of the small-size-specimens-proportional-to-standard (Fig. 4) and the specimen shall have a reduced section as large as possible. In all cases, the longitudinal axis of the specimen shall be concentric with the axis of the bolt; the head and threaded section of the bolt may be left intact, as in Fig. A3.3 and Fig. A3.4, or shaped to fit the holders or grips of the testing machine so that the load is applied axially. The gage length for measuring the elongation shall be four times the diameter of the specimen.

(2) For bolts $1\frac{1}{2}$ in. and over in diameter, a standard $\frac{1}{2}$ in. round 2 in. gage length test specimen shall be turned

from the bolt, having its axis midway between the center and outside surface of the body of the bolt as shown in Fig. A3.5.

(3) Machined specimens are to be tested in tension to determine the properties prescribed by the product specifications. The methods of testing and determination of properties shall be in accordance with Section 13 of these test methods.

A3.3 Hardness Tests for Externally Threaded Fasteners

A3.3.1 When specified, externally threaded fasteners shall be hardness tested. Fasteners with hexagonal or square heads shall be Brinell or Rockwell hardness tested on the side or top of the head. Externally threaded fasteners with other type of heads and those without heads shall be Brinell or Rockwell hardness tested on one end. Due to possible distortion from the Brinell load, care should be taken that this test meets the requirements of Section 16 of these test methods. Where the Brinell hardness test is impractical, the Rockwell hardness test shall be substituted. Rockwell hardness test procedures shall conform to Section 18 of these test methods.

A3.3.2 In cases where a dispute exists between buyer and seller as to whether externally threaded fasteners meet or exceed the hardness limit of the product specification, for purposes of arbitration, hardness may be taken on two transverse sections through a representative sample fastener selected at random. Hardness readings shall be taken at the locations shown in Fig. A3.6. All hardness values must conform with the hardness limit of the product specification in order for the fasteners represented by the sample to be considered in compliance. This provision for arbitration of a dispute shall not be used to accept clearly rejectable fasteners.

A3.4 Testing of Nuts

A3.4.1 Proof Load — A sample nut shall be assembled on a hardened threaded mandrel or on a bolt conforming to the particular specification. A load axial with the mandrel or bolt and equal to the specified proof load of the nut shall be applied. The nut shall resist this load without stripping or rupture. If the threads of the mandrel are damaged during the test the individual test shall be discarded. The mandrel shall be threaded to American National Standard Class 3 tolerance, except that the major diameter shall be the minimum major diameter with a tolerance of +0.002 in. (0.051 mm).

A3.4.2 Hardness Test — Rockwell hardness of nuts shall be determined on the top or bottom face of the nut. Brinell hardness shall be determined on the side of the nuts. Either method may be used at the option of the manufacturer, taking into account the size and grade of the nuts under test. When the standard Brinell hardness

test results in deforming the nut it will be necessary to use a minor load or substitute a Rockwell hardness test.

A4. ROUND WIRE PRODUCTS

A4.1 Scope

A4.1.1 This supplement covers the apparatus, specimens and methods of testing peculiar to steel wire products which are not covered in the general section of Test Methods A 370.

A4.2 Apparatus

A4.2.1 Gripping Devices — Grips of either the wedge or snubbing types as shown in Fig. A4.1 and Fig. A4.2 shall be used (Note A4.1). When using grips of either type, care shall be taken that the axis of the test specimen is located approximately at the center line of the head of the testing machine (Note A4.2). When using wedge grips the liners used behind the grips shall be of the proper thickness.

NOTE A4.1 — Testing machines usually are equipped with wedge grips. These wedge grips, irrespective of the type of testing machine, may be referred to as the “usual type” of wedge grips. The use of fine (180 or 240) grit abrasive cloth in the “usual” wedge type grips, with the abrasive contacting the wire specimen, can be helpful in reducing specimen slipping and breakage at the grip edges at tensile loads up to about 1000 pounds. For tests of specimens of wire which are liable to be cut at the edges by the “usual type” of wedge grips, the snubbing type gripping device has proved satisfactory.

For testing round wire, the use of cylindrical seat in the wedge gripping device is optional.

NOTE A4.2 — Any defect in a testing machine which may cause nonaxial application of load should be corrected.

A4.2.2 Pointed Micrometer — A micrometer with a pointed spindle and anvil suitable for reading the dimensions of the wire specimen at the fractured ends to the nearest 0.001 in. (0.025 mm) after breaking the specimen in the testing machine shall be used.

A4.3 Test Specimens

A4.3.1 Test specimens having the full cross-sectional area of the wire they represent shall be used. The standard gage length of the specimens shall be 10 in. (254 mm). However, if the determination of elongation values is not required, any convenient gage length is permissible. The total length of the specimens shall be at least equal to the gage length (10 in.) plus twice the length of wire required for the full use of the grip employed. For example, depending upon the type of testing machine and grips used, the minimum total length of specimen may vary from 14 to 24 in. (360 to 610 mm) for a 10 in. gage length specimen.

A4.3.2 Any specimen breaking in the grips shall be discarded and a new specimen tested.

A4.4 Elongation

A4.4.1 In determining permanent elongation, the ends of the fractured specimen shall be carefully fitted together and the distance between the gage marks measured to the nearest 0.01 in. (0.25 mm) with dividers and scale or other suitable device. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In recording elongation values, both the percentage increase and the original gage length shall be given.

A4.4.2 In determining total elongation (elastic plus plastic extension) autographic or extensometer methods may be employed.

A4.4.3 If fracture takes place outside of the middle third of the gage length, the elongation value obtained may not be representative of the material.

A4.5 Reduction of Area

A4.5.1 The ends of the fractured specimen shall be carefully fitted together and the dimensions of the smallest cross section measured to the nearest 0.001 in. (0.025 mm) with a pointed micrometer. The difference between the area thus found and the area of the original cross section, expressed as a percentage of the original area, is the reduction of area.

A4.5.2 The reduction of area test is not recommended in wire diameters less than 0.092 in. (2.34 mm) due to the difficulties of measuring the reduced cross sections.

A4.6 Rockwell Hardness Test

A4.6.1 On heat-treated wire of diameter 0.100 in. (2.54 mm) and larger, the specimen shall be flattened on two parallel sides by grinding before testing. The hardness test is not recommended for any diameter of hard drawn wire or heat-treated wire less than 0.100 in. (2.54 mm) in diameter. For round wire, the tensile strength test is greatly preferred over the hardness test.

A4.7 Wrap Test

A4.7.1 This test is used as a means for testing the ductility of certain kinds of wire.

A4.7.2 The test consists of coiling the wire in a closely spaced helix tightly against a mandrel of a specified diameter for a required number of turns. (Unless other specified, the required number of turns shall be five.) The wrapping may be done by hand or a power device. The wrapping rate may not exceed 15 turns per min. The mandrel diameter shall be specified in the relevant wire product specification.

A4.7.3 The wire tested shall be considered to have failed if the wire fractures or if any longitudinal or transverse cracks develop which can be seen by the unaided eye after the first complete turn. Wire which fails in the first turn shall be retested, as such fractures may be caused

by bending the wire to a radius less than specified when the test starts.

A4.8 Coiling Test

A4.8.1 This test is used to determine if imperfections are present to the extent that they may cause cracking or splitting during spring coiling and spring extension. A coil of specified length is closed wound on an arbor of a specified diameter. The closed coil is then stretched to a specified permanent increase in length and examined for uniformity of pitch with no splits or fractures. The required arbor diameter, closed coil length, and permanent coil extended length increase may vary with wire diameter, properties, and type.

A5. NOTES ON SIGNIFICANCE OF NOTCHED-BAR IMPACT TESTING

A5.1 Notch Behavior

A5.1.1 The Charpy and Izod type tests bring out notch behavior (brittleness versus ductility) by applying a single overload of stress. The energy values determined are quantitative comparisons on a selected specimen but cannot be converted into energy values that would serve for engineering design calculations. The notch behavior indicated in an individual test applies only to the specimen size, notch geometry, and testing conditions involved and cannot be generalized to other sizes of specimens and conditions.

A5.1.2 The notch behavior of the face-centered cubic metals and alloys, a large group of nonferrous materials and the austenitic steels can be judged from their common tensile properties. If they are brittle in tension they will be brittle when notched, while if they are ductile in tension, they will be ductile when notched, except for unusually sharp or deep notches (much more severe than the standard Charpy or Izod specimens). Even low temperatures do not alter this characteristic of these materials. In contrast, the behavior of the ferritic steels under notch conditions cannot be predicted from their properties as revealed by the tension test. For the study of these materials the Charpy and Izod type tests are accordingly very useful. Some metals that display normal ductility in the tension test may nevertheless break in brittle fashion when tested or when used in the notched condition. Notched conditions include restraints to deformation in directions perpendicular to the major stress, or multiaxial stresses, and stress concentrations. It is in this field that the Charpy and Izod tests prove useful for determining the susceptibility of a steel to notch-brittle behavior though they cannot be directly used to appraise the serviceability of a structure.

A5.1.3 The testing machine itself must be sufficiently rigid or tests on high-strength low-energy materials will result in excessive elastic energy losses either upward

through the pendulum shaft or downward through the base of the machine. If the anvil supports, the pendulum striking edge, or the machine foundation bolts are not securely fastened, tests on ductile materials in the range of 80 ft•lbf (108 J) may actually indicate values in excess of 90 to 100 ft•lbf (122 to 136 J).

A5.2 Notch Effect

A5.2.1 The notch results in a combination of multiaxial stresses associated with restraints to deformation in directions perpendicular to the major stress, and a stress concentration at the base of the notch. A severely notched condition is generally not desirable, and it becomes of real concern in those cases in which it initiates a sudden and complete failure of the brittle type. Some metals can be deformed in a ductile manner even down to the low temperatures of liquid air, while others may crack. This difference in behavior can be best understood by considering the cohesive strength of a material (or the property that holds it together) and its relation to the yield point. In cases of brittle fracture, the cohesive strength is exceeded before significant plastic deformation occurs and the fracture appears crystalline. In cases of the ductile or shear type of failure, considerable deformation precedes the final fracture and the broken surface appears fibrous instead of crystalline. In intermediate cases the fracture comes after a moderate amount of deformation and is part crystalline and part fibrous in appearance.

A5.2.2 When a notched bar is loaded, there is a normal stress across the base of the notch which tends to initiate fracture. The property that keeps it from cleaving, or holds it together, is the “cohesive strength.” The bar fractures when the normal stress exceeds the cohesive strength. When this occurs without the bar deforming it is the condition for brittle fracture.

A5.2.3 In testing, though not in service because of side effects, it happens more commonly that plastic deformation precedes fracture. In addition to the normal stress, the applied load also sets up shear stresses which are about 45° to the normal stress. The elastic behavior terminates as soon as the shear stress exceeds the shear strength of the material and deformation or plastic yielding sets in. This is the condition for ductile failure.

A5.2.4 This behavior, whether brittle or ductile, depends on whether the normal stress exceeds the cohesive strength before the shear stress exceeds the shear strength. Several important facts of notch behavior follow from this. If the notch is made sharper or more drastic, the normal stress at the root of the notch will be increased in relation to the shear stress and the bar will be more prone to brittle fracture (see Table A5.1). Also, as the speed of deformation increases, the shear strength increases and the likelihood of brittle fracture increases. On the other hand, by raising

the temperature, leaving the notch and the speed of deformation the same, the shear strength is lowered and ductile behavior is promoted, leading to shear failure.

A5.2.5 Variations in notch dimensions will seriously affect the results of the tests. Tests on E 4340 steel specimens have shown the effect of dimensional variations on Charpy results (see Table A5.1).

A5.3 Size Effect

A5.3.1 Increasing either the width or the depth of the specimen tends to increase the volume of metal subject to distortion, and by this factor tends to increase the energy absorption when breaking the specimen. However, any increase in size, particularly in width, also tends to increase the degree of restraint and by tending to induce brittle fracture, may decrease the amount of energy absorbed. Where a standard-size specimen is on the verge of brittle fracture, this is particularly true, and a double-width specimen may actually require less energy for rupture than one of standard width.

A5.3.2 In studies of such effects where the size of the material precludes the use of the standard specimen, as for example when the material is $\frac{1}{4}$ in. plate, subsize specimens are necessarily used. Such specimens (see Fig. 6 of Test Methods E 23) are based on the Type A specimen of Fig. 4 of Test Methods E 23.

A5.3.3 General correlation between the energy values obtained with specimens of different size or shape is not feasible, but limited correlations may be established for specification purposes on the basis of special studies of particular materials and particular specimens. On the other hand, in a study of the relative effect of process variations, evaluation by use of some arbitrarily selected specimen with some chosen notch will in most instances place the methods in their proper order.

A5.4 Effects of Testing Conditions

A5.4.1 The testing conditions also affect the notch behavior. So pronounced is the effect of temperature on the behavior of steel when notched that comparisons are frequently made by examining specimen fractures and by plotting energy value and fracture appearance versus temperature from tests of notched bars at a series of temperatures. When the test temperature has been carried low enough to start cleavage fracture, there may be an extremely sharp drop in impact value or there may be a relatively gradual falling off toward the lower temperatures. This drop in energy value starts when a specimen begins to exhibit some crystalline appearance in the fracture. The transition temperature at which this embrittling effect takes place varies considerably with the size of the part or test specimen and with the notch geometry.

A5.4.2 Some of the many definitions of transition temperature currently being used are: (1) the lowest temperature at which the specimen exhibits 100% fibrous fracture,

(2) the temperature where the fracture shows a 50% crystalline and a 50% fibrous appearance, (3) the temperature corresponding to the energy value 50% of the difference between values obtained at 100% and 0% fibrous fracture, and (4) the temperature corresponding to a specific energy value.

A5.4.3 A problem peculiar to Charpy-type tests occurs when high-strength, low-energy specimens are tested at low temperatures. These specimens may not leave the machine in the direction of the pendulum swing but rather in a sidewise direction. To ensure that the broken halves of the specimens do not rebound off some component of the machine and contact the pendulum before it completes its swing, modifications may be necessary in older model machines. These modifications differ with machine design. Nevertheless the basic problem is the same in that provisions must be made to prevent rebounding of the fractured specimens into any part of the swinging pendulum. Where design permits, the broken specimens may be deflected out of the sides of the machine and yet in other designs it may be necessary to contain the broken specimens within a certain area until the pendulum passes through the anvils. Some low-energy high-strength steel specimens leave impact machines at speeds in excess of 50 ft (15.3 m)/s although they were struck by a pendulum traveling at speeds approximately 17 ft (5.2 m)/s. If the force exerted on the pendulum by the broken specimens is sufficient, the pendulum will slow down and erroneously high energy values will be recorded. This problem accounts for many of the inconsistencies in Charpy results reported by various investigators within the 10 to 25-ft•lbf (14 to 34 J) range. The Apparatus Section (the paragraph regarding Specimen Clearance) of Test Methods E 23 discusses the two basic machine designs and a modification found to be satisfactory in minimizing jamming.

A5.5 Velocity of Straining

A5.5.1 Velocity of straining is likewise a variable that affects the notch behavior of steel. The impact test shows somewhat higher energy absorption values than the static tests above the transition temperature and yet, in some instances, the reverse is true below the transition temperature.

A5.6 Correlation with Service

A5.6.1 While Charpy or Izod tests may not directly predict the ductile or brittle behavior of steel as commonly used in large masses or as components of large structures, these tests can be used as acceptance tests of identity for different lots of the same steel or in choosing between different steels, when correlation with reliable service behavior has been established. It may be necessary to make the tests at properly chosen temperatures other than room temperature. In this, the service temperature or the transition temperature of full-scale specimens does not give the

desired transition temperatures for Charpy or Izod tests since the size and notch geometry may be so different. Chemical analysis, tension, and hardness tests may not indicate the influence of some of the important processing factors that affect susceptibility to brittle fracture nor do they comprehend the effect of low temperatures in inducing brittle behavior.

A6. PROCEDURE FOR CONVERTING PERCENTAGE ELONGATION OF A STANDARD ROUND TENSION TEST SPECIMEN TO EQUIVALENT PERCENTAGE ELONGATION OF A STANDARD FLAT SPECIMEN

A6.1 Scope

A6.1.1 This method specifies a procedure for converting percentage elongation after fracture obtained in a standard 0.500 in. (12.7 mm) diameter by 2 in. (51 mm) gage length test specimen to standard flat test specimens ½ in. by 2 in. and 1½ in. by 8 in. (38.1 by 203 mm).

A6.2 Basic Equation

A6.2.1 The conversion data in this method are based on an equation by Bertella, and used by Oliver and others. The relationship between elongations in the standard 0.500 in. diameter by 2.0 in. test specimen and other standard specimens can be calculated as follows:

$$e = e_o [4.47(\sqrt{A})/L]^a \quad (\text{A6.1})$$

where:

e_o = percentage elongation after fracture on a standard test specimen having a 2 in. gage length and 0.500 in. diameter

e = percentage elongation after fracture on a standard test specimen having a gage length L and a cross-sectional area A , and

a = constant characteristic of the test material

A6.3 Application

A6.3.1 In applying the above equation the constant a is characteristic of the test material. The value $a = 0.4$ has been found to give satisfactory conversions for carbon, carbon-manganese, molybdenum, and chromium-molybdenum steels within the tensile strength range of 40 000 to 85 000 psi (275 to 585 MPa) and in the hot-rolled, in the hot-rolled and normalized, or in the annealed condition, with or without tempering. Note that the cold reduced and quenched and tempered states are excluded. For annealed austenitic stainless steels, the value $a = 0.127$ has been found to give satisfactory conversions.

A6.3.2 Table A6.1 has been calculated taking $a = 0.4$, with the standard 0.500 in. (12.7 mm) diameter by 2 in. (51 mm) gage length test specimen as the reference

specimen. In the case of the subsize specimens 0.350 in. (8.89 mm) in diameter by 1.4 in. (35.6 mm) gage length, and 0.250 in. (6.35-mm) diameter by 1.0 in. (25.4 mm) gage length the factor in the equation is 4.51 instead of 4.47. The small error introduced by using Table A6.1 for the subsized specimens may be neglected. Table A6.2 for annealed austenitic steels has been calculated taking $a = 0.127$, with the standard 0.500-in. diameter by 2-in. gage length test specimen as the reference specimen.

A6.3.3 Elongation given for a standard 0.500 in. diameter by 2 in. gage length specimen may be converted to elongation for $\frac{1}{2}$ in. by 2 in. or $1\frac{1}{2}$ in. by 8 in. (38.1 by 203 mm) flat specimens by multiplying by the indicated factor in Table A6.1 and Table A6.2.

A6.3.4 These elongation conversions shall not be used where the width to thickness ratio of the test piece exceeds 20, as in sheet specimens under 0.025 in. (0.635 mm) in thickness.

A6.3.5 While the conversions are considered to be reliable within the stated limitations and may generally be used in specification writing where it is desirable to show equivalent elongation requirements for the several standard ASTM tension specimens covered in Test Methods A 370, consideration must be given to the metallurgical effects dependent on the thickness of the material as processed.

A7. METHOD OF TESTING MULTI-WIRE STRAND FOR PRESTRESSED CONCRETE

A7.1 Scope

A7.1.1 This method provides procedures for the tension testing of multi-wire strand for prestressed concrete. This method is intended for use in evaluating the strand properties prescribed in specifications for “prestressing steel strands.”

A7.2 General Precautions

A7.2.1 Premature failure of the test specimens may result if there is any appreciable notching, cutting, or bending of the specimen by the gripping devices of the testing machine.

A7.2.2 Errors in testing may result if the seven wires constituting the strand are not loaded uniformly.

A7.2.3 The mechanical properties of the strand may be materially affected by excessive heating during specimen preparation.

A7.2.4 These difficulties may be minimized by following the suggested methods of gripping described in A7.4.

A7.3 Gripping Devices

A7.3.1 The true mechanical properties of the strand are determined by a test in which fracture of the specimen

occurs in the free span between the jaws of the testing machine. Therefore, it is desirable to establish a test procedure with suitable apparatus which will consistently produce such results. Due to inherent physical characteristics of individual machines, it is not practical to recommend a universal gripping procedure that is suitable for all testing machines. Therefore, it is necessary to determine which of the methods of gripping described in A7.3.2 to A7.3.8 is most suitable for the testing equipment available.

A7.3.2 *Standard V-Grips with Serrated Teeth* (Note A7.1).

A7.3.3 *Standard V-Grips with Serrated Teeth* (Note A7.1), *Using Cushioning Material* — In this method, some material is placed between the grips and the specimen to minimize the notching effect of the teeth. Among the materials which have been used are lead foil, aluminum foil, carborundum cloth, bra shims, etc. The type and thickness of material required is dependent on the shape, condition, and coarseness of the teeth.

A7.3.4 *Standard V-Grips with Serrated Teeth* (Note A7.1), *Using Special Preparation of the Gripped Portions of the Specimen* — One of the methods used is tinning, in which the gripped portions are cleaned, fluxed, and coated by multiple dips in molten tin alloy held just above the melting point. Another method of preparation is encasing the gripped portions in metal tubing or flexible conduit, using epoxy resin as the bonding agent. The encased portion should be approximately twice the length of lay of the strand.

A7.3.5 *Special Grips with Smooth, Semi-Cylindrical Grooves* (Note A7.2) — The grooves and the gripped portions of the specimen are coated with an abrasive slurry which holds the specimen in the smooth grooves, preventing slippage. The slurry consists of abrasive such as Grade 3-F aluminum oxide and a carrier such as water or glycerin.

A7.3.6 *Standard Sockets of the Type Used for Wire Rope* — The gripped portions of the specimen are anchored in the sockets with zinc. The special procedures for socketting usually employed in the wire rope industry must be followed.

A7.3.7 *Dead-End Eye Splices* — These devices are available in sizes designed to fit each size of strand to be tested.

A7.3.8 *Chucking Devices* — Use of chucking devices of the type generally employed for applying tension to strands in casting beds is not recommended for testing purposes.

NOTE A7.1 — The number of teeth should be approximately 15 to 30 per in., and the minimum effective gripping length should be approximately 4 in. (102 mm).

NOTE A7.2 — The radius of curvature of the grooves is approximately the same as the radius of the strand being tested, and is located $\frac{1}{32}$ in. (0.79 mm) above the flat face of the grip. This prevents the two grips from closing tightly when the specimen is in place.

A7.4 Specimen Preparation

A7.4.1 If the molten-metal temperatures employed during hot-dip tinning or socketing with metallic material are too high, over approximately 700°F (370°C), the specimen may be heat affected with a subsequent loss of strength and ductility. Careful temperature controls should be maintained if such methods of specimen preparation are used.

A7.5 Procedure

A7.5.1 Yield Strength — For determining the yield strength use a Class B-1 extensometer (Note A7.3) as described in Practice E 83. Apply an initial load of 10% of the expected minimum breaking strength to the specimen, then attach the extensometer and adjust it to a reading of 0.001 in./in. of gage length. Then increase the load until the extensometer indicates an extension of 1%. Record the load for this extension as the yield strength. The extensometer may be removed from the specimen after the yield strength has been determined.

A7.5.2 Elongation — For determining the elongation use a Class D extensometer (Note A7.3), as described in Practice E 83, having a gage length of not less than 24 in. (610 mm) (Note A7.4). Apply an initial load of 10% of the required minimum breaking strength to the specimen, then attach the extensometer (Note A7.3) and adjust it to a zero reading. The extensometer may be removed from the specimen prior to rupture after the specified minimum elongation has been exceeded. It is not necessary to determine the final elongation value.

A7.5.3 Breaking Strength — Determine the maximum load at which one or more wires of the strand are fractured. Record this load as the breaking strength of the strand.

NOTE A7.3 — The yield-strength extensometer and the elongation extensometer may be the same instrument or two separate instruments. Two separate instruments are advisable since the more sensitive yield-strength extensometer, which could be damaged when the strand fractures, may be removed following the determination of yield strength. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that little damage would result if fracture occurs while the extensometer is attached to the specimen.

NOTE A7.4 — Specimens that break outside the extensometer or in the jaws and yet meet the minimum specified values are considered as meeting the mechanical property requirements of the product specification, regardless of what procedure of gripping has been used. Specimens that break outside of the extensometer or in the jaws and do not meet the minimum specified values are subject to retest. Specimens that break between the jaws and the extensometer and do not meet the minimum specified values are subject to retest as provided in the applicable specification.

A8. ROUNDING OF TEST DATA

A8.1 Rounding

A8.1.1 An observed value or a calculated value shall be rounded off in accordance with the applicable product specification. In the absence of a specified procedure, the rounding-off method of Practice E 29 shall be used.

A8.1.1.1 Values shall be rounded up or rounded down as determined by the rules of Practice E 29.

A8.1.1.2 In the special case of rounding the number “5” when no additional numbers other than “0” follow the “5,” rounding shall be done in the direction of the specification limits if following Practice E 29 would cause rejection of material.

A8.1.2 Recommended levels for rounding reported values of test data are given in Table A8.1. These values are designed to provide uniformity in reporting and data storage, and should be used in all cases except where they conflict with specific requirements of a product specification.

NOTE A8.1 — To minimize cumulative errors, whenever possible, values should be carried to at least one figure beyond that of the final (rounded) value during intervening calculations (such as calculation of stress from load and area measurements) with rounding occurring as the final operation. The precision may be less than that implied by the number of significant figures.

A9. METHODS FOR TESTING STEEL REINFORCING BARS

A9.1 Scope

A9.1.1 This annex covers additional details specific to testing steel reinforcing bars for use in concrete reinforcement.

A9.2 Test Specimens

A9.2.1 All test specimens shall be the full section of the bar as rolled.

A9.3 Tension Testing

A9.3.1 Test Specimen — Specimens for tension tests shall be long enough to provide for an 8-in. (200-mm) gage length, a distance of at least two bar diameters between each gage mark and the grips, plus sufficient additional length to fill the grips completely leaving some excess length protruding beyond each grip.

A9.3.2 Gripping Device — The grips shall be shimmed so that no more than $\frac{1}{2}$ in. (13 mm) of a grip protrudes from the head of the testing machine.

A9.3.3 Gage Marks — The 8 in. (200 mm) gage length shall be marked on the specimen using a preset 8 in. (200 mm) punch or, alternately, may be punch marked every 2 in. (50 mm) along the 8 in. (200 mm) gage length, on one of the longitudinal ribs, if present, or in clear spaces

of the deformation pattern. The punch marks shall not be put on a transverse deformation. Light punch marks are desirable because deep marks severely indent the bar and may affect the results. A bullet-nose punch is desirable.

A9.3.4 The yield strength or yield point shall be determined by one of the following methods:

A9.3.4.1 Extension under load using an autographic diagram method or an extensometer as described in 13.1.2 and 13.1.3,

A9.3.4.2 By the drop of the beam or halt in the gage of the testing machine as described in 13.1.1 where the steel tested as a sharp-kneed or well-defined type of yield point.

A9.3.5 The unit stress determinations for yield and tensile strength on full-size specimens shall be based on the nominal bar area.

A9.4 Bend Testing

A9.4.1 Bend tests shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

A9.4.1.1 Continuous and uniform application of force throughout the duration of the bending operation,

A9.4.1.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate, and

A9.4.1.3 Close wrapping of the specimen around the pin during the bending operation.

A9.4.2 Other acceptable more severe methods of bend testing, such as placing a specimen across two pins free to rotate and applying the bending force with a fix pin, may be used.

A9.4.3 When retesting is permitted by the product specification, the following shall apply:

A9.4.3.1 Sections of bar containing identifying roll marking shall not be used.

A9.4.3.2 Bars shall be so placed that longitudinal ribs lie in a plane at right angles to the plane of bending.

A10. PROCEDURE FOR USE AND CONTROL OF HEAT-CYCLE SIMULATION

A10.1 Purpose

A10.1.1 To ensure consistent and reproducible heat treatments of production forgings and the test specimens that represent them when the practice of heat-cycle simulation is used.

A10.2 Scope

A10.2.1 Generation and documentation of actual production time — temperature curves (MASTER CHARTS).

A10.2.2 Controls for duplicating the master cycle during heat treatment of production forgings. (Heat treating within the essential variables established during A1.2.1).

A10.2.3 Preparation of program charts for the simulator unit.

A10.2.4 Monitoring and inspection of the simulated cycle within the limits established by the ASME Code.

A10.2.5 Documentation and storage of all controls, inspections, charts, and curves.

A10.3 Referenced Documents

A10.3.1 ASME Standards:

ASME Boiler and Pressure Vessel Code Section III, latest edition.

ASME Boiler and Pressure Vessel Code Section VIII, Division 2, latest edition.

A10.4 Terminology

A10.4.1 Definitions:

A10.4.1.1 master chart — a record of the heat treatment received from a forging essentially identical to the production forgings that it will represent. It is a chart of time and temperature showing the output from thermocouples imbedded in the forging at the designated test immersion and test location or locations.

A10.4.1.2 program chart — the metallized sheet used to program the simulator unit. Time-temperature data from the master chart are manually transferred to the program chart.

A10.4.1.3 simulator chart — a record of the heat treatment that a test specimen had received in the simulator unit. It is a chart of time and temperature and can be compared directly to the master chart for accuracy of duplication.

A10.4.1.4 simulator cycle — one continuous heat treatment of a set of specimens in the simulator unit. The cycle includes heating from ambient, holding at temperature, and cooling. For example, a simulated austenitize and quench of a set of specimens would be one cycle; a simulated temper of the same specimens would be another cycle.

A10.5 Procedure

A10.5.1 Production Master Charts:

A10.5.1.1 Thermocouples shall be imbedded in each forging from which a master chart is obtained. Temperature shall be monitored by a recorder with resolution sufficient to clearly define all aspects of the heating, holding, and cooling process. All charts are to be clearly identified with all pertinent information and identification required for maintaining permanent records.

A10.5.1.2 Thermocouples shall be imbedded 180° apart if the material specification requires test locations 180° apart.

A10.5.1.3 One master chart (or two if required in accordance with A10.5.3.1) shall be produced to represent essentially identical forgings (same size and shape). Any change in size or geometry (exceeding rough machining tolerances) of a forging will necessitate that a new master cooling curve be developed.

A10.5.1.4 If more than one curve is required per master forging (180° apart) and a difference in cooling rate is achieved, then the most conservative curve shall be used as the master curve.

A10.5.2 *Reproducibility of Heat Treatment Parameters on Production Forgings:*

A10.5.2.1 All information pertaining to the quench and temper of the master forging shall be recorded on an appropriate permanent record, similar to the one shown in Table A10.1.

A10.5.2.2 All information pertaining to the quench and temper of the production forgings shall be appropriately recorded, preferably on a form similar to that used in A10.5.2.1. Quench records of production forgings shall be retained for future reference. The quench and temper record of the master forging shall be retained as a permanent record.

A10.5.2.3 A copy of the master forging record shall be stored with the heat treatment record of the production forging.

A10.5.2.4 The essential variables, as set forth on the heat treat record, shall be controlled within the given parameters on the production forging.

A10.5.2.5 The temperature of the quenching medium prior to quenching each production forging shall be equal to or lower than the temperature of the quenching medium prior to quenching the master forging.

A10.5.2.6 The time elapsed from opening the furnace door to quench for the production forging shall not exceed that elapsed for the master forging.

A10.5.2.7 If the time parameter is exceeded in opening the furnace door to beginning of quench, the forging shall be placed back into the furnace and brought back up to equalization temperature.

A10.5.2.8 All forgings represented by the same master forging shall be quenched with like orientation to the surface of the quench bath.

A10.5.2.9 All production forgings shall be quenched in the same quench tank, with the same agitation as the master forging.

A10.5.2.10 *Uniformity of Heat Treat Parameters* — (1) The difference in actual heat treating temperature between production forgings and the master forging used to establish the simulator cycle for them shall not

exceed $\pm 25^{\circ}\text{F}$ ($\pm 14^{\circ}\text{C}$) for the quench cycle. (2) The tempering temperature of the production forgings shall not fall below the actual tempering temperature of the master forging. (3) At least one contact surface thermocouple shall be placed on each forging in a production load. Temperature shall be recorded for all surface thermocouples on a Time Temperature Recorder and such records shall be retained as permanent documentation.

A10.5.3 *Heat-Cycle Simulation:*

A10.5.3.1 Program charts shall be made from the data recorded on the master chart. All test specimens shall be given the same heating rate above the AC1, the same holding time and the same cooling rate as the production forgings.

A10.5.3.2 The heating cycle above the AC1, a portion of the holding cycle, and the cooling portion of the master chart shall be duplicated and the allowable limits on temperature and time, as specified in (a)–(c), shall be established for verification of the adequacy of the simulated heat treatment.

(a) *Heat Cycle Simulation of Test Coupon Heat Treatment for Quenched and Tempered Forgings and Bars* —

If cooling rate data for the forgings and bars and cooling rate control devices for the test specimens are available, the test specimens may be heat-treated in the device.

(b) The test coupons shall be heated to substantially the same maximum temperature as the forgings or bars. The test coupons shall be cooled at a rate similar to and no faster than the cooling rate representative of the test locations and shall be within 25°F (14°C) and 20 s at all temperatures after cooling begins. The test coupons shall be subsequently heat treated in accordance with the thermal treatments below the critical temperature including tempering and simulated post weld heat treatment.

(c) *Simulated Post Weld Heat Treatment of Test Specimens* (for ferritic steel forgings and bars) — Except for carbon steel (P Number 1, Section IX of the Code) forgings and bars with a nominal thickness or diameter of 2 in. (51 mm) or less, the test specimens shall be given a heat treatment to simulate any thermal treatments below the critical temperature that the forgings and bars may receive during fabrication. The simulated heat treatment shall utilize temperatures, times, and cooling rates as specified on the order. The total time at temperature(s) for the test material shall be at least 80% of the total time at temperature(s) to which the forgings and bars are subjected during postweld heat treatment. The total time at temperature(s) for the test specimens may be performed in a single cycle.

A10.5.3.3 Prior to heat treatment in the simulator unit, test specimens shall be machined to standard sizes that have been determined to allow adequately for subsequent removal of decarb and oxidation.

A10.5.3.4 At least one thermocouple per specimen shall be used for continuous recording of temperature on an independent external temperature-monitoring source. Due to the sensitivity and design peculiarities of the heating chamber of certain equipment, it is mandatory that the hot junctions of control and monitoring thermocouples always be placed in the same relative position with respect to the heating source (generally infrared lamps).

A10.5.3.5 Each individual specimen shall be identified, and such identification shall be clearly shown on the simulator chart and simulator cycle record.

A10.5.3.6 The simulator chart shall be compared to the master chart for accurate reproduction of simulated quench in accordance with A10.5.3.2(a). If any one specimen is not heat treated within the acceptable limits of temperature and time, such specimen shall be discarded and replaced by a newly machined specimen. Documentation of such action and reasons for deviation from the master chart shall be shown on the simulator chart, and on the corresponding nonconformance report.

A10.5.4 Reheat Treatment and Retesting:

A10.5.4.1 In the event of a test failure, retesting shall be handled in accordance with rules set forth by the material specification.

A10.5.4.2 If retesting is permissible, a new test specimen shall be heat treated the same as previously. The

production forging that it represents will have received the same heat treatment. If the test passes, the forging shall be acceptable. If it fails, the forging shall be rejected or shall be subject to reheat treatment if permissible.

A10.5.4.3 If reheat treatment is permissible, proceed as follows: (1) Reheat treatment same as original heat treatment (time, temperature, cooling rate): Using new test specimens from an area as close as possible to the original specimens, repeat the austenitize and quench cycles twice, followed by the tempering cycle (double quench and temper). The production forging shall be given the identical double quench and temper as its test specimens above. (2) Reheat treatment using a new heat treatment practice. Any change in time, temperature, or cooling rate shall constitute a new heat treatment practice. A new master curve shall be produced and the simulation and testing shall proceed as originally set forth.

A10.5.4.4 In summation, each test specimen and its corresponding forging shall receive identical heat treatment or heat treatment; otherwise the testing shall be invalid.

A10.5.5 Storage, Recall, and Documentation of Heat-Cycle Simulation Data — All records pertaining to heat-cycle simulation shall be maintained and held for a period of 10 years or as designed by the customer. Information shall be so organized that all practices can be verified by adequate documented records.

FIG. A2.1 METAL PLUGS FOR TESTING TUBULAR SPECIMENS, PROPER LOCATION OF PLUGS IN SPECIMEN AND OF SPECIMEN IN HEADS OF TESTING MACHINE

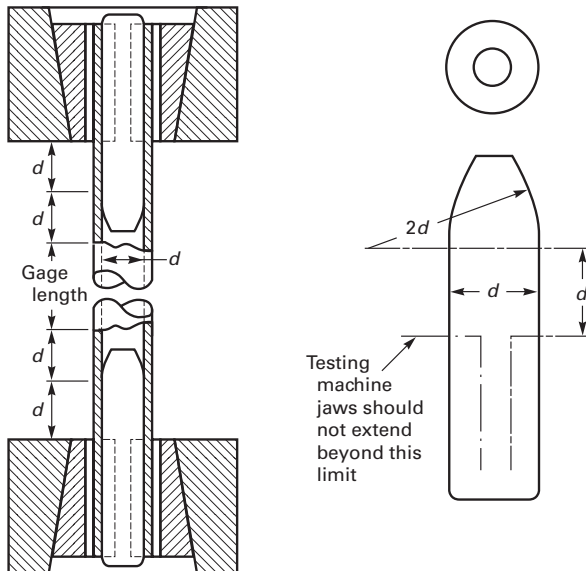
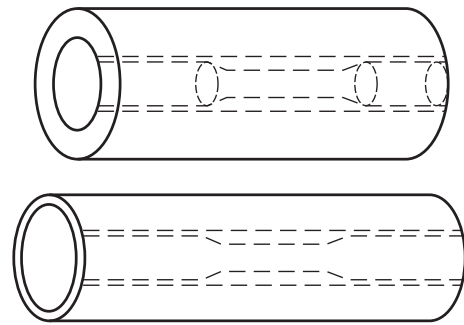
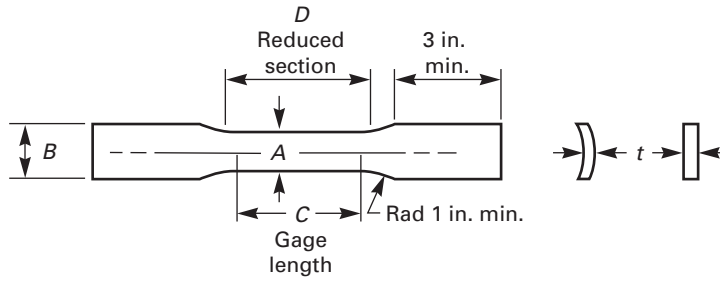


FIG. A2.2 LOCATION OF LONGITUDINAL TENSION — TEST SPECIMENS IN RING CUT FROM TUBULAR PRODUCTS



GENERAL NOTE: The edges of the blank for the specimen shall be cut parallel to each other.

FIG. A2.3 DIMENSIONS AND TOLERANCES FOR LONGITUDINAL STRIP TENSION TEST SPECIMENS FOR TUBULAR PRODUCTS



DIMENSIONS

Specimen No.	Dimensions, in.			
	A	B	C	D
1	$\frac{1}{2} \pm 0.015$	$1\frac{1}{16}$ approximately	2 ± 0.005	$2\frac{1}{4}$ min
2	$\frac{3}{4} \pm 0.031$	1 approximately	2 ± 0.005	$2\frac{1}{4}$ min
			4 ± 0.005	$4\frac{1}{2}$ min
3	1 ± 0.062	$1\frac{1}{2}$ approximately	2 ± 0.005	$2\frac{1}{4}$ min
			4 ± 0.005	$4\frac{1}{2}$ min
4	$1\frac{1}{2} \pm \frac{1}{8}$	2 approximately	2 ± 0.010	$2\frac{1}{4}$ min
			4 ± 0.015	$4\frac{1}{2}$ min
			8 ± 0.020	9 min

GENERAL NOTES:

- (a) Cross-sectional area may be calculated by multiplying *A* and *t*.
- (b) The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.
- (c) The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.
- (d) The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.
- (e) Metric equivalent: 1 in. = 25.4 mm.
- (f) Specimens with sides parallel throughout their length are permitted, except for referee testing, provided: (a) the above tolerances are used; (b) an adequate number of marks are provided for determination of elongation; and (c) when yield strength is determined, a suitable extensometer is used. If the fracture occurs at a distance of less than 2*A* from the edge of the gripping device, the tensile properties determined may not be representative of the material. If the properties meet the minimum requirements specified, no further testing is required, but if they are less than the minimum requirements, discard the test and retest.

FIG. A2.4 LOCATION OF TRANSVERSE TENSION TEST SPECIMENS IN RING CUT FROM TUBULAR PRODUCTS

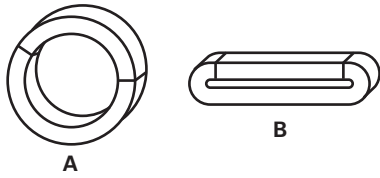


FIG. A2.7 ROLLER CHAIN TYPE EXTENSOMETER, UNCLAMPED

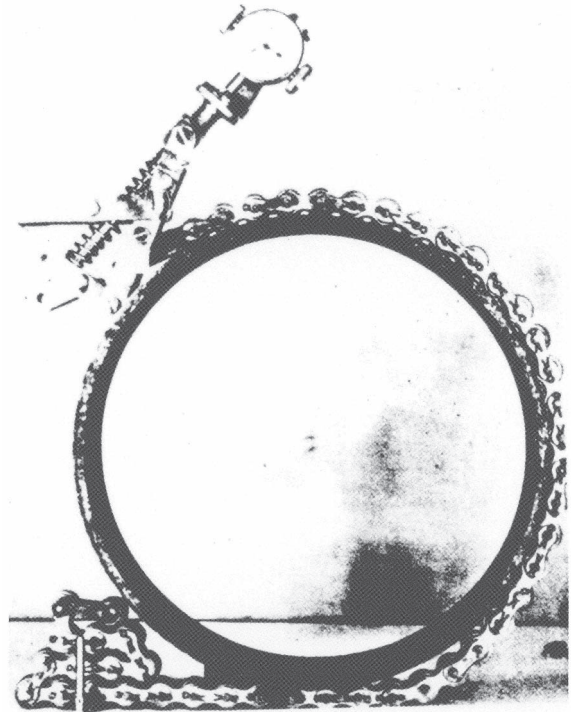
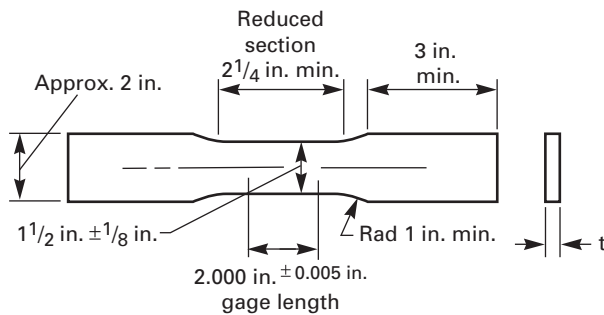


FIG. A2.5 TRANSVERSE TENSION TEST SPECIMEN MACHINED FROM RING CUT FROM TUBULAR PRODUCTS



GENERAL NOTES:

- (a) The dimension t is the thickness of the test specimen as provided for in the applicable material specifications.
- (b) The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.
- (c) The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.
- (d) Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.8 ROLLER CHAIN TYPE EXTENSOMETER, CLAMPED

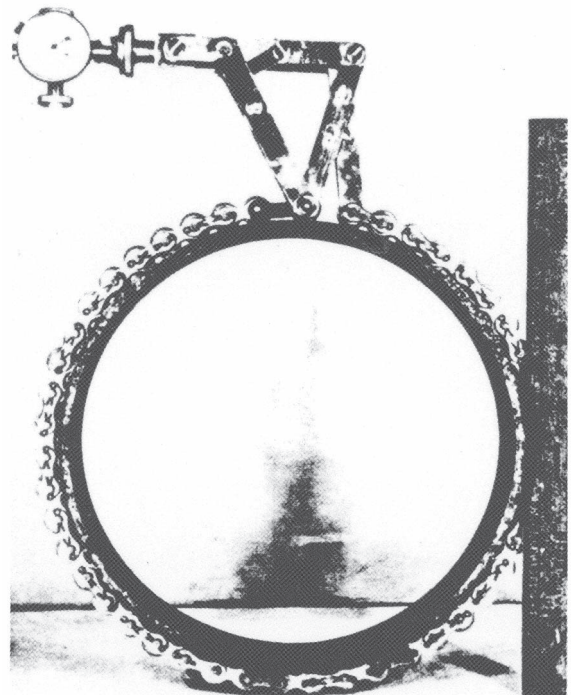


FIG. A2.6 TESTING MACHINE FOR DETERMINATION OF TRANSVERSE YIELD STRENGTH FROM ANNULAR RING SPECIMENS

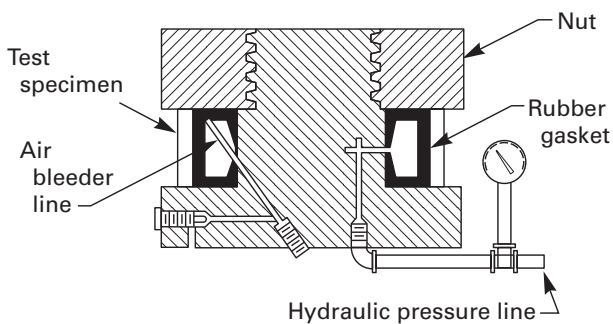


FIG. A2.9 REVERSE FLATTENING TEST

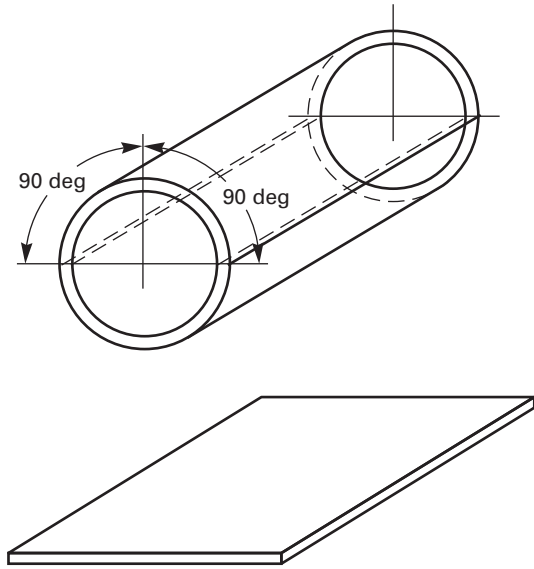


FIG. A2.10 CRUSH TEST SPECIMEN

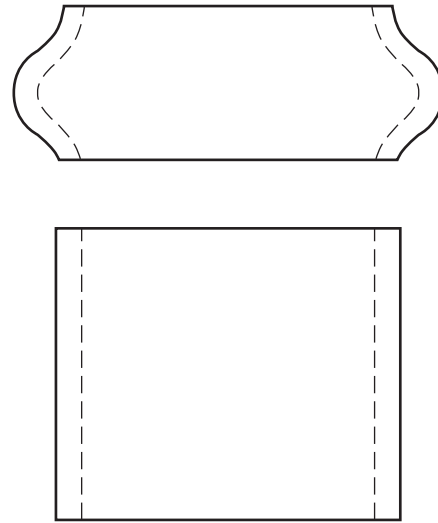
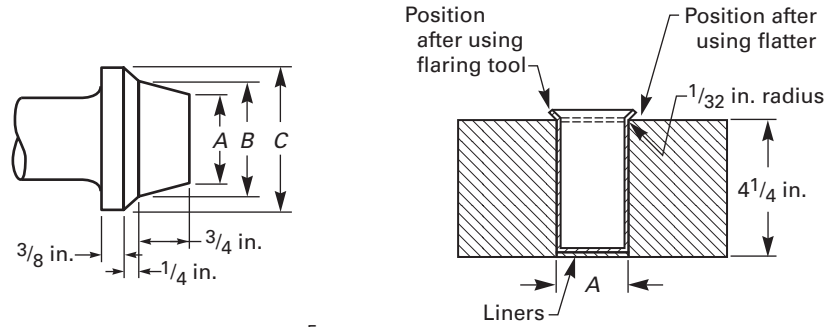


FIG. A2.11 FLARING TOOL AND DIE BLOCK FOR FLANGE TEST



A = Outside diameter of tube less $\frac{5}{8}$ in.
 B = Outside diameter of tube less $\frac{3}{8}$ in.
 C = Outside diameter of tube plus $\frac{3}{16}$ in.

A = Outside diameter of tube plus $\frac{1}{32}$ in.

Flaring Tool

Die Block

GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.12 TAPERED MANDRELS FOR FLARING TEST

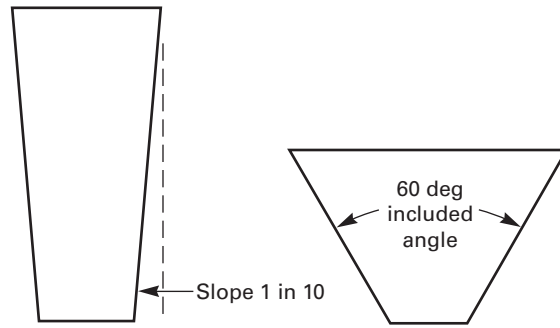
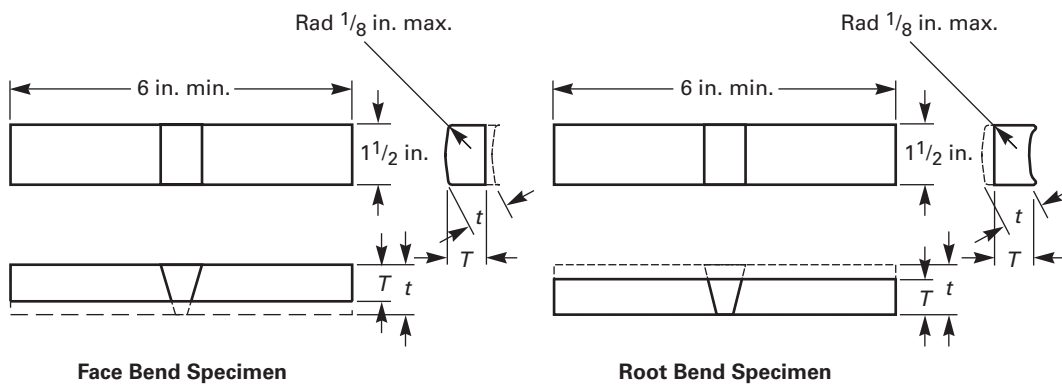


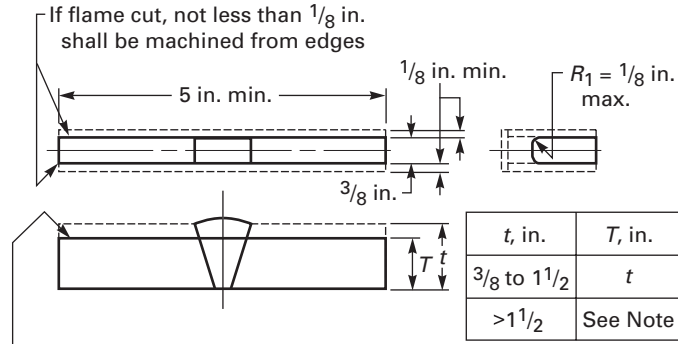
FIG. A2.13 TRANSVERSE FACE- AND ROOT-BEND TEST SPECIMENS



GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

Pipe Wall Thickness (t), in.	Test Specimen Thickness, in.
Up to $\frac{3}{8}$, incl	t
Over $\frac{3}{8}$	$\frac{3}{8}$

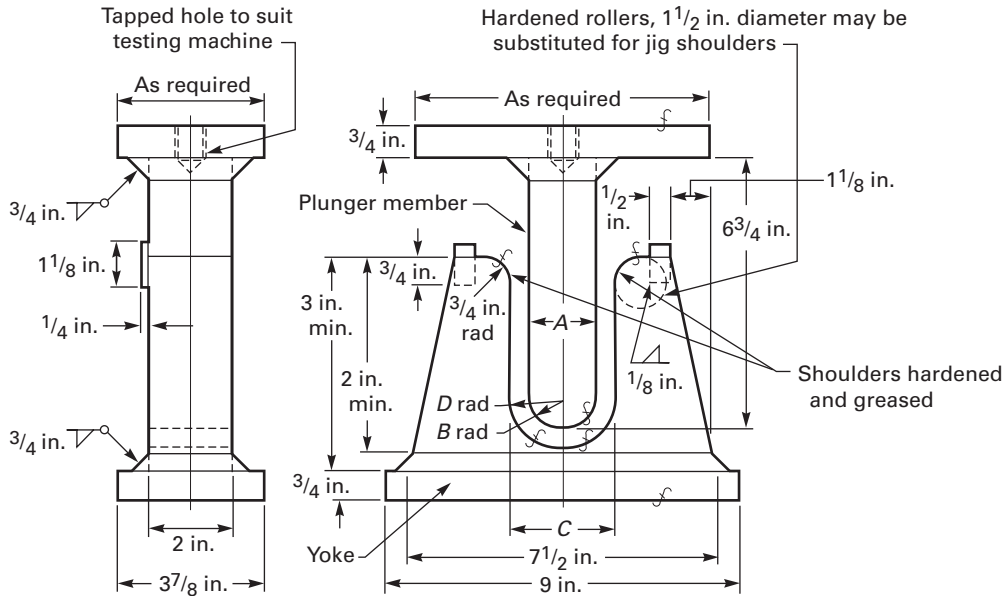
FIG. A2.14 SIDE-BEND SPECIMEN FOR FERROUS MATERIALS



- When t exceeds $1 1/2$ use one of the following:
1. Cut along line indicated by arrow. Edge may be flame cut and may or may not be machined.
 2. Specimens may be cut into approximately equal strips between $3/4$ in. and $1 1/2$ in. wide for testing or the specimens may be bent at full width (see requirements on jig width in Fig. 32.)

GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.15 GUIDED-BEND TEST JIG



GENERAL NOTE: Metric equivalent 1 in. = 25.4 mm.

Test Specimen Thickness, in.	A	B	C	D	
$3/8$	$1 1/2$	$3/4$	$2 3/8$	$1 3/16$	
t	$4t$	$2t$	$6t + 1/8$	$3t + 1/16$	
	Material				
$3/8$	$2 1/2$	$1 1/4$	$3 3/8$	$1 11/16$	Materials with a specified minimum tensile strength of 95 ksi or greater.
t	$6 2/3 t$	$3 1/3 t$	$8 2/3 t + 1/8$	$4 1/2 t + 1/16$	

FIG. A3.1 TENSION TESTING FULL-SIZE BOLT

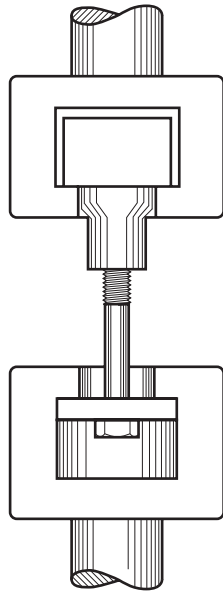


FIG. A3.2 WEDGE TEST DETAIL

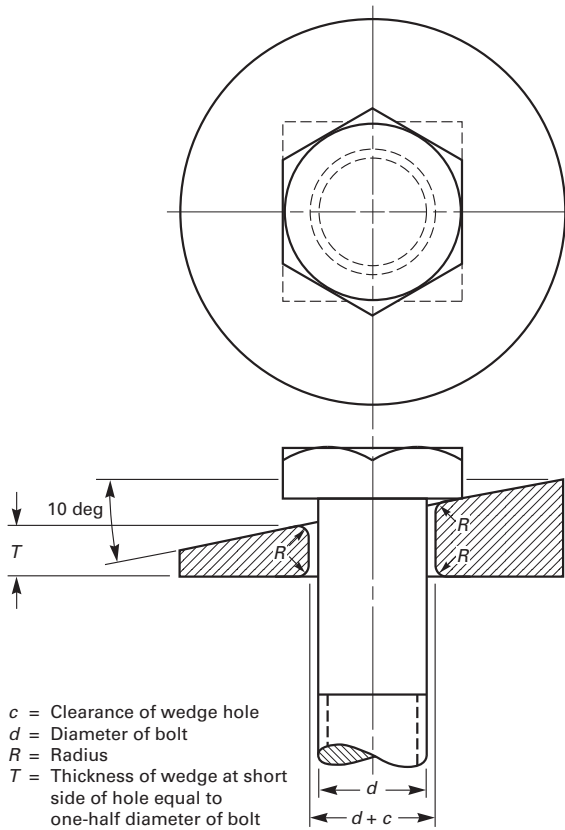
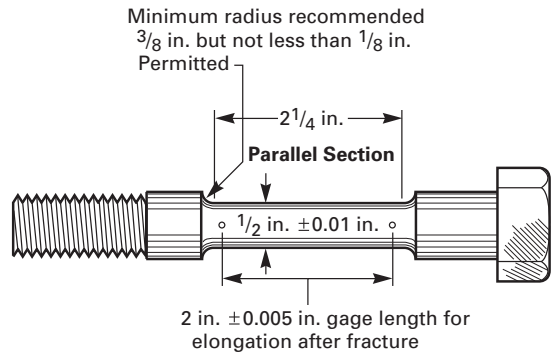
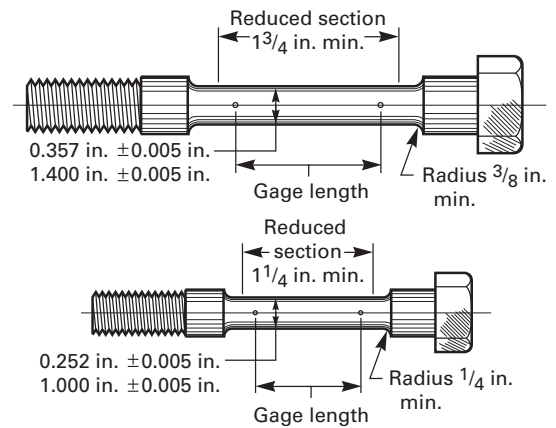


FIG. A3.3 TENSION TEST SPECIMEN FOR BOLT WITH TURNED-DOWN SHANK



GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A3.4 EXAMPLES OF SMALL SIZE SPECIMENS PROPORTIONAL TO STANDARD 2 in. GAGE LENGTH SPECIMEN



GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A3.5 LOCATION OF STANDARD ROUND 2 in. GAGE LENGTH TENSION TEST SPECIMEN WHEN TURNED FROM LARGE SIZE BOLT

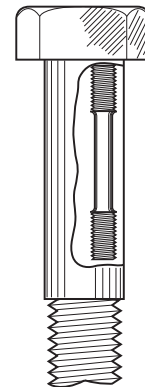
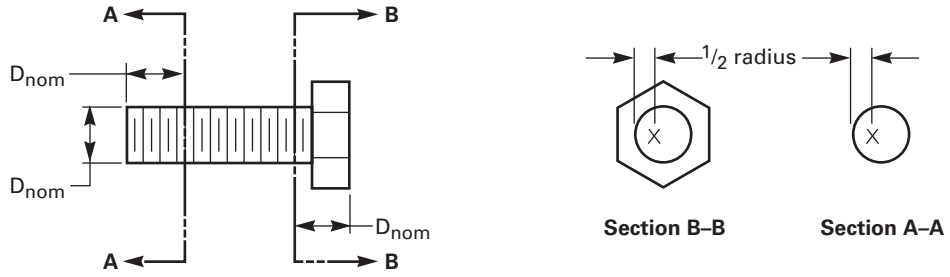


FIG. A3.6 HARDNESS TEST LOCATIONS FOR BOLTS IN A DISPUTE



GENERAL NOTE: X=Location of hardness impressions.

FIG. A4.1 WEDGE-TYPE GRIPPING DEVICE

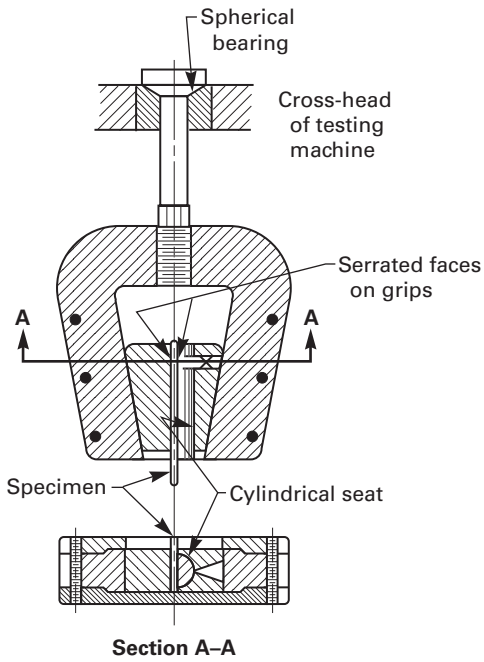
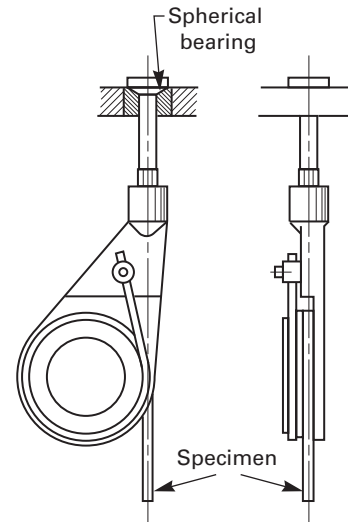


FIG. A4.2 SNUBBING-TYPE GRIPPING DEVICE



**TABLE A1.1
PRACTICES FOR SELECTING TENSION TEST SPECIMENS FOR STEEL BAR PRODUCTS**

Thickness, in. (mm)	Width, in. (mm)	Hot-Rolled Bars		Cold-Finished Bars
		Flats		
Under $\frac{5}{8}$ (16)	Up to $1\frac{1}{2}$ (38), incl	Full section by 8 in. (203 mm) gage length (Fig. 4).		Mill reduced section to 2 in. (51 mm) gage length and approximately 25% less than test specimen width. Mill reduced section to 2 in. gage length and $1\frac{1}{2}$ in. wide.
	Over $1\frac{1}{2}$ (38)	Full section, or mill to $1\frac{1}{2}$ in. (38 mm) wide by 8 in. (203 mm) gage length (Fig. 4).		
$\frac{5}{8}$ to $1\frac{1}{2}$ (16 to 38), excl	Up to $1\frac{1}{2}$ (38), incl	Full section by 8 in. gage length or machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from center of section (Fig. 5).		Mill reduced section to 2 in. (51 mm) gage length and approximately 25% less than test specimen width or machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from center of section (Fig. 5). Mill reduced section to 2 in. gage length and $1\frac{1}{2}$ in. wide or machine standard $\frac{1}{2}$ by 2 in. gage length specimen from midway between edge and center of section (Fig. 5).
	Over $1\frac{1}{2}$ (38)	Full section, or mill $1\frac{1}{2}$ in. (38 mm) width by 8 in. (203 mm) gage length (Fig. 4) or machine standard $\frac{1}{2}$ by 2 in. gage (13 by 51 mm) gage length specimen from midway between edge and center of section (Fig. 5).		
$1\frac{1}{2}$ (38) and over		Full section by 8 in. (203 mm) gage length, or machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center (Fig. 5).		Machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center (Fig. 5).
Rounds, Squares, Hexagons, and Octagons				
Diameter or Distance Between Parallel Faces, in. (mm)	Hot-Rolled Bars		Cold-Finished Bars	
Under $\frac{5}{8}$	Full section by 8 in. (203 mm) gage length on machine to subsize specimen (Fig. 5).		Machine to sub-size specimen (Fig. 5).	
$\frac{5}{8}$ to $1\frac{1}{2}$ (16 to 38), excl	Full section by 8 in. (203 mm) gage length or machine standard $\frac{1}{2}$ in. by 2 in. (13 by 51 mm) gage length specimen from center of section (Fig. 5).		Machine standard $\frac{1}{2}$ in. by 2 in. gage length specimen from center of section (Fig. 5).	
$1\frac{1}{2}$ (38) and over	Full section by 8 in. (203 mm) gage length or machine standard $\frac{1}{2}$ in. by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center of section (Fig. 5).		Machine standard $\frac{1}{2}$ in. by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center of section (Fig. 5)).	
Other Bar-Size Sections				
All sizes	Full section by 8 in. (203 mm) gage length or prepare test specimen $1\frac{1}{2}$ in. (38 mm) wide (if possible) by 8 in. (203 mm) gage length.		Mill reduced section to 2 in. (51 mm) gage length and approximately 25% less than test specimen width.	

GENERAL NOTE: For bar sections where it is difficult to determine the cross-sectional area by simple measurement, the area in square inches may be calculated by dividing the weight per linear inch of specimen in pounds by 0.2833 (weight of 1 in.³ of steel) or by dividing the weight per linear foot of specimen by 3.4 (weight of steel 1 in. square and 1 ft long).

TABLE A1.2
RECOMMENDED PRACTICE FOR SELECTING BEND TEST SPECIMENS FOR STEEL
BAR PRODUCTS

Flats		
Thickness, in. (mm)	Width, in. (mm)	Recommended Size
Up to 1/2 (13), incl	Up to 3/4 (19), incl Over 3/4 (19)	Full section. Full section or machine to not less than 3/4 in. (19 mm) in width by thickness of specimen.
Over 1/2 (13)	All	Full section or machine to 1 by 1/2 in. (25 by 13 mm) specimen from midway between center and surface.
Rounds, Squares, Hexagons, and Octagons		
Diameter or Distance Between Parallel Faces, in. (mm)	Recommended Size	
Up to 1 1/2 (38), incl Over 1 1/2 (38)	Full section. Machine to 1 by 1/2-in. (25 by 13-mm) specimen from midway between center and surface.	

GENERAL NOTES:

- (1) The length of all specimens is to be not less than 6 in. (150 mm).
(2) The edges of the specimen may be rounded to a radius not exceeding 1/16 in. (1.6 mm).

TABLE A2.1
WALL THICKNESS LIMITATIONS OF SUPERFICIAL
HARDNESS TEST ON ANNEALED OR DUCTILE
MATERIALS FOR STEEL TUBULAR PRODUCTS (A)
(“T” Scale (1/16 in. Ball))

Wall Thickness, in. (mm)	Load, kgf
Over 0.050 (1.27)	45
Over 0.035 (0.89)	30
0.020 and over (0.51)	15

NOTE:

(A) The heaviest load recommended for a given wall thickness is generally used.

TABLE A2.2
WALL THICKNESS LIMITATIONS OF SUPERFICIAL
HARDNESS TEST ON COLD WORKED OR HEAT
TREATED MATERIAL FOR STEEL TUBULAR
PRODUCTS (A)
(“N” Scale (Diamond Penetrator))

Wall Thickness, in. (mm)	Load, kgf
Over 0.035 (0.89)	45
Over 0.025 (0.51)	30
0.015 and over (0.38)	15

NOTE:

(A) The heaviest load recommended for a given wall thickness is generally used.

TABLE A5.1
EFFECT OF VARYING NOTCH DIMENSIONS ON STANDARD SPECIMENS

	High-Energy Specimens, ft • lbf (J)	High-Energy Specimens, ft • lbf (J)	Low-Energy Specimens, ft • lbf (J)
Specimen with standard dimensions	76.0 ± 3.8 (103.0 ± 5.2)	44.5 ± 2.2 (60.3 ± 3.0)	12.5 ± 1.0 (16.9 ± 1.4)
Depth of notch, 0.084 in. (2.13 mm) (A)	72.2 (97.9)	41.3 (56.0)	11.4 (15.5)
Depth of notch, 0.0805 in. (2.04 mm) (A)	75.1 (101.8)	42.2 (57.2)	12.4 (16.8)
Depth of notch, 0.0775 in. (1.77 mm) (A)	76.8 (104.1)	45.3 (61.4)	12.7 (17.2)
Depth of notch, 0.074 in. (1.57 mm) (A)	79.6 (107.9)	46.0 (62.4)	12.8 (17.3)
Radius at base of notch, 0.005 in. (0.127 mm) (B)	72.3 (98.0)	41.7 (56.5)	10.8 (14.6)
Radius at base of notch, 0.015 in. (0.381 mm) (B)	80.0 (108.5)	47.4 (64.3)	15.8 (21.4)

NOTES:

- (A) Standard 0.079 ± 0.002 in. (2.00 ± 0.05 mm).
(B) Standard 0.010 ± 0.001 in. (0.25 ± 0.025 mm).

TABLE A6.1
CARBON AND ALLOY STEELS — MATERIAL
CONSTANT $a = 0.4$. MULTIPLICATION FACTORS FOR
CONVERTING PERCENT ELONGATION FROM $\frac{1}{2}$ IN.
DIAMETER BY 2 IN. GAGE LENGTH STANDARD
TENSION TEST SPECIMEN TO STANDARD $\frac{1}{2}$ BY 2 IN.
AND $1\frac{1}{2}$ BY 8 IN. FLAT SPECIMENS

Thickness, in.	$\frac{1}{2}$ by 2 in. Specimen	$1\frac{1}{2}$ by 8 in. Specimen	Thickness in.	$1\frac{1}{2}$ by 8 in. Specimen
0.025	0.574	...	0.800	0.822
0.030	0.596	...	0.850	0.832
0.035	0.614	...	0.900	0.841
0.040	0.631	...	0.950	0.850
0.045	0.646	...	1.000	0.859
0.050	0.660	...	1.125	0.880
0.055	0.672	...	1.250	0.898
0.060	0.684	...	1.375	0.916
0.065	0.695	...	1.500	0.932
0.070	0.706	...	1.625	0.947
0.075	0.715	...	1.750	0.961
0.080	0.725	...	1.875	0.974
0.085	0.733	...	2.000	0.987
0.090	0.742	0.531	2.125	0.999
0.100	0.758	0.542	2.250	1.010
0.110	0.772	0.553	2.375	1.021
0.120	0.786	0.562	2.500	1.032
0.130	0.799	0.571	2.625	1.042
0.140	0.810	0.580	2.750	1.052
0.150	0.821	0.588	2.875	1.061
0.160	0.832	0.596	3.000	1.070
0.170	0.843	0.603	3.125	1.079
0.180	0.852	0.610	3.250	1.088
0.190	0.862	0.616	3.375	1.096
0.200	0.870	0.623	3.500	1.104
0.225	0.891	0.638	3.625	1.112
0.250	0.910	0.651	3.750	1.119
0.275	0.928	0.664	3.875	1.127
0.300	0.944	0.675	4.000	1.134
0.325	0.959	0.686	...	...
0.350	0.973	0.696	...	...
0.375	0.987	0.706	...	...
0.400	1.000	0.715	...	...
0.425	1.012	0.724	...	...
0.450	1.024	0.732	...	...
0.475	1.035	0.740	...	...
0.500	1.045	0.748	...	...
0.525	1.056	0.755	...	...
0.550	1.066	0.762	...	...
0.575	1.075	0.770	...	...
0.600	1.084	0.776	...	...
0.625	1.093	0.782	...	...
0.650	1.101	0.788	...	...
0.675	1.110	...	...	...
0.700	1.118	0.800	...	...
0.725	1.126	...	...	...
0.750	1.134	0.811	...	...

TABLE A6.2
ANNEALED AUSTENITIC STAINLESS STEELS —
MATERIAL CONSTANT $a = 0.127$. MULTIPLICATION
FACTORS FOR CONVERTING PERCENT ELONGATION
FROM $\frac{1}{2}$ IN. DIAMETER BY 2 IN. GAGE LENGTH
STANDARD TENSION TEST SPECIMEN TO STANDARD
 $\frac{1}{2}$ BY 2 IN. AND $1\frac{1}{2}$ BY 8 IN. FLAT SPECIMENS

Thickness, in.	$\frac{1}{2}$ by 2 in. Specimen	$1\frac{1}{2}$ by 8 in. Specimen	Thickness, in.	$1\frac{1}{2}$ by 8 in. Specimen
0.025	0.839	...	0.800	0.940
0.030	0.848	...	0.850	0.943
0.035	0.857	...	0.900	0.947
0.040	0.864	...	0.950	0.950
0.045	0.870	...	1.000	0.953
0.050	0.876	...	1.125	0.960
0.055	0.882	...	1.250	0.966
0.060	0.886	...	1.375	0.972
0.065	0.891	...	1.500	0.978
0.070	0.895	...	1.625	0.983
0.075	0.899	...	1.750	0.987
0.080	0.903	...	1.875	0.992
0.085	0.906	...	2.000	0.996
0.090	0.909	0.818	2.125	1.000
0.095	0.913	0.821	2.250	1.003
0.100	0.916	0.823	2.375	1.007
0.110	0.921	0.828	2.500	1.010
0.120	0.926	0.833	2.625	1.013
0.130	0.931	0.837	2.750	1.016
0.140	0.935	0.841	2.875	1.019
0.150	0.940	0.845	3.000	1.022
0.160	0.943	0.848	3.125	1.024
0.170	0.947	0.852	3.250	1.027
0.180	0.950	0.855	3.375	1.029
0.190	0.954	0.858	3.500	1.032
0.200	0.957	0.860	3.625	1.034
0.225	0.964	0.867	3.750	1.036
0.250	0.970	0.873	3.875	1.038
0.275	0.976	0.878	4.000	1.041
0.300	0.982	0.883	...	...
0.325	0.987	0.887	...	...
0.350	0.991	0.892	...	...
0.375	0.996	0.895	...	...
0.400	1.000	0.899	...	...
0.425	1.004	0.903	...	...
0.450	1.007	0.906	...	...
0.475	1.011	0.909	...	...
0.500	1.014	0.912	...	...
0.525	1.017	0.915	...	...
0.550	1.020	0.917	...	...
0.575	1.023	0.920	...	...
0.600	1.026	0.922	...	...
0.625	1.029	0.925	...	...
0.650	1.031	0.927	...	...
0.675	1.034	...	...	...
0.700	1.036	0.932	...	...
0.725	1.038	...	...	...
0.750	1.041	0.936	...	...

TABLE A8.1
RECOMMENDED VALUES FOR ROUNDING TEST DATA

Test Quantity	Test Data Range	Rounded Value (A)
Yield Point,	up to 50 000 psi, excl (up to 50 ksi)	100 psi (0.1 ksi)
Yield Strength,	50 000 to 100 000 psi, excl (50 to 100 ksi)	500 psi (0.5 ksi)
Tensile Strength	100 000 psi and above (100 ksi and above)	1000 psi (1.0 ksi)
	up to 500 MPa, excl	1 MPa
	500 to 1000 MPa, excl	5 MPa
	1000 MPa and above	10 MPa
Elongation	0 to 10%, excl	0.5%
	10% and above	1%
Reduction of Area	0 to 10%, excl	0.5%
	10% and above	1%
Impact Energy	0 to 240 ft • lbf (or 0 to 325 J)	1 ft • lbf (or 1 J) (B)
Brinell Hardness	all values	tabular value (C)
Rockwell Hardness	all scales	1 Rockwell Number

NOTES:

- (A) Round test data to the nearest integral multiple of the values in this column. If the data value is exactly midway between two rounded values, round in accordance with A8.1.1.2.
- (B) These units are not equivalent but the rounding occurs in the same numerical ranges for each. (1 ft • lbf = 1.356 J.)
- (C) Round the mean diameter of the Brinell impression to the nearest 0.05 mm and report the corresponding Brinell hardness number read from the table without further rounding.

TABLE A10.1
HEAT-TREAT RECORD-ESSENTIAL VARIABLES

	Master Forging	Production Forging 1	Production Forging 2	Production Forging 3	Production Forging 4	Production Forging 5
Program chart number						
Time at temperature and actual temperature of heat treatment						
Method of cooling						
Forging thickness						
Thermocouple immersion						
Beneath buffer (yes/no)						
Forging number						
Product						
Material						
Thermocouple location — 0 deg						
Thermocouple location — 180 deg						
Quench tank No.						
Date of heat treatment						
Furnace number						
Cycle number						
Heat treater						
Starting quench medium temperature						
Time from furnace to quench						
Heating rate above 1000°F (538°C)						
Temperature upon removal from quench after 5 min						
Orientation of forging in quench						

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SPECIFICATION FOR CARBON AND ALLOY STEEL FORGINGS FOR THIN-WALLED PRESSURE VESSELS



SA-372/SA-372M



(21)

(Identical with ASTM Specification A372/A372M-03(2008).)

SPECIFICATION FOR CARBON AND ALLOY STEEL FORGINGS FOR THIN-WALLED PRESSURE VESSELS



SA-372/SA-372M



[Identical with ASTM Specification A 372/A 372M-03(2008).]

1. Scope

1.1 This specification covers relatively thin-walled forgings (including gas bottles) for pressure vessel use. Three types of carbon steel and six types of alloy steel are included. Provision is made for integrally forging the ends of vessel bodies made from seamless pipe or tubing.

NOTE 1 — When working to the chemical and tensile requirements of this specification, the influence of wall thickness and cooling rate will necessarily eliminate certain forging sizes in each class.

NOTE 2 — Designations have been changed as follows:

Current	Formerly
Grade A	Type I
Grade B	Type II
Grade C	Type III
Grade D	Type IV
Grade E Class 55	Type V Grade 1 Class 55
Grade E Class 65	Type V Grade 1 Class 65
Grade E Class 70	Type V Grade 1 Class 70
Grade F Class 55	Type V Grade 2 Class 55
Grade F Class 65	Type V Grade 2 Class 65
Grade F Class 70	Type V Grade 2 Class 70
Grade G Class 55	Type V Grade 3 Class 55
Grade G Class 65	Type V Grade 3 Class 65
Grade G Class 70	Type V Grade 3 Class 70
Grade H Class 55	Type V Grade 4 Class 55
Grade H Class 65	Type V Grade 4 Class 65
Grade H Class 70	Type V Grade 4 Class 70
Grade J Class 55	Type V Grade 5 Class 55
Grade J Class 65	Type V Grade 5 Class 65
Grade J Class 70	Type V Grade 5 Class 70
Grade K	Type VI
Grade L	Type VII
Grade J Class 110	Type VIII
Grade M Class 85	Type IX Class A
Grade M Class 100	Type IX Class B

1.2 The values stated in either inch-pound or SI [metric] units are to be regarded separately as the standard. Within the text and the tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents;

therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 Unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 ASTM Standards:

- A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings
- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- A 788 Specification for Steel Forgings, General Requirements
- E 112 Test Methods for Determining the Average Grain Size
- E 165 Practice for Liquid Penetrant Examination
- E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials
- E 433 Reference Photographs for Liquid Penetrant Inspection

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging and the areas of significant loading in the forging when required (see 6.4.2.2).

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 Melting Practice:

4.1.1 The steel melting procedures of Specification A 788 shall apply except that for Grade M forgings, only steel that has been vacuum treated prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen, shall be used.

4.2 Production Methods:

4.2.1 Methods for the production of gas bottles and similar vessels shall include the cupping of slabs or plates, the piercing of billets or plates, and the subsequent drawing of cups so produced. Such semifinished forgings or seamless steel pipe or tubing shall be closed by spinning, swedging, or pressing. In all cases there shall be sufficient discard to ensure soundness in the completed forging.

4.3 Heat Treatment:

4.3.1 At the option of the manufacturer, Grades A, B, C, D and Classes 55, 65, 70 of Grades E, F, G, H, and J forgings shall be normalized, normalized and tempered, or liquid-quenched and tempered.

4.3.2 Grades K, L, M, and Class 110 of Grade J forgings shall be liquid-quenched and tempered.

4.3.3 When normalized forgings are to be tempered, or when forgings have been quenched, they shall be reheated to a subcritical temperature and held for at least $\frac{1}{2}$ h/in. [25 mm] of maximum cross section.

4.3.3.1 Minimum tempering temperatures shall be as follows:

Grades E, F, G, H, J in Classes 55, 65, 70	1100°F [595°C]
Grade K	1100°F [595°C]
Grade L	1000°F [540°C]
Grade J Class 110	1000°F [540°C]
Grade M	1100°F [595°C]

4.3.3.2 If an attachment is welded onto a previously quenched and tempered pressure vessel, the post weld heat treatment temperature of a weldment shall not exceed the prior tempering temperature of the pressure vessel. Fabrication welding of pressure shell is not permitted.

Attachment welding prior to heat treatment is not permitted.

4.3.4 All quenched and tempered forgings shall be subject to magnetic particle examination in accordance with Section 7.

4.3.5 Heat treatment is to be performed after all forming operations.

5. Chemical Composition

5.1 Heat Analysis — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1.

5.2 Product Analysis — The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

5.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 1 for the applicable grade of material is not permitted. This does not preclude use of deoxidation or inclusion control additions. Supplementary Requirements S1 and S2 of Specification A 788 shall apply.

6. Mechanical Properties

6.1 Mechanical tests for acceptance shall be made after the final heat treatment of the forgings.

6.2 Tension Test — When tested in accordance with Test Methods and Definitions A 370, the material shall conform to the requirements of Table 2. The yield strength shall be determined by the 0.2% offset method.

6.3 Bending Properties — Depending upon the outside diameter, D , and the wall thickness, T , of hollow or bored forgings, a bend test or flattening test will be required.

6.3.1 For bored or hollow forgings with outside diameters of 14 in. [355 mm] or less and with a D/T ratio of more than 10.0, a flattening test is required. This shall be carried out in accordance with Specification A 530/A 530M and Table 3. No breaks or cracks in the test ring are acceptable until the distance between the plates is less than that shown in Table 3.

6.3.2 For bored or hollow forgings with outside diameters over 14 in. [355 mm], or where the D/T ratio is 10.0 or less at the manufacturer's option, the flattening test specified in 6.3.1, or a transverse bend test in accordance with Arrangement C of Test Method E 290 is required. The bend test pin diameter shall be as specified in Table 4. No cracks or ruptures in the test piece are allowable when the test piece is bent through the required angle.

6.4 Orientation and Location of Test Specimens:

6.4.1 Test specimens representing vessel bodies or shells shall be taken from a prolongation of a forging, from test rings that have been heat treated with the forgings they represent, or from a representative forging after heat treatment in accordance with 4.3.

6.4.1.1 Test specimens representing vessel bodies or shells shall be located at a position corresponding to the mid-wall location of the parallel side wall of the heat-treated forging and shall be oriented parallel to the longitudinal axis of the vessel.

6.4.1.2 A test ring shall be in the shape of a right circular cylinder having the same diameter and wall thickness as the cylinders it represents. In addition, the test ring shall be from the same heat of steel and be subjected to the same heat treatment as the cylinders it represents. The method of quenching the test ring must duplicate that of the cylinders; if the cylinders are quenched from the outside only, then the test ring must have its ends closed. The length of test rings that will be liquid quenched must be at least 24 in. [610 mm]. The ends of such test rings may be vented to prevent pressure buildup during heat treating.

6.4.2 Test specimens representing vessel covers or similar components may be taken from a full section prolongation of the cover, from a representative forging, or from an integral prolongation when the part is contour-machined prior to heat treatment.

6.4.2.1 Test specimens taken from full size prolongations or representative forgings shall be located at a position midway between the center and the surface.

6.4.2.2 When forgings are contour-machined prior to heat treatment so that highly stressed surfaces are exposed, the test specimens may be taken at an equal distance (t) from the nearest quenched surface as the highly stressed area, but not less than $\frac{3}{4}$ in. [20 mm]. The location of the specimens from a second surface shall be at least the greater of $1\frac{1}{2}$ in. [40 mm] or $2t$.

6.5 Number of Tests:

6.5.1 Up to 200 like forgings, each with a heat-treated weight of less than 1000 lb [510 kg] when heat treated in a single batch furnace charge, shall have one tension test taken in accordance with 6.4.1 or 6.4.2 to represent each heat. In addition, for hollow or bored forgings, one bend or flattening test shall be taken in accordance with 6.3.

6.5.2 Like forgings, weighing less than 1000 lb [450 kg] each when heat treated in a continuous furnace, shall have one tensile test taken to represent each heat and not more than 200 forgings in any continuous period up to 4 h duration. In addition, bored or hollow forgings shall have one bend or flattening test taken per heat per 200

forgings in any continuous period up to 4 h duration in accordance with 6.3.

6.5.3 For heat-treated forgings weighing 1000 lb [450 kg] or more, one tension test shall be taken in accordance with 6.4.1 or 6.4.2 to represent each heat and not more than ten forgings in a heat-treat lot. In addition, hollow or bored forgings shall have one bend or flattening test, taken in accordance with 6.3, to represent each ten or fewer forgings from the same heat and heat-treatment lot.

6.6 Hardness Testing:

6.6.1 Forgings under 1000 lb [450 kgm] in weight, heat treated in a batch lot of up to 200 pieces (6.5.1) or in a continuous furnace run covering up to 200 pieces in up to four hours production (6.5.2) shall be subject to a uniformity check by Brinell hardness testing, or an equivalent method. For this purpose, 10% of the furnace production shall be sampled and shall meet the minimum hardness specified in Table 2 for the type and shall also be within 20 Brinell points of the hardness of the forging from which the tensile test was taken.

6.6.2 In the event that the test sample does not meet these criteria, the remainder of that production group shall be hardness tested and all of those forgings that fall outside these limits shall be retempered or reheat-treated at the manufacturer's option and retested.

7. Magnetic Particle Examination

7.1 All quenched and tempered forgings shall be subject to magnetic particle examination after heat treatment. The methods used shall be in accordance with Test Method A 275/A 275M.

7.2 Only direct current or rectified alternating (full or half wave) current shall be used as the electric power source for any of the magnetizing methods.

7.3 The forgings shall be free from linear indications indicative of cracks. In case of doubt as to the type of condition giving rise to linear magnetic particle indications, they may be inspected for Type II indications referenced in Reference Photographs E 433 when inspected by the liquid penetrant method in accordance with Practice E 165. Alternatively, some other suitable method for classifying the indications may be used as agreed upon between the manufacturer and the purchaser.

8. Workmanship

8.1 If the thickness of a portion of the wall of a forging is less than that specified, the forgings may be accepted by the purchaser, provided that such irregularity will not require lowering the allowable working pressure below that for which the forging was designed.

9. Repair Welding

9.1 Repair welding shall be permitted when mutually agreed upon between the purchaser and the manufacturer and shall be performed in accordance with all the requirements of the applicable code or rules of construction.

10. Keywords

10.1 alloy steel forgings; carbon steel forgings; gas bottles; pressure vessels; thin wall

**TABLE 1
CHEMICAL REQUIREMENTS**

Elements	Composition, %				
	Grade A	Grade B	Grade C	Grade D	
Carbon	0.30 max	0.35 max	0.48 max	0.40–0.50	
Manganese	1.00 max	1.35 max	1.65 max	1.40–1.80	
Phosphorus, max	0.025	0.025	0.025	0.025	
Sulfur, max	0.025	0.025	0.025	0.025	
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	
Nickel	...	...	...	...
Chromium	...	...	...	...
Molybdenum	...	...	...	0.17–0.27
	Grade E Classes 55, 65, 70	Grade F Classes 55, 65, 70	Grade G Classes 55, 65, 70	Grade H Classes 55, 65, 70	Grade J Classes 55, 65, 70, 110
Carbon	0.25–0.35	0.30–0.40	0.25–0.35	0.30–0.40	0.35–0.50
Manganese	0.40–0.90	0.70–1.00	0.70–1.00	0.75–1.05	0.75–1.05
Phosphorus, max	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Nickel
Chromium	0.80–1.15	0.80–1.15	0.40–0.65	0.40–0.65	0.80–1.15
Molybdenum	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25
	Grade K	Grade L	Grade M Classes 85 and 100		
Carbon	0.18 max	0.38–0.43	0.23 max		
Manganese	0.10–0.40	0.60–0.80	0.20–0.40		
Phosphorus, max	0.025	0.025	0.020		
Sulfur, max	0.025	0.025	0.020		
Silicon	0.15–0.35	0.15–0.35	0.30 max		
Nickel	2.0–3.3	1.65–2.00	2.8–3.9		
Chromium	1.00–1.80	0.70–0.90	1.50–2.00		
Molybdenum	0.20–0.60	0.20–0.30	0.40–0.60		
Vanadium	...	...	0.08 max	

TABLE 2
MECHANICAL REQUIREMENTS

Type	Tensile Strength, ksi [MPa]	Yield Strength (0.2% Offset), ksi [MPa], min	Elongation in 2 in. [50 mm], min, %	Hardness, HB, min ^A
Grade A	60–85 [415–585]	35 [240]	20	121
Grade B	75–100 [515–690]	45 [310]	18	156
Grade C	90–115 [620–795]	55 [380]	15	187
Grade D	105–130 [725–895]	65 [450]	15	217
Grades E, F, G, H, J (Class 55)	85–110 [545–760]	55 [380]	20	179
Grades E, F, G, H, J (Class 65)	105–130 [725–895]	65 [450]	19	217
Grades E, F, G, H, J (Class 70)	120–145 [825–1000]	70 [485]	18	248
Grade J (Class 110)	135–160 [930–1100]	110 [760]	15	277
Grade K	100–125 [690–860]	80 [550]	20	207
Grade L	155–180 [1070–1240]	135 [930]	12	311
Grade M (Class 85)	105–130 [725–895]	85 [585]	18	217
Grade M (Class 100)	120–145 [825–1000]	100 [690]	16	248

^A When required by 6.6.

TABLE 3
DISTANCE BETWEEN PLATES FOR FLATTENING
TESTS^A

Type	Distance Between Plates, min, in. [mm]
Grade A	0.50 <i>D</i>
Grade B	0.6 <i>D</i>
Grade C	0.65 <i>D</i>
Grade D	0.7 <i>D</i>
Grades E, F, G, H, J (Class 55)	0.7 <i>D</i>
Grades E, F, G, H, J (Class 65)	0.8 <i>D</i>
Grades E, F, G, H, J (Class 70)	0.8 <i>D</i>
Grade J (Class 110)	0.9 <i>D</i>
Grade K	0.8 <i>D</i>
Grade L	0.9 <i>D</i>
Grade M (Class 85)	0.7 <i>D</i>
Grade M (Class 100)	0.8 <i>D</i>

^A *D* = outside diameter.

TABLE 4
MAXIMUM PIN DIAMETERS AND MINIMUM ANGLE
FOR BEND TEST

Type	Pin Diameter	Angle, deg
Grade A	2 <i>t</i>	180
Grade B	2 <i>t</i>	180
Grade C	3 <i>t</i>	180
Grade D	4 <i>t</i>	150
Grades E, F, G, H, J (Class 55)	4 <i>t</i>	150
Grades E, F, G, H, J (Class 65)	4 <i>t</i>	150
Grades E, F, G, H, J (Class 70)	4 <i>t</i>	150
Grade J (Class 110)	6 <i>t</i>	150
Grade K	4 <i>t</i>	150
Grade L	6 <i>t</i>	150
Grade M (Class 85)	4 <i>t</i>	150
Grade M (Class 100)	4 <i>t</i>	150

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Grain Size

S1.1 When a grain size range is required, it shall be specified in the ordering information, and shall be determined by an agreed-upon method from Test Methods E 112.

S1.2 Samples for grain size estimation shall be taken from the tension test specimen location.

S2. Rough Machining

S2.1 Rough machining shall be performed in the sequence and manner as specified.

S3. Impact Testing

S3.1 Charpy V-notch test specimens shall be taken from the same location and in the same orientation as tension test specimens. The number of specimens, minimum energy values, and test temperature(s) shall be as specified.

S4. Fracture Toughness

S4.1 Specific fracture toughness requirements are levied by certain sections of the ASME Boiler and Pressure Vessel Code. Forgings in the permitted types shall comply with the applicable code sections.

S4.2 The necessary code references toughness criteria and test temperature data shall be included in the ordering information.

S5. Ultrasonic Examination

S5.1 Ultrasonic examination of forgings shall be carried out in accordance with Practice A 388/A 388M.

S5.2 Acceptance criteria shall be specified and shall be in accordance with the applicable Code or purchaser's specification and shall be included as part of the ordering information.

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SPECIFICATION FOR SEAMLESS AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE CENTRAL-STATION SERVICE



SA-376/SA-376M

(Identical with ASTM Specification A376/A376M-06 except for the deletion of HT-O option from 6.2 and 14.1 and clarification of heat treatment requirements in 6.2.)

SPECIFICATION FOR SEAMLESS AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE CENTRAL-STATION SERVICE



SA-376/SA-376M

(Identical with ASTM Specification A 376/A 376M-06, except for the deletion of HT-O option from 6.2 and 14.1 and clarification of heat treatment requirements in 6.2.)

1. Scope

1.1 This specification covers seamless austenitic steel pipe intended for high-temperature central-station service. Among the grades covered are five H grades and two nitrogen grades (304N and 316N) that are specifically intended for high-temperature service.

1.2 Optional supplementary requirements (S1 through S10) are provided. These supplementary requirements specify additional tests that will be made only when stated in the order, together with the number of such tests required.

1.3 Grades TP321 and TP321H have lower strength requirements for nominal wall thicknesses greater than $\frac{3}{8}$ in. [9.5 mm].

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 ASTM Standards:

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E 112 Test Methods for Determining Average Grain Size
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

2.2 Other Standards:

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

3. Terminology

3.1 Definitions — For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required to describe the desired material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (seamless austenitic steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (nominal size, or outside diameter and schedule number or average wall thickness),

4.1.5 Lengths (specific or random), (Permissible Variations in Length Section of Specification A 999/A 999M),

4.1.6 End finish (Ends Section of Specification A 999/A 999M),

4.1.7 Optional requirements (Section 9) (see Hydrostatic Test Requirements Section and the Permissible Variation in Weight for Seamless Pipe Section for weighing individual lengths, of Specification A 999/A 999M), (see 10.6, repairing by welding; 14.3, die stamping),

4.1.8 Test report required (Certification Section of Specification A 999/A 999M),

4.1.9 Specification designation, and

4.1.10 Special requirements or any supplementary requirements selected, or both.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Manufacture* — At the manufacturer's option, pipe may be either hot finished or cold finished, with a suitable finishing treatment, where necessary.

6.2 Heat Treatment:

6.2.1 All pipe shall be furnished in the heat-treated condition. For H grades, separate solution treatments are required for solution annealing; in process heat treatments are not permitted as a substitute for the separate solution annealing treatments.

6.2.2 As an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes may be individually quenched in water or rapidly cooled by other means.

6.2.3 *Grades TP304, TP304N, TP304LN, TP316, TP316N, TP316LN, TP321, TP347, TP348, 16-8-2H, S31725, and S31726* — Unless otherwise stated in the order, heat treatment shall consist of heating to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

6.2.3.1 The purchaser may specify controlled structural or special service characteristics which shall be used as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature under 1900°F [1040°C], each pipe shall be stenciled with the final heat treatment temperature in degrees Fahrenheit or Celsius after the suffix "HT."

6.2.4 *Grades TP304H, TP316H, TP321H, TP347H, TP348H, and 16-8-2H* — If cold working is involved in

processing, the minimum solution-treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C], for Grades TP304H and TP316H, 1900°F [1040°C], and for Grade 16-8-2H, 1800°F [980°C]. If the material is hot-rolled, the minimum solution-treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], for Grades TP304H and TP316H, 1900°F [1040°C], and for Grade 16-8-2H, 1800°F [980°C].

6.2.5 *Grade S34565* — Heat treatment shall consist of heating to a temperature in the range of 2050°F [1120°C] minimum and 2140°F [1170°C] maximum, and quenching in water or rapidly cooling by other means.

6.3 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S9).

6.4 The grain size of grades 304H, 316H, 321H, 347H, and 348H as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet from each heat or two pipes from each lot (Note 2) shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Lengths of Pipe in Lot
Under NPS 2	400 or fraction thereof
NPS 2 to NPS 5, incl	200 or fraction thereof
Over NPS 5	100 or fraction thereof

NOTE 2 — A lot shall consist of the number of lengths specified in 8.1 of the same size and wall thickness from any one heat of steel.

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

8.3 If the analysis of one of the tests specified in Section 9 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

10. Workmanship, Finish, and Appearance

10.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 10.2.

10.2 Surface imperfections that penetrate more than $12\frac{1}{2}\%$ of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

10.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

10.2.2 Repaired in accordance with the repair welding provisions of 10.6.

10.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

10.2.4 Rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with 10.2, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions (see Note 3), and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm].

NOTE 3 — Marks and abrasions are defined as cable marks, dings, guide marks, roll marks, ball scratches, scores, die marks, and so forth.

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 10.1 to be deeper than 5% of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 10.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

10.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

10.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated

nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

10.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 999/A 999M.

10.7 The finished pipe shall be reasonably straight.

10.8 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

11. Hydrostatic or Nondestructive Electric Test

11.1 Each pipe shall be subjected to the Nondestructive Electric Test or the Hydrostatic Test. Unless specified by the purchaser, either test may be used at the option of the producer.

11.2 *Hydrostatic Test* — Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 11.3 and 11.4.

11.3 For pipe sizes NPS 24 and over, the purchaser, with the agreement of the manufacturer, may complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH."

11.4 *Nondestructive Examination* — Each pipe shall be examined with a nondestructive test in accordance with Practice E 213 or Practice E 426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

11.4.1 The following information is for the benefit of the user of this specification:

11.4.1.1 The reference standards defined in 11.10.1 through 11.10.4 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

11.4.1.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

11.4.1.3 The eddy-current testing (ET) referenced in Practice E 426 has the capability of detecting significant discontinuities, especially the short abrupt type.

11.4.1.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.5 Time of Examination — Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

11.6 Surface Condition:

11.6.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

11.6.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

11.7 Extent of Examination:

11.7.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 6.2.

11.7.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

11.8 Operator Qualifications — The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

11.9 Test Conditions:

11.9.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

11.9.2 The maximum eddy-current coil frequency used shall be as follows:

- On specified walls up to 0.050 in.—100 KHz max
- On specified walls up to 0.150 in.—50 KHz max
- On specified walls up to 0.150 in.—10 KHz max

11.9.3 Ultrasonic — For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

11.9.3.1 If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

11.10 Reference Standards:

11.10.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish, and heat treatment condition as the pipe to be examined.

11.10.2 For Ultrasonic Testing, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed $12\frac{1}{2}\%$ of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

11.10.3 For Eddy-Current Testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

11.10.3.1 Drilled Hole — The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
	0.039 in. (1 mm)
above $\frac{1}{2}$ to $1\frac{1}{4}$	0.055 in. (1.4 mm)
above $1\frac{1}{4}$ to 2	0.071 in. (1.8 mm)
above 2 to 5	0.087 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

11.10.3.2 Transverse Tangential Notch — Using a round tool or file with a $\frac{1}{4}$ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding $12\frac{1}{2}\%$ of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

11.10.3.3 Longitudinal Notch — A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding $12\frac{1}{2}\%$ of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

11.10.3.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

11.11 Standardization Procedure:

11.11.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

11.11.2 The test apparatus shall also be standardized after any change in test system settings; change of operator; equipment repair; or interruption due to power loss, process shutdown, or when a problem is suspected.

11.11.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

11.11.4 The signal-to-noise ratio for the reference standard shall be $2\frac{1}{2}$ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, and so forth, shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50% of full scale of the readout display.

11.11.5 If upon any standardization, the rejection amplitude has decreased by 29% (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

11.12 Evaluation of Imperfections:

11.12.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

11.12.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired in accordance with Sections 13 and 14. To be accepted, a repaired pipe must pass the same nondestructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

11.12.3 If the test signals were produced by visual imperfections such as:

- (1) Scratches,
- (2) Surface roughness,
- (3) Dings,
- (4) Straightener marks,
- (5) Cutting chips,
- (6) Steel die stamps,
- (7) Stop marks, or
- (8) Pipe reducer ripple.

The pipe may be accepted based on visual examination provided the imperfection is less than 0.004 in. (0.1 mm) or $12\frac{1}{2}\%$ of the specified wall thickness (whichever is greater).

11.12.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

11.12.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

12. Mechanical Tests Required

12.1 Transverse or Longitudinal Tension Test — The tension test shall be performed on 1% of the pipe from each lot.

NOTE 4 — The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace or by directly obtaining the heat treated condition by quenching after hot forming. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

12.2 Flattening Test — For pipe heat treated in a batch-type furnace, the flattening test shall be made on 5% of the pipe from each heat-treated lot (see Note 4). When heat treated by the continuous process or when treated condition is obtained directly by quenching after hot forming, this test shall be made on a sufficient number of pipe to constitute 5% of the lot (Note 4) but in no case less than two pipes.

13. Certification

13.1 In addition to the certification required by Specification A 999/A 999M, the certification for pipe furnished to this specification shall identify each length of pipe which is furnished without the manufacturer's completed hydrostatic test, in accordance with 11.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the ANSI schedule number, the heat number or manufacturer's number by which the heat can be identified, and, if applicable,

NH when hydrotesting is not performed and ET when eddy-current testing is performed, or UT when ultrasonic testing is performed.

14.2 If the pipe conforms to any of the supplementary requirements specified in S1 through S10, compliance shall be so indicated by adding the symbol “S” directly followed by the number of the applicable supplementary requirement to the marking prescribed in 14.1.

14.3 No steel indentation stamping shall be done without the purchaser’s consent.

15. Keywords

15.1 austenitic stainless steel; feedwater heater tubes; stainless steel tube; steel tube; welded steel tube

TABLE 1 CHEMICAL REQUIREMENTS

Grade	UNS Designation	Composition, %												
		Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium	Tantalum	Nitrogen (A)	Others
TP304	S30400	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	...	...
TP304N	S30451	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP304LN	S30453	0.035 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP316	S31600	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316N	S31651	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP316LN	S31653	0.035 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP321	S32100	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	(B)	...	...	...	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	(C)	...	...	...	...
TP347	S34700	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	(D)	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	(E)	...	...	...
TP348 (F)	S34800	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	(D)	0.10	...	Co 0.20 max
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–19.0	...	...	(E)	...	...	...
16-8-2H	S16800	0.05–0.10	2.00	0.045	0.030	0.75	7.5–9.5	14.5–16.5	1.50–2.00	...	...	...	...	...
...	S31725	0.030 max	2.00	0.045	0.030	0.75	13.5–17.5	18.0–20.0	4.0–5.0	...	...	...	0.20 max	Cu 0.75 max
...	S31726	0.030 max	2.00	0.045	0.030	0.75	14.5–17.5	17.0–20.0	4.0–5.0	...	...	...	0.10–0.20	Cu 0.75 max
...	S34565	0.030 max	5.0–7.0	0.030	0.010	1.0	16.0–18.0	23.0–25.0	4.0–5.0	...	...	...	0.040–0.060	Cb 0.10 max

NOTES:

- (A) The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
- (B) The titanium content shall be not less than five times the carbon content and not more than 0.70%.
- (C) The titanium content shall be not less than four times the carbon content and not more than 0.70%.
- (D) The columbium content shall be not less than ten times the carbon content and not more than 1.10%.
- (E) The columbium content shall be not less than eight times the carbon content and not more than 1.10%.
- (F) This grade is intended for special purpose applications.

TABLE 2 TENSILE REQUIREMENTS

Grade	Tensile (A) Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm (or 4D) min, %	
			Longitudinal	Transverse
TP304, TP304H, TP304LN, TP316, TP316H, TP316LN, TP347, TP347H, TP348, TP348H, 16-8-2H, S31725	75 [515]	30 [205]	35	25
TP304N, TP316N, S31726	80 [550]	35 [240]	35	25
S34565	115 [790]	60 [415]	35	30
TP321, TP321H				
$\leq \frac{3}{8}$ "	75 [515]	30 [205]	35	25
$> \frac{3}{8}$ " (B)	70 [480]	25 [170]	35	25

NOTES:

- (A) For grade TP304, NPS 8 or larger, and in schedules 140 and heavier, the required minimum tensile strength shall be 70 ksi [480 MPa].
- (B) Prior to the issuance of A 376/A 376M — 88, the tensile and yield strength values were 75 [520] and 30 [210] respectively, for nominal wall greater than $\frac{3}{8}$ in. [9.5 mm].

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over in nominal diameter. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects,

the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters may be made from one end of each piece of pipe furnished in sizes 6 in. [152 mm] and larger in the as-furnished condition. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, piece number, and heat. Such photomicrographs are for information only, and shall show the actual metal structure of the pipe as finished.

S6. Ultrasonic Test

S6.1 Each piece of pipe may be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Each piece shall be ultrasonically tested in a circumferential direction in such a manner that the entire piece is scanned by the ultrasonic beam. The calibration standard shall be prepared from a section of pipe which has two notches, one in the inside surface and one in the outside surface. The notches shall be at least $1\frac{1}{2}$ in. [38 mm] long and have a depth of 3% of the wall thickness, or 0.004 in. [0.1 mm], whichever is the greater. Any pipe showing an ultrasonic indication of greater amplitude than the amplitude of the indication from the calibration standard shall be subject to rejection.

S7. Hot Ductility Test for Indicating Weldability

S7.1 A high-temperature ductility test may be made upon each heat of material supplied in heavy-wall pipe sections. An appropriate specimen shall be heated to an initial temperature, cooled 100°F [50°C], then subjected to a tension test, and shall show a minimum reduction of area of 60%. The initial temperature is that temperature 50°F [30°C] below the temperature at which material exhibits zero ductility. Rejection of material shall not be based upon this test.

S8. Retests

S8.1 Upon the purchaser's request, retests shall be made from sections of material removed from any part of the pipe. Failure to meet the requirements stated in this specification shall be cause for rejection.

S9. Stabilization Heat Treatment

S9.1 Subsequent to the solution anneal required in 6.4, Grades TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S10. Intergranular Corrosion Test

S10.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S10.1 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S10.2 A stabilization heat treatment in accordance with Supplementary Requirement S9 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, CHROMIUM-MOLYBDENUM



SA-387/SA-387M



(Identical with ASTM Specification A387/A387M-17a.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium- Molybdenum

1. Scope

1.1 This specification covers chromium-molybdenum alloy steel plates intended primarily for welded boilers and pressure vessels designed for elevated temperature service.

1.2 Plates are available under this specification in several grades having different alloy contents as follows:

Grade	Nominal Chromium Content, %	Nominal Molybdenum Content, %
2	0.50	0.50
12	1.00	0.50
11	1.25	0.50
22	2.25	1.00
21	3.00	1.00
5	5.00	0.50
9	9.00	1.00
91	9.00	1.00

1.3 Each grade except Grade 91 is available in two classes of tensile strength levels as defined in the Tensile Requirements tables. Grade 91 is available only as Class 2. Grade 91 consists of two types, with Type 2 differentiated from Type 1 by requiring restricted composition for the enhancement of creep resistance.

NOTE 1—Grade 911, previously covered by this specification, is now covered by Specification A1017/A1017M.

1.4 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must

be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

A1017/A1017M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten

2.2 AWS Specifications:

A5.5/A5.5M Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

5. Heat Treatment

5.1 Except for Grade 91, all plates shall be thermally treated either by annealing, normalizing and tempering, or, when permitted by the purchaser, accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Minimum tempering temperatures shall be as follows:

Grade	Temperature, °F [°C]
2, 12, and 11	1150 [620]
22, 21, and 9	1250 [675]
5	1300 [705]

5.1.1 Grade 91 plates shall be thermally treated, either by normalizing and tempering or by accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Grade 91 plates shall be austenitized at 1900 to 1975°F [1040 to 1080°C] and shall be tempered at 1350 to 1470°F [730 to 800°C].

5.2 Grade 5, 9, 21, 22, and 91 plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress relieved or the annealed condition.

5.3 For plates ordered without the heat treatment required by 5.1, heat treatment of the plates to conform to 5.1 and to Table 2 or Table 3, as applicable, shall be the responsibility of the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M for grades other than Grade 11.

7. Metallurgical Structure

7.1 *Austenitic Grain Size*—Grade 2 material shall have a coarse austenitic grain size.

8. Mechanical Requirements

8.1 Tension Test Requirements:

8.1.1 The material as represented by the tension test specimens shall conform to the applicable requirements of Table 2 or Table 3, as specified on the order.

8.1.2 Adjustment of the percentage elongation requirements is permitted in accordance with Specification A20/A20M for plates up to ¾ in. [20 mm] inclusive, in thickness when an 8-in. [200-mm] gage length is used.

9. Repair Welding

9.1 Repair welding shall be permitted only with the approval of the purchaser. Repair welds shall meet the requirements of the construction code specified by the purchaser.

9.2 All repair welds in Grade 91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair Grade 91 plate shall not exceed 1.0 %.

10. Marking

10.1 In addition to the marking required in Specification A20/A20M, each plate shall be legibly stamped or stenciled, depending upon the ordered thickness, with the letter *A* for annealed, *N* for normalized and tempered, and *Q* for accelerated cooled and tempered, as applicable. Grade 91 plates shall be marked with the appropriate type. Plates ordered to, and conforming to, Type 2 may be marked Type 1 as well.

11. Keywords

11.1 alloy steel; alloy steel plate; creep resistance; elevated temperature; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessels

TABLE 1 Chemical Requirements

NOTE 1—Where “...” appears, there is no requirement.

Element	Composition, % Grade and UNS Number								
	Grade 2 S50460	Grade 12 K11757	Grade 11 K11789	Grade 22 K21590	Grade 21 K31545	Grade 5 S50200	Grade 9 K90941	Grade 91 Type 1 K90901	Grade 91 Type 2 K90901
Carbon:									
Heat analysis	0.05–0.21	0.05–0.17	0.05–0.17	0.05–0.15 ^A	0.05–0.15 ^A	0.15 max	0.15 max	0.08–0.12	0.08–0.12
Product analysis	0.04–0.21	0.04–0.17	0.04–0.17	0.04–0.15 ^A	0.04–0.15 ^A	0.15 max	0.15 max	0.06–0.15	0.06–0.15
Manganese:									
Heat analysis	0.55–0.80	0.40–0.65	0.40–0.65	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.50
Product analysis	0.50–0.88	0.35–0.73	0.35–0.73	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.30–0.50
Phosphorus, max:									
Heat analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.020	0.020
Product analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.020
Sulfur, max:									
Heat analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.010	0.005
Product analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.012	0.005
Silicon:									
Heat analysis	0.15–0.40	0.15–0.40	0.50–0.80	0.50 max	0.50 max	0.50 max	1.00 max	0.20–0.50	0.20–0.40
Product analysis	0.13–0.45	0.13–0.45	0.44–0.86	0.50 max	0.50 max	0.55 max	1.05 max	0.18–0.56	0.20–0.40
Chromium:									
Heat analysis	0.50–0.80	0.80–1.15	1.00–1.50	2.00–2.50	2.75–3.25	4.00–6.00	8.00–10.00	8.00–9.50	8.0–9.50
Product analysis	0.46–0.85	0.74–1.21	0.94–1.56	1.88–2.62	2.63–3.37	3.90–6.10	7.90–10.10	7.90–9.60	8.0–9.50
Molybdenum:									
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.65	0.90–1.10	0.90–1.10	0.45–0.65	0.90–1.10	0.85–1.05	0.85–1.05
Product analysis	0.40–0.65	0.40–0.65	0.40–0.70	0.85–1.15	0.85–1.15	0.40–0.70	0.85–1.15	0.80–1.10	0.80–1.05
Nickel, max:									
Heat analysis	...	...	...	...	...	...	...	0.40	0.20
Product analysis	...	...	...	...	...	...	...	0.43	0.20
Vanadium:									
Heat analysis	...	...	...	...	...	...	0.04 max	0.18–0.25	0.18–0.25
Product analysis	...	...	...	...	...	...	0.05 max	0.16–0.27	0.16–0.27
Columbium (niobium): ^B									
Heat analysis	...	...	...	...	...	...	...	0.06–0.10	0.06–0.10
Product analysis	...	...	...	...	...	...	...	0.05–0.11	0.05–0.11
Boron, max ^C									
Heat analysis	...	...	...	...	...	...	...	...	0.001
Nitrogen:									
Heat analysis	...	...	...	...	...	...	...	0.030–0.070	0.035–0.070
Product analysis	...	...	...	...	...	...	...	0.025–0.080	0.035–0.070
Nitrogen/aluminum									
Aluminum, max ^C	...	...	...	...	...	...	...	...	≥4.0
Titanium, max ^C	...	...	...	...	...	...	...	0.02	0.020
Zirconium, max ^C	...	...	...	...	...	...	...	0.01	0.01
Tungsten, max ^C	...	...	...	...	...	...	...	0.01	0.01
Copper, max ^C	...	...	...	...	...	...	...	...	0.05
Antimony, max ^C	...	...	...	...	...	...	...	...	0.10
Arsenic, max ^C	...	...	...	...	...	...	...	...	0.003
Tin, max ^C	...	...	...	...	...	...	...	...	0.010

^A The carbon content for plates over 5 in. [125 mm] in thickness is 0.17 max on product analysis.^B Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.^C Applies to both heat and product analysis.

TABLE 2 Tensile Requirements for Class 1 Plates

	Grades 2 and 12	Grade 11	Grades 22, 21, 5, 9
Tensile strength, ksi [MPa]	55 to 80 [380 to 550]	60 to 85 [415 to 585]	60 to 85 [415 to 585]
Yield strength, min, ksi [MPa]	33 [230]	35 [240]	30 [205]
Elongation in 8 in. [200 mm], min, % ^A	18	19	...
Elongation in 2 in. [50 mm], min, % ^A	22	22	18
Reduction of area, min, %	...	...	45 ^B 40 ^C

^A See Specification A20/A20M, elongation adjustments.

^B Measured on round test specimens.

^C Measured on flat specimen.

TABLE 3 Tensile Requirements for Class 2 Plates^A

	Grade 2	Grade 11	Grade 12	Grades 22, 21, 5, 9	Grade 91
Tensile strength, ksi [MPa]	70 to 90 [485 to 620]	75 to 100 [515 to 690]	65 to 85 [450 to 585]	75 to 100 [515 to 690]	85 to 110 [585 to 760]
Yield strength, min, ksi [MPa]/(0.2 % offset)	45 [310]	45 [310]	40 [275]	45 [310]	60 [415]
Elongation in 8 in. [200 mm], min, % ^B	18	18	19	...	...
Elongation in 2 in. [50 mm], min, % ^B	22	22	22	18	18
Reduction of area, min, %	...	...	...	45 ^C 40 ^D	...

^A Not applicable to annealed material.

^B See Specification A20/A20M, elongation adjustments.

^C Measured on round test specimens.

^D Measured on flat specimen.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

- S1. Vacuum Treatment,
- S2. Product Analysis,
- S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
 - S4.1 Additional Tension Test,
- S5. Charpy V-Notch Impact Test,
- S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),
- S7. High-Temperature Tension Test,
- S8. Ultrasonic Examination in accordance with Specification A435/A435M,
- S9. Magnetic Particle Examination,
- S11. Ultrasonic Examination in accordance with Specification A577/A577M,
- S12. Ultrasonic Examination in accordance with Specification A578/A578M, and
- S17. Vacuum Carbon-Deoxidized Steel.

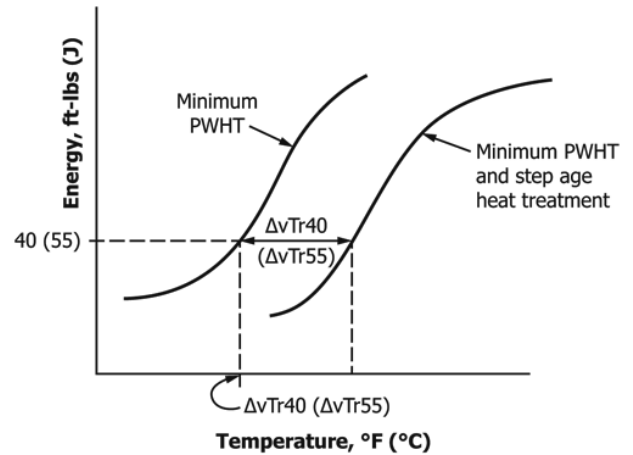


FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirements are suitable for this application. S62 and S63 are applicable for Grades 22 and 21 only.

S53. Alternative Location for Mechanical Testing

When specified by the purchaser, the axis of the tensile and impact test specimens shall come from the mid-thickness of each plate tested, in lieu of midway between the center thickness and the top or bottom surface of the plate.

S60. Restricted Carbon

S60.1 The maximum carbon content of Grade 5 shall be 0.10 %.

S62. Temper Embrittlement Factor

S62.1 The composition of the steel, based on heat analysis, shall be restricted in accordance with the following equations:

$$J = (Si + Mn) \times (P + Sn) \times 10^4 \leq 150 \quad (Si, Mn, P \text{ and } Sn \text{ in wt } \%)$$

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

S62.1.1 Lower values of J, Cu, and Ni can be specified by agreement between purchaser and the supplier.

S62.1.2 When so specified by the purchaser, the maximum value of J shall not exceed 100.

S62.1.3 The values of J shall be reported.

S62.1.4 If the plates are repaired by welding, the composition of the weld deposit shall be restricted in accordance with the following equations:

$$X = (10P + 5Sb + 4Sn + As) / 100 \leq 15 \quad (P, Sb, Sn \text{ and } As \text{ in ppm})$$

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

S62.1.5 The values of X shall be reported.

S63. Impact Properties After Step Cooling

S63.1 The Charpy V-notch impact properties shall be determined as follows:

S63.1.1 A sufficient amount of Charpy V-notch test specimens shall be taken from the same location from a plate from each heat of steel to construct two transition temperature curves.

S63.1.2 The test specimens for one transition temperature curve shall be given the minimum post weld heat treatment (PWHT) cycle specified by the purchaser.

S63.2 The test specimens for the other transition temperature curve shall be given the PWHT cycle specified in S63.1.2 plus the following step cooling heat treatment:

Hold at 1100°F (593°C) for 1 h, then cool at 10°F (5.6°C)/h to 1000°F (538°C).

Hold at 1000°F (538°C) for 15 h, then cool at 10°F (5.6°C)/h to 975°F (524°C).

Hold at 975°F (524°C) for 24 h, then cool at 10°F (5.6°C)/h to 925°F (496°C).

Hold at 925°F (496°C) for 60 h, then cool at 5°F (2.8°C)/h to 875°F (468°C).

Hold at 875°F (468°C) for 100 h, then cool at 50°F (27.8°C)/h to 600°F (315°C).

Cool in still air.

S63.3 Test the Charpy V-notch test specimens in accordance with Test Methods and Definitions A370 to determine the 40 ft-lbs (55 J) transition temperature from each transition temperature curve using a set of three test specimens at each test temperature. The test temperatures shall include tests on the upper and lower shelves and a minimum of four intermediate temperatures.

S63.4 The following requirements shall be met.

$$vTr40 + 2.5\Delta vTr40 \leq 50^\circ F$$

$$vTr55 + 2.5\Delta vTr55 \leq 10^\circ C$$

where:

$vTr40$ ($vTr55$) = the 40 ft-lbs (55 J) transition temperature of the material subjected to the minimum PWHT specified by the purchaser.

$\Delta vTr40$ ($\Delta vTr55$) = the shift of the 40 ft-lbs (55 J) transition temperature the of the step cooled material. (The 40 ft-lbs (55 J) transition temperature the of the step cooled material minus that of the material subjected to the minimum PWHT only).

S63.5 The 40 ft-lbs (55 J) transition temperatures for the two material conditions shall be reported.

SPECIFICATION FOR FERRITIC DUCTILE IRON PRESSURE-RETAINING CASTINGS FOR USE AT ELEVATED TEMPERATURES



SA-395/SA-395M



(21)

(Identical with ASTM Specification A395/A395M-99(2018).)

SPECIFICATION FOR FERRITIC DUCTILE IRON PRESSURE-RETAINING CASTINGS FOR USE AT ELEVATED TEMPERATURES



SA-395/SA-395M



[Identical with ASTM Specification A 395/A 395M-99(2018).]

1. Scope

1.1 This specification covers ductile iron castings for pressure-retaining parts for use at elevated temperatures. Castings of all grades are suitable for use up to 450°F. For temperatures above 450°F and up to 650°F, only Grade 60–40–18 castings are suitable (Note 1).

1.2 Valves, flanges, pipe fittings, pumps, and other piping components are generally manufactured in advance and supplied from stock by the manufacturer, jobber, or dealer.

1.3 For supplemental casting requirements, Specification A 834 may be utilized.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance to the specification.

NOTE 1 — For service other than as specified in this section, reference should be made to Specification A 536 for Ductile Iron Castings.

2. Referenced Documents

2.1 ASTM Standards:

- A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 536 Specification for Ductile Iron Castings
- A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application,

and Cobalt Alloy for High Strength at Elevated Temperatures

- A 834 Specification for Common Requirements for Iron Castings for General Industrial Use
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. [51 to 114 mm]) Steel Castings
- E 280 Reference Radiographs for Heavy-Walled (4½ to 12 in. [114 to 305 mm]) Steel Castings
- E 446 Reference Radiographs for Steel Castings up to 2 in. [51 mm] in Thickness
- E 689 Reference Radiographs for Ductile Iron Castings
- E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition
- F 1476 Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications
- F 1548 Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings used in Piping Applications

2.2 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

- SP 25 Standard Marking Systems for Valves, Flanges, Pipe Fittings, and Unions

3. Classification

3.1 Castings ordered to this specification are classified by grades based on mechanical property requirements, as listed in Table 1. See note following Table 1.

4. Ordering Information

4.1 Orders for material under this specification shall include the following applicable information:

4.1.1 Drawing, catalog number, or part identifications,

4.1.1.1 For grade 65-45-15, drawing indicating critical area(s) of casting (see 7.2.2 and 7.3.2).

4.1.2 Quantity (weight or number of pieces),

4.1.3 ASTM designation and year of issue,

4.1.4 Grade (See Table 1), if a Grade is not specified, the manufacturer shall supply grade 60-40-18.

4.1.5 Heat-treating requirements (see 5.2.1),

4.1.6 Pressure test requirements (see 7.4.3),

4.1.7 Test samples from castings (see 11.1.1 and 12.1.1),

4.1.8 Test coupons size (see 11.2),

4.1.9 Metallographic option (see 12.1.1),

4.1.10 Place of inspection (see 16.1),

4.1.11 Certification requirements (see 17.1),

4.1.12 Identification marking (see 18.2), and

4.1.13 Supplemental Requirements (see 1.4, 7.4.2, S1 and S2).

5. Materials and Manufacture

5.1 The melting method and the nodularizing practice shall be optional with the foundry.

5.2 Except as provided in 5.2.1, all castings Grade 60-40-18 shall be given a ferritizing heat treatment that produces essentially a ferritic structure that contains no massive carbides.

5.2.1 When specified in the purchase order, Grade 60-40-18 castings may be provided in an as-cast condition provided they comply with the requirements of 7.1 and 7.2.1.

5.2.2 Castings supplied in accordance with 5.2.1 may be stress relieved by agreement between the manufacturer and purchaser.

5.3 Castings Grade 65-45-15 may be provided in as-cast condition or heat treated, provided they comply with the requirements of 7.1, 7.2.2, and 7.3.2.

6. Chemical Requirements

6.1 The casting shall conform to the following requirements for chemical composition (Note 2):

Total carbon, min, %	3.00
Silicon, max, %	2.50
Phosphorus, max, %	0.08

6.1.1 The chemical analysis for total carbon shall be made on chilled cast pencil type specimens or from thin

wafers approximately $\frac{1}{32}$ in. [0.8 mm] thick cut from test coupons. Drillings are not reliable because of the probable loss of graphite.

6.1.2 For each reduction of 0.01% below the maximum specified phosphorus content, an increase of 0.08% silicon above the specified maximum will be permitted up to a maximum of 2.75%.

NOTE 2 — Silicon contents above 2.75%, or phosphorus contents above 0.08 % have a tendency to lower the impact resistance of the material. If the carbon content is below 3.00%, excess cementite may form during cooling and if this is not removed during heat treatment, the impact resistance of the material may be lowered.

7. Requirements

7.1 Tensile Properties:

7.1.1 The ductile iron as represented by the test specimens shall conform to the mechanical property requirements in Table 1.

7.2 Hardness:

7.2.1 For Grade 60-40-18, the hardness of the castings and test specimens shall be within the limits in Table 1.

7.2.2 For Grade 65-45-15, the hardness of test specimen and the critical area(s) of the casting, as identified on the casting drawing, shall be within the limits in Table 1. If the grade 65-45-15 casting drawing does not have critical area(s) of the casting identified, all areas of the casting shall be within the hardness limits in Table 1.

7.3 Microstructure:

7.3.1 For Grade 60-40-18, the microstructure of the separately cast test coupon or the casting shall be essentially ferritic and contain no massive carbides, and have a minimum of 90% Type I and Type II Graphite as in Fig. 1 or Plate I of Test Method A 247.

7.3.2 For Grade 65-45-15, the microstructure of the critical areas of the casting, as identified on the casting drawing, shall be 45% pearlitic, maximum, contain no massive carbides, and have a minimum 90% Type I and Type II Graphite as in Fig. 1 or Plate I of Test Method A 247.

7.4 Pressure Test Requirements:

7.4.1 Each pressure retaining Grade 60-40-18 casting shall be tested after machining to the test pressure specified by the applicable standard of ANSI, ASME Boiler and Pressure Vessel Code, or other pertinent code, and shall show no leaks.

7.4.2 Castings Grade 65-45-15 manufactured under this specification shall be capable of passing hydrostatic test(s) compatible with the rating of the finished cast component. Such tests shall be conducted by the casting manufacturer only when Supplementary Requirement S2 is specified.

7.4.3 Castings Grade 60-40-18, ordered under this specification not covered by ANSI standards and ASME Pressure Vessel Code, and castings for special service applications, shall be tested to such pressures as may be agreed upon by the manufacturer and the purchaser.

7.4.4 For castings Grade 60-40-18, it is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final hydrostatic test.

8. Workmanship and Finish

8.1 The surface of the casting shall be examined visually and shall be free from adhering sand, scale, cracks, and hot tears. Any other surface discontinuities shall meet visual acceptance standards specified in the order.

9. Repair

9.1 Castings for valves, flanges, pipe fittings, pumps, and other piping components ordered under applicable ANSI standards shall not be repaired by plugging, welding, brazing, or impregnation.

9.2 Castings Grade 60-40-18 not covered in 9.1 which leak on hydrostatic tests may be repaired by plugging, provided the following requirements are met:

9.2.1 No welding or brazing is permitted.

9.2.2 The diameter of the plug shall not exceed the diameter of a standard 2 in. [ISO R2] pipe plug.

9.2.3 The plugs, where practical, shall conform in all dimensions to the standard ISO $\frac{3}{8}$ plugs. In addition, they shall have full thread engagement corresponding to the thickness in the repaired section. Where a tapered plug is impractical because of the excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full engagement and effective sealing against pressure are obtained. Where possible, the ends of the plug should be ground smooth after installation to conform to the inside and outside contours of the wall of the pressure vessel or pressure part.

9.2.4 The material from which the plug is manufactured shall conform in all respects to the materials specifications that apply to the pressure vessel or pressure part.

9.2.5 The area adjacent to the drilled hole shall be examined by radiography, and shall meet the Level 3 acceptance requirements of Reference Radiographs E 689

and supporting Reference Radiographs E 446, E 186, or E 280 as applicable and defined in accordance with Reference Radiographs E 689.

9.2.6 The thickness of any repaired section in relation to the size of the plug used shall not be less than that given in Table 2.

9.2.7 The minimum radius of repaired sections of cylinders or cones in relation to the size of plug used shall not be less than that given in Table 3.

9.2.8 A repaired area may consist of a maximum of three plugs with a spacing such that the ligaments between adjacent plugs shall not be less than listed in Table 4. Other defective areas may also be repaired by plugging provided the minimum ligament between plugs in adjacent areas is not less than twice the distance from the nearest plug, the values for which are listed in Table 4.

9.3 Surface imperfections in castings Grade 60-40-18 other than valves, flanges, pipe fittings, pumps, and other piping components may be repaired by plugging provided the depth of the plug is not greater than 20% of the thickness of the casting section and the diameter of the plug is not greater than its length. Repair of surface defects may not be done on pressure-containing portions of castings. The plug need not be threaded. The conditions of 9.2.1 and 9.2.4 shall also be satisfied.

10. Sampling

10.1 A lot shall consist of one of the following:

10.1.1 All the metal from a single heating in a batch-type melting furnace.

10.1.2 All the metal poured from two or more batch-type melting furnaces into a single ladle or a single casting.

10.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry, or 8 h, whichever is the shorter period.

11. Test Coupon

11.1 The separately cast test coupons poured from the same lot as the castings they represent from which the tension test specimen is machined shall be cast to the size and shape shown in Fig. 2, Fig. 3, or Fig. 4. Cast coupons shall be identified with the castings they represent. Sectioning procedure for removing test specimens from Y-blocks is shown in Fig. 5.

11.1.1 Test samples may be removed from castings at locations designated on a drawing or as agreed to by manufacturer and purchaser.

11.1.2 Test bars removed from castings shall conform to Fig. 6. The testing diameter shall be $\frac{1}{2}$ in. [12.5 mm] if possible. Smaller diameters shall be utilized if necessary.

11.2 The test coupon size shall be as mutually agreed upon between the manufacturer and purchaser. In the absence of agreement, it shall be the option of the manufacturer.

11.3 The test coupons shall be cast in molds made of suitable core sand having a minimum wall thickness of $\frac{1}{2}$ in. [38 mm] for the $\frac{1}{2}$ in. [12.5 mm], 1 in. [25 mm] sizes, and 3 in. [75 mm] for the 3 in. [75 mm] size. The coupons shall be left in the mold until they have changed to a black color (approximately 900°F [480°C] or less). The keel block as shown in Fig. 2 or the modified keel block produced from the mold shown in Fig. 4 may be substituted for the 1 in. [25 mm] block shown in Fig. 3.

11.4 When investment castings are made to this specification, the manufacturer may use test specimens cast to size incorporated in the mold with the castings or separately cast to size using the same type of mold and the same thermal conditions that are used to produce the castings. These test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732/A 732M or Fig. 5 and Fig. 6 of Test Methods and Definitions A 370.

11.5 The manufacturer shall cast a sufficient number of test coupons to provide for each ferritizing anneal. The test coupons shall be heat treated with the castings they represent. Sectioning of the test coupons prior to heat treating is not permitted.

11.6 The metallographic examination shall be made on a test lug from the test coupon shown in Fig. 7 or from a casting; or from a representative test coupon poured with the casting(s). The test coupon shall represent the metal treated with the nodularizing agent.

12. Number of Tests and Retests

12.1 One tension test shall be made from sections cut from the test coupons (Fig. 5) required by Section 11.

12.1.1 Unless otherwise stated in the contract or order for castings, a metallographic examination may be substituted for the tension test when separately cast test coupons are used. When the microstructure option is used, a minimum of one tension test is required from each day's melt and for each heat treatment (see 12.2).

12.2 If any tension test specimen shows obvious defects, another from the same coupon, or from another coupon/or representing the same metal and the same anneal charge, may be tested. If an apparently sound test specimen fails to conform to this specification, castings may be re-annealed, if required, and two retests made. If either retest

fails to conform to this specification, the castings they represent shall be rejected.

13. Tension Test Specimen Preparation

13.1 The standard machined $\frac{1}{2}$ in. [12.5 mm] round tension test specimen with 2 in. [50 mm] gage length as shown in Fig. 6 shall be used except where the $\frac{1}{2}$ in. [12.5 mm] Y-block test coupon is required. In this case, either of the small size specimens, 0.375 or 0.250 in. [9 or 6.5 mm] round as shown in Fig. 6, shall be used.

14. Test Methods

14.1 Chemical analysis shall be made in accordance with Test Method E 1806.

14.2 The yield strength shall be determined in accordance with Test Methods E 8 using one of the following methods:

14.2.1 The 0.2% off-set method, or

14.2.2 Extension under load method where the yield strength may be determined as the stress producing an elongation under load of 0.375%; that is, 0.0075 in. [0.19 mm] in a gage length of 2 in. [50 mm].

14.3 The hardness of the ductile iron as represented by the test specimens and castings shall be determined in accordance with Test Method E 10.

14.4 The percentage of each graphite type shall be determined by manual counting, semi-automatic, or automatic image analysis methods. The sum of all graphite types shall total to 100%.

15. Records

15.1 Records of the chemical composition, mechanical properties, and metallographic examination, when applicable, shall be systematically made and maintained.

16. Inspection

16.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspection required by this specification.

16.2 The inspector representing the purchaser shall have entry at all time, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacturer of the material ordered. The manufacturer shall afford the inspector all

reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, all tests and inspection shall be made at the place of manufacture or by an approved independent laboratory prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Certification

17.1 When agreed upon in writing by the purchaser and the supplier, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

18. Product Marking

18.1 Castings for valves, flanges, pipe fittings, and unions shall be marked for material identification in accordance with the Standard Marking System for Valves, Flanges, Pipe Fittings, and Unions, SP-25. Castings for gasketed mechanical couplings and fittings may be marked in accordance with Specification F 1476 or F 1548 respectively.

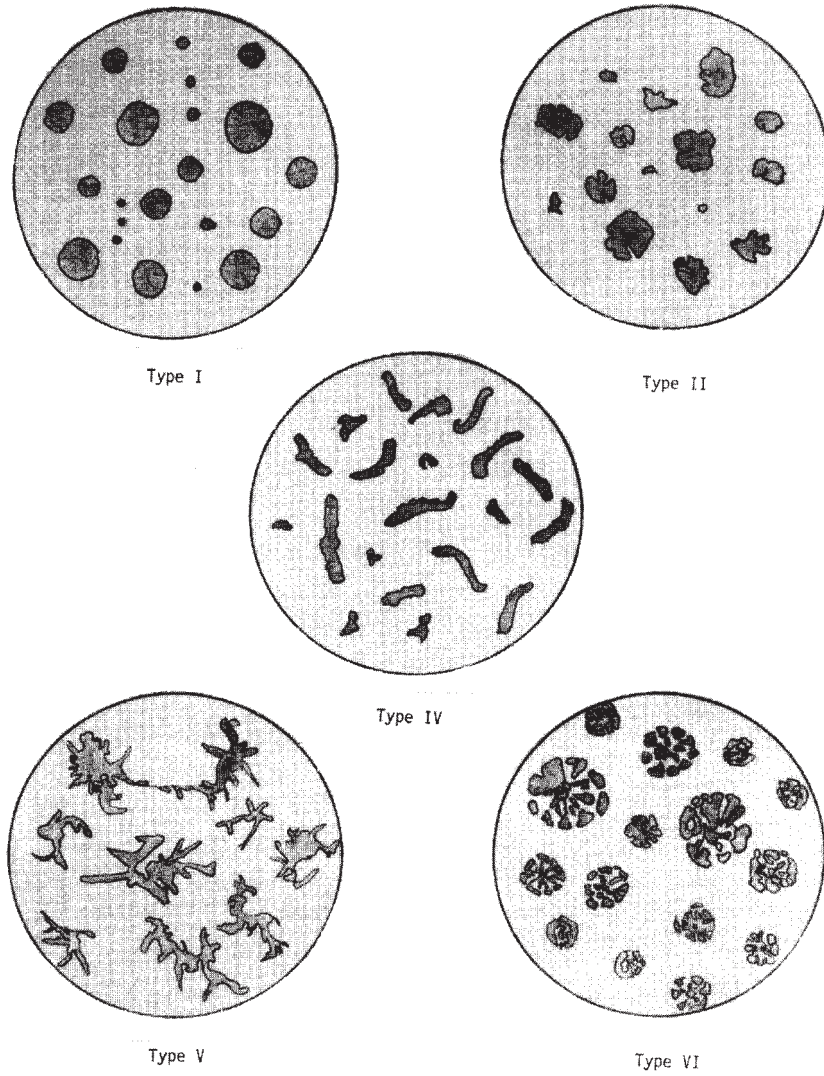
18.2 Castings, other than valves, flanges, pipe fittings, and unions, shall be identified subject to agreement by the manufacturer and the purchaser.

18.3 Marking shall be in such a position as not to injure the usefulness of the castings.

19. Keywords

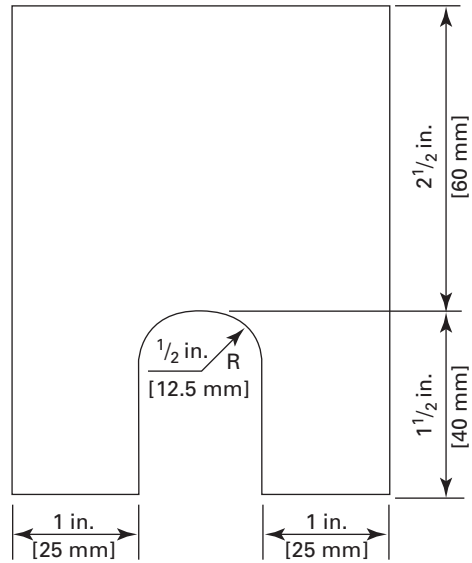
19.1 casting; ductile iron; mechanical properties; pressure-retaining; pressure test; tensile strength; tension testing; yield strength

FIG. 1 SUGGESTED CLASSIFICATION OF GRAPHITE FORM IN DUCTILE CAST IRON



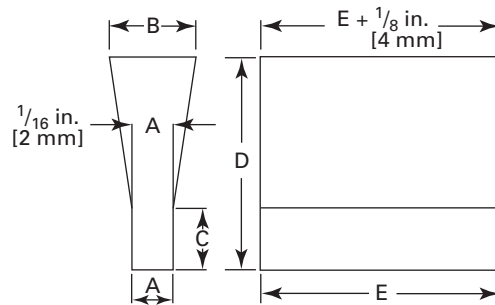
NOTE—Graphite types are identical with Plate 1 of Test Method A 247 and are so identified.

FIG. 2 KEEL BLOCK FOR TEST COUPONS



NOTE: The length of the keel block shall be 6 in. [152 mm]

FIG. 3 Y-BLOCKS FOR TEST COUPONS



"Y" Block Size

Dimensions	For Castings of Thickness Less Than 1/2 in. [13 mm]	For Castings of Thickness 1/2 in. [13 mm] to 1 1/2 in. [38 mm]	For Castings of Thickness of 1 1/2 in. [38 mm] and Over
	in. [mm]	in. [mm]	in. [mm]
A	1/2 [13]	1 [25]	3 [75]
B	1 5/8 [40]	2 3/8 [55]	5 [125]
C	2 [50]	3 [75]	4 [100]
D	4 [100]	6 [150]	8 [200]
E	7 [175]	7 [175]	7 [175]
	approx.	approx.	approx.

FIG. 4 MOLD FOR MODIFIED KEEL BLOCK

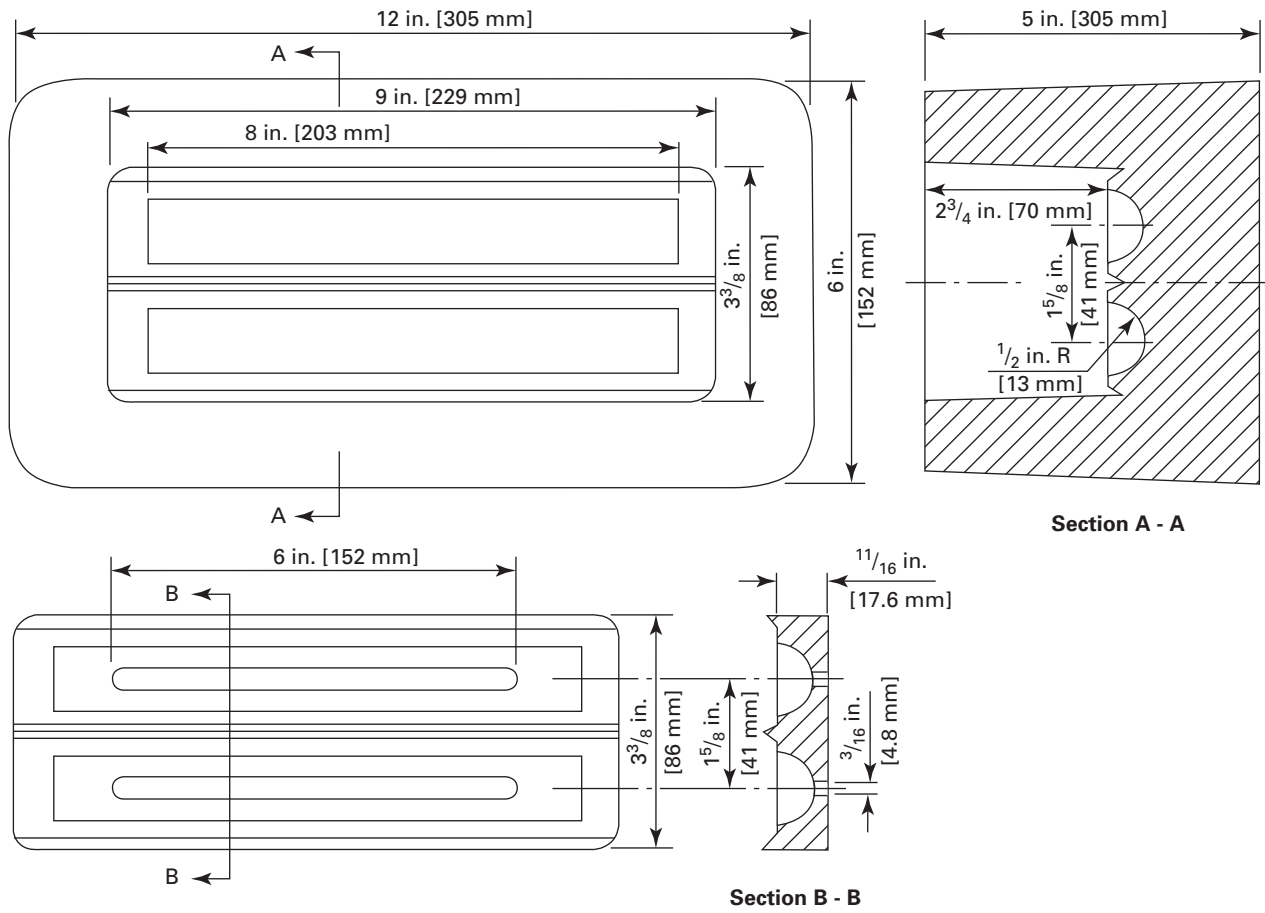
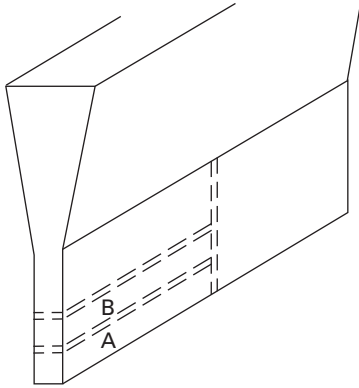
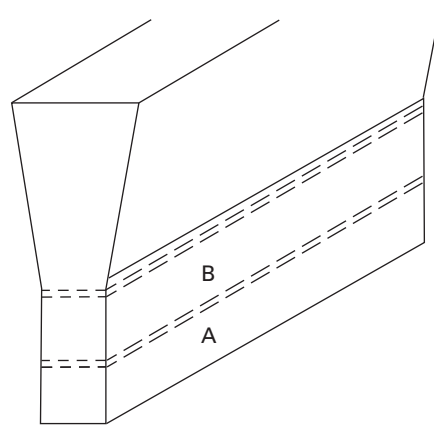


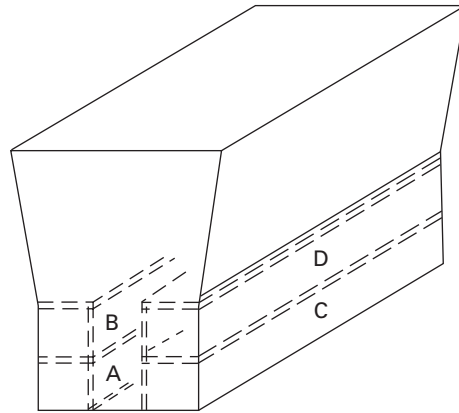
FIG. 5 SECTIONING PROCEDURE FOR Y-BLOCKS



(a) 1/2 in. [13 mm] Y-block — two blanks for 0.252 in. [6.40 mm] diameter tension test specimens.

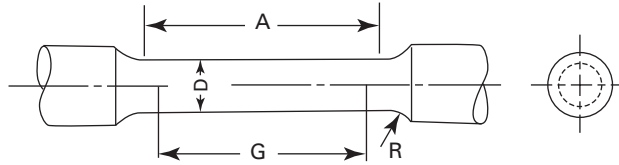


(b) 1 in. [25 mm] Y-block — two blanks for 0.50 in. [12.5 mm] diameter tension test specimens.



(c) 3 in. [75 mm] Y-block — two blanks for 0.50 in. [12.5 mm] diameter tension test specimens.

FIG. 6 STANDARD 1/2 IN. [12.5 MM] ROUND TENSION TEST SPECIMEN WITH 2 IN. [50.0 MM] GAGE LENGTH AND EXAMPLES OF SMALL SIZE SPECIMENS PROPORTIONAL TO THE STANDARD SPECIMEN



Dimensions	Standard Specimen, in. [mm]		
	1/2 [12.5] Round	0.350 [9] Round	0.250 [6.5] Round
G—Gage length	2.000 ± 0.005 [50 ± 0.13]	1.4 ± 0.005 [35 ± 0.13]	1.0 ± 0.005 [25 ± 0.13]
D—Diameter (Note 1)	0.500 ± 0.010 [12.5 ± 0.25]	0.350 ± 0.007 [9 ± 0.18]	0.250 ± 0.005 [6.5 ± 0.13]
R—Radius of fillet	3/8 [9.5], min	3/8 [9.5], min	1/4 [6.5], min
A—Length of reduced section (Note 2)	2 1/4 [58], min	1 3/4 [45], min	1 1/4 [32], min

NOTES:

- (1) The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 0.005 in. [0.13 mm] larger in diameter than the center on the standard specimen, and not more than 0.003 in. [0.076 mm] larger in diameter than the center on the small size specimens.
- (2) If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for measurement of elongation should nevertheless be spaced at the indicated gage length.
- (3) The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips it is desirable, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

FIG. 7 TEST COUPONS FOR MICROSCOPICAL EXAMINATION OF DUCTILE IRON

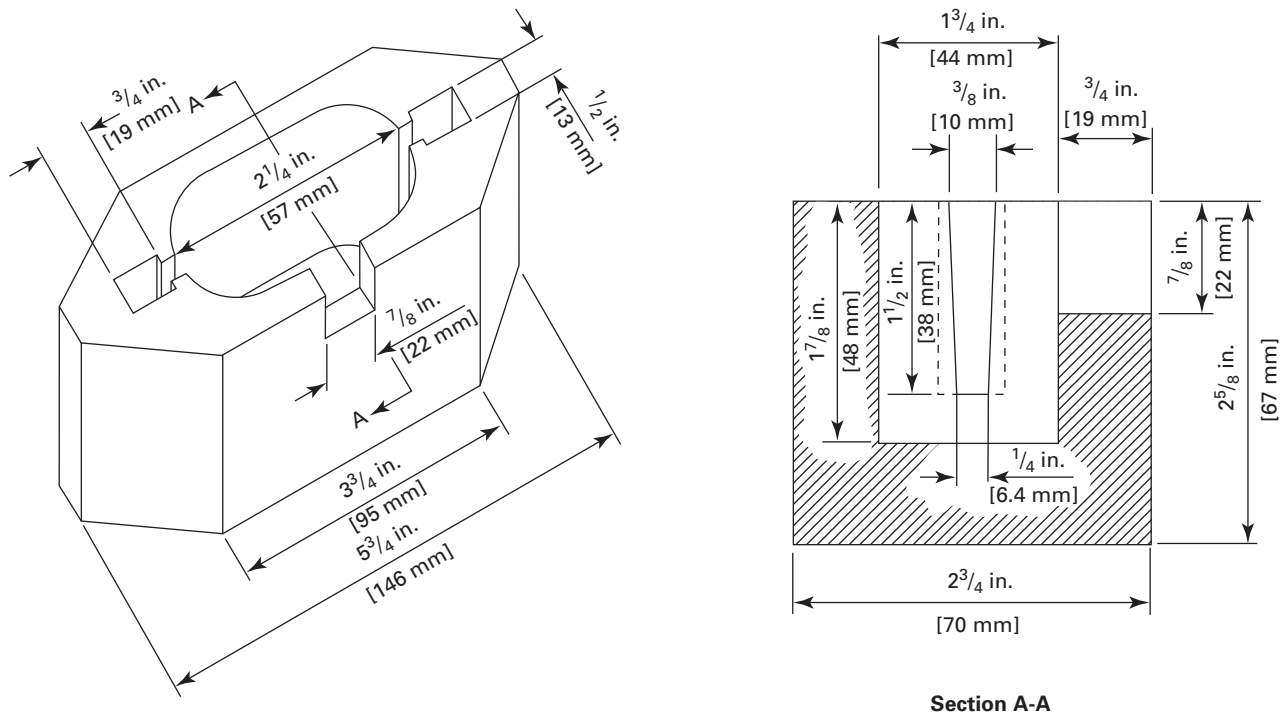


TABLE 1
MECHANICAL PROPERTY REQUIREMENTS

Property	Grade 60-40-18	Grade 65-45-15
Tensile Strength Minimum, psi [MPa]	60 000 [415]	65 000 [450]
Yield Strength Minimum, psi [MPa]	40 000 [275]	45 000 [310]
Elongation in 2 in. Minimum, %	18	15
Hardness HB, 3000 kgf Load	143–187	156–201

NOTE: If a grade is not specified in the ordering information, grade 60–40–18 will be supplied.

TABLE 2
MINIMUM THICKNESS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Thickness Repaired Section, in. [mm]
$\frac{1}{8}$	$\frac{11}{32}$ [8]
$\frac{1}{4}$	$\frac{7}{16}$ [10]
$\frac{3}{8}$	$\frac{1}{2}$ [13]
$\frac{1}{2}$	$2\frac{1}{32}$ [17]
$\frac{3}{4}$	$\frac{3}{4}$ [19]
1	$\frac{13}{16}$ [21]
$1\frac{1}{4}$	$\frac{7}{8}$ [23]
$1\frac{1}{2}$	$\frac{15}{16}$ [24]
2	1 [26]

TABLE 3
MINIMUM RADIUS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Radius of Cylinder or Cone, in. [mm]
$\frac{1}{8}$	$\frac{9}{16}$ [15]
$\frac{1}{4}$	$\frac{11}{16}$ [18]
$\frac{3}{8}$	$1\frac{1}{16}$ [28]
$\frac{1}{2}$	$1\frac{1}{4}$ [32]
$\frac{3}{4}$	2 [52]
1	$2\frac{1}{2}$ [64]
$1\frac{1}{4}$	4 [104]
$1\frac{1}{2}$	$5\frac{1}{4}$ [136]
2	$8\frac{1}{8}$ [208]

TABLE 4
MINIMUM LIGAMENT BETWEEN PLUGS^{A,B}

Nominal Plug Diameter, in.	Minimum Ligament Between Plugs, in. [mm]			
	$\frac{1}{8}, \frac{1}{4}, \frac{3}{8}$	$\frac{1}{2}, \frac{1}{4}$	1, $1\frac{1}{4}$	$1\frac{1}{2}, 2$
$\frac{1}{8}, \frac{1}{4}, \frac{3}{8}$	$2\frac{5}{8}$ [67]	$4\frac{1}{8}$ [105]	$6\frac{5}{8}$ [169]	$9\frac{1}{2}$ [242]
$\frac{1}{2}, \frac{3}{4}$	$4\frac{1}{8}$ [105]	$4\frac{1}{8}$ [105]	$6\frac{5}{8}$ [169]	$9\frac{1}{2}$ [242]
1, $1\frac{1}{4}$	$6\frac{5}{8}$ [169]	$6\frac{5}{8}$ [169]	$6\frac{5}{8}$ [169]	$9\frac{1}{2}$ [242]
$1\frac{1}{2}, 2$	$9\frac{1}{2}$ [242]	$9\frac{1}{2}$ [242]	$9\frac{1}{2}$ [242]	$9\frac{1}{2}$ [242]

^A Based on efficiency of 80%.

^B Example: Assume three plugs are required for repair, one $\frac{1}{8}$ in., one $\frac{3}{8}$ in., and one $1\frac{1}{2}$ in. The minimum distance permitted is as follows:

Ligament distance between $\frac{1}{8}$ and $\frac{3}{8}$ in. plugs is $2\frac{5}{8}$ in. [67 mm]

Ligament distance between $\frac{1}{8}$ and $1\frac{1}{2}$ in. plugs is $9\frac{1}{2}$ in. [242 mm]

Ligament distance between $\frac{3}{8}$ and $1\frac{1}{2}$ in. plugs is $9\frac{1}{2}$ in. [242 mm]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall not apply unless specified in the purchase order.

S1. Casting

S1.1 For Castings Grade 60-40-18, a microstructure test lug is to be cast attached to the casting at the location designated on the casting drawing. The microstructure of the test lug shall be essentially ferritic and contain no massive carbides.

S2. Pressure Test, Casting Grade 65-45-15

S2.1 A hydrostatic test at a pressure agreed upon by the manufacturer and the purchaser shall be applied by the manufacturer.

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SPECIFICATION FOR WROUGHT AUSTENITIC STAINLESS STEEL PIPING FITTINGS



SA-403/SA-403M

(Identical with ASTM Specification A403/A403M-15 except for the correction of Table 2 Ni minimum for Grade WP S38815, the deletion of 5.14 and 5.15, clarified heat treatment requirements in 6.1 and 6.4, and the deletion of requirements for Grades 321 and 321H in Table 5.)

Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings

1. Scope

1.1 This specification covers wrought stainless steel fittings for pressure piping applications.

1.2 Several grades of austenitic stainless steel alloys are included in this specification. Grades are designated with a prefix, WP or CR, based on the applicable ASME or MSS dimensional and rating standards, respectively.

1.3 For each of the WP stainless grades, several classes of fittings are covered, to indicate whether seamless or welded construction was utilized. Class designations are also utilized to indicate the nondestructive test method and extent of nondestructive examination (NDE). Table 1 is a general summary of the fitting classes applicable to all WP grades of stainless steel covered by this specification. There are no classes for the CR grades. Specific requirements are covered elsewhere.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 This specification does not apply to cast steel fittings. Austenitic stainless steel castings are covered in Specifications A351/A351M, A743/A743M, and A744/A744M.

2. Referenced Documents

2.1 *ASTM Standards:*

A351/A351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A743/A743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

A744/A744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A960/A960M Specification for Common Requirements for Wrought Steel Piping Fittings

E112 Test Methods for Determining Average Grain Size

E165 Practice for Liquid Penetrant Examination for General Industry

2.2 *ASME Standards:*

ASME B16.9 Factory-Made Wrought Steel Butt-Welding Fittings

ASME B16.11 Forged Steel Fittings, Socket-Welding and Threaded

2.3 *MSS Standards:*

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings

MSS SP-79 Socket-Welding Reducer Inserts

MSS SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS SP-95 Swage(d) Nipples and Bull Plugs

MSS SP-97 Integrally Reinforced Forged Branch Outlet Fittings—Socket Welding, Threaded and Buttwelding Ends

TABLE 1 Fitting Classes for WP Grades

Class	Construction	Nondestructive Examination
S	Seamless	None
W	Welded	Radiography or Ultrasonic
WX	Welded	Radiography
WU	Welded	Ultrasonic

2.4 *ASME Boiler and Pressure Vessel Code:*
Section VIII Division I
Section IX

2.5 *AWS Standards:*

A 5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

A 5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

A 5.11 Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding

A5.14 Specification for Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

2.6 *ASNT:*

SNT-TC-1A (1984) Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Common Requirements and Ordering Information

3.1 Material furnished to this specification shall conform to the requirements of Specification A960/A960M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the common requirements of Specification A960/A960M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A960/A960M, this specification shall prevail.

3.2 Specification A960/A960M identifies the ordering information that should be complied with when purchasing material to this specification.

4. Material

4.1 The material for fittings shall consist of forgings, bars, plates, or seamless or welded tubular products that conform to the chemical requirements in Table 2. See Table 3 for a list of common names.

4.2 The steel shall be melted by one of the following processes:

4.2.1 Electric furnace (with separate degassing and refining optional),

4.2.2 Vacuum furnace, or

4.2.3 One of the former followed by vacuum or electroslag-consumable remelting.

4.3 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

4.4 *Grain Size*—Annealed Alloys UNS N08810 and UNS N08811 shall conform to an average grain size of ASTM No. 5 or coarser.

5. Manufacture

5.1 *Forming*—Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

5.2 All fittings shall be heat treated in accordance with Section 6.

5.3 Grade WP fittings ordered as Class S shall be of seamless construction and shall meet all requirements of ASME B16.9, ASME B16.11, MSS SP-79, MSS SP-83, MSS SP-95, or MSS SP-97.

5.4 Grade WP fittings ordered as Class W shall meet the requirements of ASME B16.9 and:

5.4.1 Shall have all pipe welds made by mill or the fitting manufacturer with the addition of filler metal radiographically examined throughout the entire length in accordance with the Code requirements stated in 5.5, and,

5.4.2 Radiographic inspection is not required on single longitudinal seam welds made by the starting pipe manufacturer if made without the addition of filler metal; and

5.4.3 Radiographic inspection is not required on longitudinal seam fusion welds made by the fitting manufacturer when all of the following conditions have been met:

5.4.3.1 No addition of filler metal,

5.4.3.2 Only one welding pass per weld seam, and,

5.4.3.3 Fusion welding from one side only.

5.4.4 In place of radiographic examination, welds made by the fitting manufacturer may be ultrasonically examined in accordance with the Code requirements stated in 5.6.

5.5 Grade WP fittings ordered as Class WX shall meet the requirements of ASME B16.9 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.6 Grade WP fittings ordered as Class WU shall meet the requirements of ASME B16.9 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, ultrasonically examined throughout their entire length in accordance with Appendix 12 of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

5.7 The radiography or ultrasonic examination of welds for this class of fittings may be done at the option of the manufacturer, either prior to or after forming.

5.8 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.9 Grade CR fittings shall meet the requirements of MSS SP-43 and do not require nondestructive examination.

TABLE 2 Chemical Requirements

NOTE 1—Where an ellipsis (...) appears in this table, there is no requirement and the element need neither be analyzed for or reported.

Grade ^A			Composition, %											Others
Grade WP	Grade CR	UNS Designation	C ^B	Mn ^B	P ^B	S ^B	Si ^B	Ni	Cr	Mo	Ti	N ^C		
WPXM-19	CRXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	...	0.20–0.40	^D	
WP20CB	CR20CB	N08020	0.07	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	...		Cu 3.0-4.0 Cb 8XC min, 1.00 max	
WP6XN	CR6XN	N08367	0.030	2.00	0.040	0.030	1.00	23.5–25.5	20.0–22.0	6.0–7.0	...	0.18–0.25	Cu 0.75	
WP700	CR700	N08700	0.04	2.00	0.040	0.030	1.00	24.0–26.0	19.0–23.0	4.3–5.0	...		Cu 0.50 Cb 8XC min	
WPNIC	CRNIC	N08800	0.10	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	0.15–0.60	...	Al 0.15–0.60 Cu 0.75	
WPNIC10	CRNIC10	N08810	0.05–0.10	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	0.15–0.60	...	Fe 39.5 min Al 0.15–0.60 Cu 0.75	
WPNIC11	CRNIC11	N08811	0.60–0.10	1.50	0.040	0.015	1.00	30.0–35.0	19.0–23.0	...	0.15–0.60	...	Fe 39.5 min Al 0.15–0.60 Cu 0.75	
WP904L	CR904L	N08904	0.020	2.00	0.045	0.035	1.00	23.0–28.0	19.0–23.0	4.0–5.0	...	0.10	Cu 1.0–2.0	
WP1925	CR1925	N08925	0.020	1.00	0.045	0.030	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	0.10–0.20	Cu 0.8-1.5	
WP1925N	CR1925N	N08926	0.020	2.00	0.030	0.010	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	0.15–0.25	Cu 0.5-1.5	
WP304	CR304	S30400	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
WP304L	CR304L	S30403	0.030 ^E	2.00	0.045	0.030	1.00	8.0–12.0	18.0–20.0	...	...	...	...
WP304H	CR304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
WP304N	CR304N	S30451	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	0.10–0.16	...
WP304LN	CR304LN	S30453	0.030	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	0.10–0.16	...
WP309	CR309	S30900	0.20	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...
WP310S	CR310S	S31008	0.08	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
WPS31254	CRS31254	S31254	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	...	0.18–0.25	Cu 0.50–1.00	
WPS31266	CRS31266	S31266	0.030	2.00–4.00	0.035	0.020	1.00	21.00–24.00	23.00–25.00	5.2–6.2	...	0.35–0.60	Cu 1.00–2.50 W 1.50–2.50	
WP316	CR316	S31600	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
WP316L	CR316L	S31603	0.030 ^E	2.00	0.045	0.030	1.00	10.0–14.0 ^F	16.0–18.0	2.00–3.00	...	...	...
WP316H	CR316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00-3.00	...	...	...
WP316N	CR316N	S31651	0.08	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	...	0.10-0.16	...	
WP316LN	CR316LN	S31653	0.030	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	...	0.10–0.16	...	
WP317	CR317	S31700	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
WP317L	CR317L	S31703	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
WPS31725	CRS31725	S31725	0.030	2.00	0.045	0.030	1.00	13.5–17.5	18.0–20.0	4.0–5.0	...	0.20	...	
WPS31726	CRS31726	S31726	0.030	2.00	0.045	0.030	1.00	13.5–17.5	17.0–20.0	4.0–5.0	...	0.10–0.20	...	
WPS31727	CRS31727	S31727	0.030	1.00	0.030	0.030	1.00	14.5–16.5	17.5–19.0	3.8–4.5	...	0.15–0.21	Cu 2.8–4.0	
WPS31730	CRS31730	S31730	0.030	2.00	0.040	0.010	1.00	15.0–16.5	17.0–19.0	3.0–4.0	...	0.045	Cu 4.0–5.0	
WPS32053	CRS32053	S32053	0.030	1.00	0.030	0.010	1.00	24.0–26.0	22.0–24.0	5.0–6.0	...	0.17–0.22	...	
WP321	CR321	S32100	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	^G	...	...
WP321H	CR321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	^H	...	...
WPS33228	CRS33228	S33228	0.04–0.08	1.00	0.020	0.015	0.30	31.0–33.0	26.0–28.0	...	...	...	Ce 0.05–0.10 Al 0.025

TABLE 2 Continued

Grade ^A			Composition, %										
Grade WP	Grade CR	UNS Designation	C ^B	Mn ^B	P ^B	S ^B	Si ^B	Ni	Cr	Mo	Ti	N ^C	Others
WPS34565	CRS34565	S34565	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	...	0.40–0.60	Cb 0.6–1.0 Cb 0.10
WP347	CR347	S34700	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	I
WP347H	CR347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	J
WP347LN	CR347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	9.0–13.0	17.0–19.0	...	...	...	Cb 0.20–0.50, ^K N 0.06–0.10 ^C
WP348	CR348	S34800	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	Cb+Ta=10×(C)–1.10 Ta 0.10 Co 0.20
WP348H	CR348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	Cb+Ta=8×(C)–1.10 Ta 0.10 Co 0.20
WPS38815	CRS38815	S38815	0.030	2.00	0.040	0.020	5.5–6.5	15.0–17.0	13.0–15.0	0.75–1.50	...	...	Cu 0.75–1.50 Al 0.30

^A See Section 15 for marking requirements.

^B Maximum, unless otherwise indicated.

^C The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

^D Columbium 0.10–0.30 %; Vanadium, 0.10–0.30 %.

^E For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.24 mm] in average wall thickness.

^F On pierced tubing, the nickel may be 11.0–16.0 %.

^G 5X(C+N) min–0.70 max.

^H 4X(C+N) min–0.70 max.

^I The columbium content shall be not less than ten times the carbon content and not more than 1.10 %.

^J The columbium content shall be not less than eight times the carbon content and not more than 1.10 %.

^K The columbium content shall be not less than 15 times the carbon content.

TABLE 3 Common Names

Grade WP ^A	Grade CR ^A	UNS Designation	Type ^B
WPXM-19	CRXM-19	S20910	XM-19 ^C
WP20CB	CR20CB	N08020	...
WP6XN	CR6XN	N08367	...
WP700	CR700	N08700	...
WPNIC	CRNIC	N08800	800 ^C
WPNIC10	CRNIC10	N08810	800H ^C
WPNIC11	CRNIC11	N08811	...
WP904L	CR904L	N08904	904L ^C
WP1925	CR1925	N08925	...
WP1925N	CR1925N	N08926	...
WP304	CR304	S30400	304
WP304L	CR304L	S30403	304L
WP304H	CR304H	S30409	304H
WP304N	CR304N	S30451	304N
WP304LN	CR304LN	S30453	304LN
WP309	CR309	S30900	309
WP310S	CR310S	S31008	310S
WPS31254	CRS31254	S31254	...
WPS31266	CRS31266	S31266	...
WP316	CR316	S31600	316
WP316L	CR316L	S31603	316L
WP316H	CR316H	S31609	316H
WP316N	CR316N	S31651	316N
WP316LN	CR316LN	S31653	316LN
WP317	CR317	S31700	317
WP317L	CR317L	S31703	317L
WPS31725	CRS31725	S31725	317LM ^C
WPS31726	CRS31726	S31726	317LMN ^C
WPS31727	CRS31727	S31727	...
WPS31730	CRS31730	S31730	...
WPS32053	CRS32053	S32053	...
WP321	CR321	S32100	321
WP321H	CR321H	S32109	321H
WPS33228	CRS33228	S33228	...
WPS34565	CRS34565	S34565	...
WP347	CR347	S34700	347
WP347H	CR347H	S34709	347H
WP347LN	CR347LN	S34751	347LN
WP348	CR348	S34800	348
WP348H	CR348H	S34809	348H
WPS38815	CRS38815	S38815	...

^A Naming system developed and applied by ASTM International.

^B Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).

^C Common name, not a trademark widely used, not associated with any one producer.

5.10 All fittings shall have the welders, welding operators, and welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code except that starting pipe welds made without the addition of filler metal do not require such qualification.

5.11 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.12 Fittings machined from bar shall be restricted to NPS 4 or smaller. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.12.1 All caps machined from bar shall be examined by liquid penetrant in accordance with Supplementary Requirement S52 in Specification A960/A960M.

5.13 Weld buildup is permitted to dimensionally correct unfilled areas produced during cold forming of stub ends.

Radiographic examination of the weld buildup shall not be required provided that all the following steps are adhered to:

5.13.1 The weld procedure and welders or welding operators meet the requirements of 5.10.

5.13.2 Annealing is performed after welding and prior to machining.

5.13.3 All weld surfaces are liquid penetrant examined in accordance with Appendix 8 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.13.4 Repair of areas in the weld is permitted, but 5.13.1, 5.13.2, and 5.13.3 must be repeated.

5.14 DELETED

5.15 DELETED

5.16 After final heat treatment, all "H-Grade" steel fittings shall have a grain size of 7 or coarser in accordance with Test Methods E112.

6. Heat Treatment

6.1 All fittings shall be furnished in the heat-treated condition. For H grades, including Grade S33228, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The heat-treat procedure, except for those grades listed in 6.2, shall consist of solution annealing the fittings at the temperatures listed for each grade in Table 4 until the chromium carbides go into solution, and then cooling at a sufficient rate to prevent reprecipitation.

6.2 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in 321, 321H,

TABLE 4 Heat Treatment

Grade WP ^A	Grade CR ^A	UNS Designation	Solution Anneal Temperature, min °F [°C] ^B	Quench Media
WPXM-19	CRXM-19	S20910	1900 [1040]	water or other rapid cool
WP20CB	CR20CB	N08020	1700–1850 [927–1010]	water or other rapid cool
WP6XN	CR6XN	N08367	2025 [1107]	water or other rapid cool
WP700	CR700	N08700	2025–2100 [1107–1150]	water or other rapid cool
WPNIC	CRNIC	N08800	1800–1900 [983–1038] ^C	water or other rapid cool
WPNIC10	CRNIC10	N08810	2100–2150 [1147–1177] ^C	water or other rapid cool
WPNIC11	CRNIC11	N08811	2100–2150 [1147–1177] ^C	water or other rapid cool
WP904L	CR904L	N08904	1985–2100 [1085–1150]	water or other rapid cool
WP1925	CR1925	N08925	1800–1900 [983–1038]	water or other rapid cool
WP1925N	CR1925N	N08926	2150 [1177]	water or other rapid cool
WP304	CR304	S30400	1900 [1040]	water or other rapid cool
WP304L	CR304L	S30403	1900 [1040]	water or other rapid cool
WP304H	CR304H	S30409	1900 [1040]	water or other rapid cool
WP304N	CR304N	S30451	1900 [1040]	water or other rapid cool
WP304LN	CR304LN	S30453	1900 [1040]	water or other rapid cool
WP309	CR309	S30900	1900 [1040]	water or other rapid cool
WP310S	CR310S	S31008	1900 [1040]	water or other rapid cool
WPS31254	CR31254	S31254	2100 [1150]	water or other rapid cool
WPS31266	CRS31266	S31266	2100 [1150]	water or other rapid cool
WP316	CR316	S31600	1900 [1040]	water or other rapid cool
WP316L	CR316L	S31603	1900 [1040]	water or other rapid cool
WP316H	CR316H	S31609	1900 [1040]	water or other rapid cool
WP316N	CR316N	S31651	1900 [1040]	water or other rapid cool
WP316LN	CR316LN	S31653	1900 [1040]	water or other rapid cool
WP317	CR317	S31700	1900 [1040]	water or other rapid cool
WP317L	CR317L	S31703	1900 [1040]	water or other rapid cool
WPS31725	CRS31725	S31725	1900 [1040]	water or other rapid cool
WPS31726	CRS31726	S31726	1900 [1040]	water or other rapid cool
WPS31727	CRS31727	S31727	1975–2155 [1080–1180]	water or other rapid cool
WPS31730	CRS31730	S31730	1900 [1040]	water or other rapid cool
WPS32053	CRS32053	S32053	1975–2155 [1080–1180]	water or other rapid cool
WP321	CR321	S32100	1900 [1040]	water or other rapid cool
WP321H	CR321H	S32109	1925 [1050]	water or other rapid cool
WPS33228	CRS33228	S33228	2050–2160 [1120–1180]	water or other rapid cool
WPS34565	CRS34565	S34565	2050–2140 [1120–1170]	water or other rapid cool
WP347	CR347	S34700	1900 [1040]	water or other rapid cool
WP347H	CR347H	S34709	1925 [1050]	water or other rapid cool
WP347LN	CR347LN	S34751	1900 [1040]	water or other rapid cool
WP348	CR348	S34800	1900 [1040]	water or other rapid cool
WP348H	CR348H	S34809	1925 [1050]	water or other rapid cool
WPS38815	CRS38815	S38815	1950 [1065]	water or other rapid cool

^ANaming system developed and applied by ASTM International.

^BWhere a range of temperature is not listed, the single value shown shall be the minimum required temperature.

^CHeat Treatment is highly dependent on intended service temperature; consult material manufacturer for specific heat treatments for end use temperature.

347, and 347H. When specified by the purchaser a lower temperature stabilization or resolution anneal shall be used subsequent to the initial high-temperature solution anneal (see Supplementary Requirement S2).

6.3 All welding shall be done prior to heat treatment.

6.4 Fittings machined directly from solution-annealed forgings and bar stock that were solution annealed in accordance with 6.1 need not be resolution annealed.

7. Chemical Composition

7.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective grades of materials listed in Table 2. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for starting materials

(pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification. Methods and practices relating to chemical analyses required by this specification shall be in accordance with Test Methods, Practices, and Terminology A751. Product analysis tolerances in accordance with Specification A960/A960M are applicable.

7.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7.3 In fittings of welded construction, the alloy content (carbon, chromium, nickel, molybdenum, columbium, and tantalum) of the deposited weld metal shall conform to that required of the base metal or for equivalent weld metal as given in the AWS filler metal specification A 5.4 or A 5.9 (Type 348 weld metal is listed in AWS A 5.9 but not in AWS A 5.4). Exceptions are when welding on Types 304L and 304 base metals, the deposited weld metal shall correspond, respectively, to AWS E308L(ER308L) and E308 (ER308), when welding on Type 321 base metal, the weld metal shall correspond to AWS Type E347 (ER347 or ER321); and, when welding on S31725, S31726, S31254, S31266, or S33228 deposited weld metal shall correspond either to the alloy content of the base metal or to AWS A5.11 E NiCrMo-3 (UNS W86112) (AWS A5.14 Ni Cr Mo-3 (UNS N06625)), and when welding on S31730, deposited weld metal and filler metal used shall correspond either to the alloy content of the base metal or to AWS A5.14 ERNiCr-3 (UNS N06082), or ERNiCrMo-3 (UNS N06625), or ERNiCrMo-4 (UNS N10276). On S38815 base metals, the deposited weld metal and filler metal used shall be agreed upon between purchaser and manufacturer. In fittings of welded construction made from predominantly ferrous alloys N08020, N08367, N08700, N08800, N08810, N08811, N08904, N08925 & N08926, the alloy content of the deposited weld metal shall conform to that required of the base metal or for the equivalent weld metal given in the AWS Filler Metal Specification A5.11 and A5.14. However, it is possible that weld deposit chemistry will not meet the limits of either the base metal or the filler metal for some elements. The weld deposit chemistry shall meet the lowest minimum and highest maximum values for each specification element in either of the base metal or filler metal specification. Dilution of the base and filler metal must be considered when determining weld deposit criteria for over-alloyed filler metals.

7.3.1 Supplementary Requirement S1 may be specified where 16-8-2 filler metal is required for joining thick sections of Types 316, 321, or 347 and has adequate corrosion resistance for the intended service.

8. Tensile Properties

8.1 The tensile properties of the fitting material shall conform to the requirements of Table 5. The testing and reporting shall be performed in accordance with Specification A960/A960M.

8.1.1 Specimens cut either longitudinally or transversely shall be acceptable for the tensile test.

8.1.2 While Table 5 specifies elongation requirements for both longitudinal and transverse specimens, it is not the intent

TABLE 5 Tensile Requirements

All WP and CR Grades	Yield Strength, min,	Tensile Strength, min,
	ksi [MPa]	ksi [MPa]
304, 304LN, 304H, 309, 310S, 316, 316LN, 316H, 317, 317L, 321, 321H, 347, 347H, 347LN, 348, 348H	30 [205]	75 [515]
S31266	61 [420]	109 [750]
S31725		
S31727	36 [245]	80 [550]
S31730	25 [175]	70 [480]
S32053	43 [295]	93 [640]
304L, 316L	25 [170]	70 [485]
304N, 316N, S31726	35 [240]	80 [550]
XM-19	55 [380]	100 [690]
N08020	35 [240]	80 [550]
N08367	45 [310]	95 [655]
N08700	35[240]	80[550]
N08800	25 [205]	65 [520]
N08810	25 [170]	65 [450]
N08811	25 [170]	65 [450]
N08904	31 [220]	71 [490]
N08925	43[295]	87 [600]
N08926	43 [295]	94 [650]
S31254	44 [300]	94 [650] to 119 [820]
S33228	27 [185]	73 [500]
S34565	60 [415]	115 [795]
S38815	37 [255]	78 [540]
Elongation Requirements		
	Longitudinal	Transverse
Standard round specimen, or small proportional specimen, or strip- type specimen, minimum % in 4 D ^A	28	20

^A S38815 Elongation in 2 in. — 30 % min.

that both requirements apply simultaneously. Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable.

8.2 Records of the tension test made on the starting material shall be certification that the material of the fitting meets the requirements of this specification provided that heat treatments are the same.

8.3 If the raw material was not tested, or if the heat treatment of the raw material was different than the heat treatment of the fitting, the fitting manufacturer shall perform at least one tension test per heat on material representative of the fitting, and in the same condition of heat treatment as the fitting it represents. Qualification of welding procedures shall be in accordance with 5.8.

8.4 If a tension test through the weld is desired, Supplementary Requirement S51 in Specification A960/A960M should be specified.

9. Hydrostatic Tests

9.1 Hydrostatic testing is not required by this specification.

9.2 All Grade WP fittings shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test

pressure equal to that prescribed for the specified matching pipe or equivalent material.

9.3 All Grade CR fittings, except tees covered in 9.3.1, shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure based on the ratings in MSS SP-43.

9.3.1 Grade CR tees fabricated using intersection welds shall be capable of passing a hydrostatic test based on 70 % of the ratings in MSS SP-43.

10. Surface Finish, Appearance, and Corrosion Protection

10.1 The requirements of Specification A960/A960M apply except as modified as follows:

10.2 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5 % of the specified nominal wall thickness, except as defined in 10.4 and 10.5, and shall have a workmanlike finish.

10.3 Surface discontinuities deeper than 5 % of the specified nominal wall thickness, except as defined in 10.4 and 10.5, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½ % of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

10.4 Surface checks (fish scale) deeper than ¼ in. [0.4 mm] shall be removed.

10.5 Mechanical marks deeper than ⅛ in. [1.6 mm] shall be removed.

10.6 When the removal of a surface discontinuity reduces the wall thickness below 87½ % of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 11.

11. Repair by Welding

11.1 Repair of unacceptable imperfections in the base metal is permissible for fittings made to the dimensional standards listed in 1.1 or for other standard fittings made for stock by the manufacturer. Prior approval of the purchaser is required to repair special fittings made to the purchaser's requirements. Welding of unacceptable imperfections in no case shall be permitted when the depth of defect exceeds 33⅓ % of the nominal wall thickness or the defect area exceeds 10 % of the surface area of the fitting.

11.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

11.3 The composition of the weld deposits shall be in accordance with 7.3 and in accordance with the procedure qualification for the applicable material.

11.4 Unacceptable imperfections shall be removed by mechanical means or by thermal cutting or gouging methods. Cavities prepared for welding shall be examine with liquid

penetrant in accordance with Practice E165. No cracks are permitted in the prepared cavities. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A

11.5 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code.

11.6 Weld repair area(s) shall be blended uniformly to those base metal and shall be examined by liquid penetrant in accordance with Practice E165. No cracks are permitted in the weld or surrounding ½ in. [12.7 mm] of base metal. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

11.7 After weld repair, material shall be heat treated in accordance with Section 6.

11.8 The fittings shall be free of scale and shall be passivated.

12. Dimensions

12.1 For fittings covered by ASME B16.9, ASME B16.11, MSS SP-43, MSS SP-79, MSS SP-83, MSS SP-95, or MSS SP-97, the sizes, shapes, and dimensions of the fittings shall be as specified in those standards.

12.1.1 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification, may be furnished in accordance with Supplementary Requirement S58 Specification A960/A960M.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for rehearing.

13.2 Fittings that develop defects in shop working or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

14. Certification

14.1 Test reports are required for all fittings covered by this specification. Each test report shall meet the requirements for certification in Specification A960/A960M as well as include the following information specific to this specification:

14.1.1 Chemical analyses results for all starting materials, Section 7 (Table 2), reported results shall be to the same number of significant figures as the limits specified in Table 2 for that element,

14.1.2 Tensile property results of all starting materials, Section 8 (Table 5), report the yield strength and the tensile strength in ksi [MPa] and elongation in percent,

14.1.3 For construction with filler metal added, weld metal chemical analysis,

14.1.4 For welded fittings, construction method, weld process and procedure specification number,

14.1.5 Type heat treatment, Section 6 (Table 4),

14.1.6 Results of all nondestructive examinations, and

14.1.7 Any supplementary testing required by the purchase order.

15. Product Marking

15.1 In addition to marking requirements of Specification A960/A960M, the following additional marking requirements shall apply:

15.1.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting. See Table 6 for marking examples of grades and classes.

15.1.2 Marking paint or ink shall not contain harmful amounts of chlorides, metals, or metallic salt, such as zinc or copper, that cause corrosive attack on heating. On wall thicknesses thinner than 0.083 in. [2.1 mm], no metal impression stamps shall be used. Vibrating pencil marking is acceptable.

TABLE 6 Product Marking Examples for Grades and Classes

Grade and Class Marking	Description
CR304 CR304/304L	Single grade: No classes in CR grades Multiple grades, meet chemical and mechanical properties of each
WP304-S WP304-W	Single Grade: seamless Single Grade; welded : RT or UT pipe welds with filler metal and all fitting manufacturer's welds
WP304-WX	Single grade: welded: RT all welds with or without filler metal
WP304-WU	Single grade; welded: UT all welds with or without filler metal
WP304-304L-S	Multiple grades: meet chemical and mechanical properties of each: seamless

15.1.3 Threaded or socket-welding fittings shall be additionally marked with the pressure class. Plugs and bushings furnished to ASME B16.11 requirements are not required to be marked. The class S marking need not be added to the material grade for threaded or socket-welded fittings.

15.1.4 When agreed upon between the purchaser and producer, and specified in the order, the markings shall be painted or stenciled on the fitting or stamped on a metal or plastic tag which shall be securely attached to the fitting.

15.1.5 Fittings meeting the chemical and mechanical property requirements of Table 2 and Table 5 for more than one grade designation may be marked with more than one class or grade designation, such as WP304/304H; WP304/304L; WP304/304L/304N, WP316/316L, etc.

15.2 *Bar Coding*—In addition to the requirements in 15.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

16. Keywords

16.1 austenitic stainless steel; corrosive service applications; pipe fittings; steel; piping applications; pressure containing parts; stainless steel fittings

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below or appearing in Specification A960/A960M may be included in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. Special Filler Metal

S1.1 Filler metal shall be AWS Type E16-8-2 or ER 16-8-2 (AWS Specifications A 5.4 and A 5.9, respectively). Fittings welded with 16-8-2 weld metal shall be marked WP ___ HRW or CR ___ HRW, as appropriate.

S2. Stabilization Treatment

S2.1 Subsequent to the solution anneal required by 6.2, Grades 321, 321H, 347, 347H, 348, and 348H shall be given a stabilization heat treatment at 1500 to 1600 °F [815 to 870 °C]

for a minimum of 2h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 15, the grade designation symbol shall be followed by the symbol "S2."

SPECIFICATION FOR WELDED LARGE DIAMETER AUSTENITIC STEEL PIPE FOR CORROSIVE OR HIGH-TEMPERATURE SERVICE



SA-409/SA-409M

(Identical with ASTM Specification A409/A409M-15 except for clarified heat treatment requirements for H grade stainless steels and S30815 in para. 5.3.1, deletion of 5.3.2.2 and 5.3.2.3 for the non-heat treated pipe provisions, and the inclusion of a grain size requirement in para. 5.1.1 for H grade stainless steels and S30815. A requirement for ASME Stamping has been added and additional requirements apply as shown in the subtitle of the specification.)

All products furnished under this SA specification are intended for application under the rules of Section III for Class 3 Piping or for application under the rules of Section VIII-1. Furnishing of such products is limited to manufacturers who hold the appropriate ASME Certification Mark. Weld procedures, welders, and welding machine operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX. The product shall meet all applicable requirements of Class 3 piping or Section VIII, if applicable including those requirements pertaining to heat treatment and butt welds. Authorized inspection at the point of manufacture and application of the appropriate Certification Mark is required.

The applicable ASME partial data report form, signed by an authorized inspector, and a certified mill test report shall be furnished for each lot of pipe. The term "lot" applies to all pipe of the same mill heat of material and wall thickness which is heat treated in one furnace charge. For pipe which is not heat treated or which is heat treated in a continuous furnace, a lot shall consist of each 200 ft [61 m] or fraction thereof of all pipe of the same mill heat of material and wall thickness, subjected to the same heat treatment. For pipe which is heat treated in a batch-type furnace which is automatically controlled within a 50°F range and is equipped with recording pyrometer so that the heating records are available, a lot may be defined the same as for continuous furnaces. Each length of pipe shall be marked in such a manner as to identify each such piece with the "lot" and the representative certified mill test report.

Standard Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service

1. Scope

1.1 This specification covers straight seam or spiral seam electric-fusion-welded, light-wall, austenitic chromium-nickel alloy steel pipe for corrosive or high-temperature service. The sizes covered are NPS 14 to 30 with extra light (Schedule 5S) and light (Schedule 10S) wall thicknesses. Table X1.1 shows the wall thickness of Schedule 5S and 10S pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.2 Several grades of alloy steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided. These call for additional tests to be made, and when desired shall be stated in the order, together with the number of such tests required.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as *nominal diameter*, *size*, and *nominal size*.

2. Referenced Documents

2.1 ASTM Standards:

A262 Practices for Detecting Susceptibility to Intergranular

Attack in Austenitic Stainless Steels

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 ASME Boiler and Pressure Vessel Code: Section IX

2.3 AWS Standards:

A 5.22 Flux Cored Arc Welding

A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding

A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes

A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

2.4 Other Standard:

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (straight seam or spiral seam electric-fusion-welded austenitic steel pipe),

3.1.3 Grade (Table 1),

TABLE 1 Chemical Requirements

UNS Designations ^A	Composition, %												
	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium	Cerium	Other Elements	
TP201	S20100	0.15	5.5–7.5	0.060	0.030	1.00	3.5–5.5	16.0–18.0	...	...	...	N 0.25
TP201LN	S20153	0.03	6.4–7.5	0.045	0.015	0.75	4.0–5.0	16.0–17.5	...	...	...	N 0.10–0.25, Cu 1.00
TP304	S30400	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...
TP304L	S30403	0.035	2.00	0.045	0.030	1.00 max	8.0–12.0	18.0–20.0	...	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00 max	12.0–16.0	22.0–24.0	...	...	...	Cb 10 × C min, 1.10 max
TP309S	S30908	0.08	2.00	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	...	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	Cb 10 × C min, 1.10 max
TP310S	S31008	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	...
TP316	S31600	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
TP316L	S31603	0.035	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
...	S31727	0.030	1.00	0.030	0.030	1.00 max	14.5–16.5	17.5–19.0	3.8–4.5	...	...	N 0.15–0.21 Cu 2.8–4.0
...	S32053	0.030	1.00	0.030	0.010	1.00 max	24.0–26.0	22.0–24.0	5.0–6.0	...	...	N 0.17–0.22
TP321	S32100	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–20.0	...	^B	...	...
TP347	S34700	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	...	^C	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	...	^D	...
...	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–19.5	6.0–6.5	...	...	Cu 0.50–1.00 N 0.18–0.25
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	N 0.14–0.20
...	S31725	0.030	2.00	0.045	0.030	1.00 max	13.5–17.5	18.0–20.0	4.0–5.0	...	...	N 0.020 max
...	S31726	0.030	2.00	0.045	0.030	1.00 max	14.5–17.5	17.0–20.0	4.0–5.0	...	...	N 0.10–0.20
...	S34565	0.030	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	...	0.10 max	N 0.40–0.60	
...	N08367	0.030	2.00	0.040	0.030	1.00 max	23.5–25.5	20.0–22.0	6.0–7.0	...	...	Cu 0.75 max Ni 0.18–0.25
...	S20400	0.030	7.0–9.0	0.45	0.030	1.00 max	1.50–3.00	15.0–17.0	...	...	...	N 0.15–0.30
...	S31266	0.030	2.00–4.00	0.035	0.020	1.00 max	21.0–24.0	23.0–25.0	5.2–6.2	...	...	Cu 1.00–2.50 W 1.50–2.50 N 0.35–0.60

^A New designation established in accordance with ASTM E527 and SAE J1086.

^B The titanium content shall be not less than 5 times the carbon content and not more than 0.70 %.

^C The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.10 %.

^D The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.10 %. The tantalum content shall be 0.10 % maximum, Co 0.20 % maximum.

3.1.4 Size (outside diameter and schedule number, or wall thickness).

3.1.5 Length (specific or random) (Section 11),

3.1.6 End finish (Section on Ends of Specification A999/A999M),

3.1.7 Optional requirements (5.2.1 – 5.2.3 removal of weld bead; 5.3.2, special heat treatment; 15.2, nondestructive test; 10.1.1, outside diameter tolerance; 11.2, length circumferentially welded; 12.3, repair by welding and heat treatment subsequent to repair welding; 12.4, sand blasted or pickled; 17.1 Certification; Supplementary Requirements S1 to S6).

3.1.8 Specification designation, and

3.1.9 Special requirements.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 If a specific type of melting is required by the purchaser it shall be stated on the order.

5.1.1 The grain size for all H grades and S30815 shall be No. 7 or coarser, when determined according to ASTM E112 Test Methods.

5.2 Welding:

5.2.1 The welds shall be made by the manual or automatic electric-welding process. For manual welding, the operator and procedure shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. Unless otherwise specified on the purchase order, the pipe may be welded with or without filler metal when the automatic electric-welding process is used.

5.2.2 The weld surface on either side of the weld may be flush with the base plate or may have a reasonably uniform crown, not to exceed $\frac{1}{16}$ in. [2 mm]. Any weld reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement should be reasonably smooth and free from irregularities. The weld metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

5.2.3 Weld defects, as determined by specified inspection requirements, shall be repaired by removal to sound metal and rewelding.

5.3 Heat Treatment:

5.3.1 Except as provided in 5.3.2, all pipe shall be furnished in the heat-treated condition. For H grades and S30815, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution heat treatments. The heat-treatment procedure shall consist of heating the material to a minimum temperature of 1900 °F [1040 °C], except for S31254, S31266, and S30815 which shall be heat treated to 2100 °F [1150 °C] and 1920 °F [1050 °C] respectively, S31727 and S32053 which shall be heat treated in the range 1975 to 2155 °F [1080 to 1180 °C], S34565 which shall be heat treated in the range 2050 °F [1120 °C] to 2140 °F [1170 °C], and N08367, which shall be heated to a minimum temperature of 2025 °F [1107 °C], all materials to be followed by quenching in water or rapidly cooling by other means.

5.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 5.3.1 is not desired by the purchaser:

5.3.2.1 A final heat-treatment temperature under 1900 °F [1040 °C]. Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix "HT." Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

5.3.2.2 DELETED

5.3.2.3 DELETED

5.4 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP347, and TP348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

6. Chemical Composition

6.1 The steel shall conform to the chemical composition in Table 1.

6.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A480/A480M shall apply.

6.3 Unless otherwise specified in the purchase order, the chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 2. Grades with no filler metal classification indicated shall be welded with filler metals producing deposited weld metal having a composition in

accordance with the chemical composition specified in Table 1. The method of analysis for nitrogen and cerium shall be a matter of agreement between the purchaser and manufacturer. The purchaser may choose a higher-alloy filler metal when needed for corrosion resistance.

7. Tensile Requirements

7.1 The tensile properties of the plate or sheet used in making the pipe shall conform to the requirements prescribed in Table 3. Certified mill test reports shall be submitted to the pipe manufacturer.

7.2 A transverse tension test taken across the welded joint of the finished pipe shall meet the same minimum tensile strength requirements as the sheet or plate. The weld section on the tension specimen shall be in the same condition as the finished pipe (with or without bead as specified).

8. Mechanical Tests Required

8.1 *Tension Test*—One transverse tension test of the weld shall be made on each lot (Note 2) of finished pipe.

NOTE 2—The term "lot" applies to each 200 ft [60 m] or less of pipe of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge. When no heat treatment is performed following final forming operations, the lot shall include each 200 ft [60 m] or less of pipe of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel.

8.2 *Transverse Guided-Bend Weld Test*—One test (two specimens) of the weld shall be made on each lot (Note 2) of finished pipe.

8.3 *Pressure or Nondestructive Electric Test*—Each length of pipe shall be subjected to a pressure test or a nondestructive electric test as prescribed in Section 5.

9. Permissible Variations in Wall Thickness

9.1 The minimum wall thickness at any point shall not be more than 0.018 in. [0.46 mm] under the specified wall thickness. (This tolerance is slightly more than commercial tolerances on sheet and plate to allow for possible loss of thickness caused by manufacturing operations.)

10. Permissible Variations in Dimensions

10.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

10.1.1 *Specified Diameter*—Where the specified wall thickness is less than 0.188 in. [4.8 mm], the actual outside diameter, based on circumferential measurement, shall not vary more than $\pm 0.20\%$ from the specified outside diameter. Where the specified wall thickness is 0.188 in. [4.8 mm] and heavier, the actual outside diameter, based on circumferential measurement, may vary a maximum of $\pm 0.40\%$ from the specified outside diameter. (Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.)

10.1.2 *Out-of-Roundness*—The difference between the major and the minor outside diameter shall not be more than 1.5 % of the specified outside diameter.

TABLE 2 Filler Metal Specifications

Grade	UNS Designation	Filler Metal Classification and UNS Designation ^A for Applicable ^B AWS Specification											
		A5.4		A5.9		A5.11		A5.14		A5.22		A5.30	
		Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
TP201	S20100	...	...	...	...	...	...	...	...	...	...	...	...
TP201LN	S20153	...	...	...	...	...	...	...	...	...	...	...	...
TP304	S30400	E308	W30810	ER308	S30880 W30840	...	...	...	...	E308T	W30831	IN308	S30880
TP304L	S30403	E308L	W30813	ER308L	S30883 W30843	...	...	...	...	E308T	W30835	IN308L	S30883
TP309Cb	S30940	E309Cb	W30917	...	...	...	...	...	...	...	...	...	...
TP310Cb	S31040	E310Cb	W31017	...	...	...	...	...	...	...	...	...	...
TP316	S31600	E316	W31610	ER316	S31680 W31640	...	...	...	...	E316T	W31631	IN316	S31680
TP316L	S31603	E316L	W31603	ER316L	S31683 W31643	...	...	...	...	E316LT	W31635	IN316L	S31683
TP317	S31700	E317	W31700	ER317	S31783 W31743	...	...	...	...	E317T	W31731	IN317	S31780
...	S31727	...	...	...	...	...	...	...	...	...	...	...	...
...	S32053	...	...	...	...	...	...	...	...	...	...	...	...
TP321	S32100	E347	W34710	ER321 ER347	S32180 W32140 S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
TP347	S34700	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
TP348	S34800	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
...	S31254	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	...	...	...	...
...	S31725	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	...	...	...	...
...	S31726	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	...	...	...	...
...	S34565	...	...	...	...	...	...	...	...	...	...	...	...
...	N08367	...	...	...	...	ENiCrMo-3	W86112	ErNiCrMo-3	NO6625	...	...	...	...
...	S20400	E209	W32210	ER209	W32240	...	...	...	...	...	...	...	...
...	S31266	...	...	...	...	ENiCrMo-4	W80276	ERNiCrMo-4	N10276	...	...	...	...
...	...	...	...	...	...	ENiCrMo-10	W86022	ERNiCrMo-10	NO6022	...	...	...	...
...	...	...	...	...	...	ENiCrMo-13	W86059	ERNiCrMo-13	NO6059	...	...	...	...
...	...	...	...	...	...	ENiCrMo-14	W86026	ERNiCrMo-14	NO6686	...	...	...	...
...	...	...	...	...	...	ENiCrMo-17	W86200	ERNiCrMo-17	NO6200	...	...	...	...

^ANew designation established in accordance with Practice E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

^BChoice of American Welding Society specification depends on the welding process used.

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]		Yield Strength, min, ksi [MPa]	
		min, ksi [MPa]	min, ksi [MPa]	min, ksi [MPa]	min, ksi [MPa]
TP201	S20100	75 [515]	38 [260]	75 [515]	38 [260]
TP201LN	S20153	95 [655]	45 [310]	95 [655]	45 [310]
TP304	S30400	75 [515]	30 [205]	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]	70 [485]	25 [170]
TP309Cb	S30940	75 [515]	30 [205]	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]	70 [485]	25 [170]
TP317	S31700	75 [515]	30 [205]	75 [515]	30 [205]
...	S31727	80 [550]	36 [245]	80 [550]	36 [245]
...	S32053	93 [640]	43 [295]	93 [640]	43 [295]
TP321	S32100	75 [515]	30 [205]	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]	75 [515]	30 [205]
...	S31254	94 [650]	44 [300]	94 [650]	44 [300]
...	S30815	87 [600]	45 [310]	87 [600]	45 [310]
...	S31725	75 [515]	30 [205]	75 [515]	30 [205]
...	S31726	80 [550]	35 [240]	80 [550]	35 [240]
...	S34565	115 [795]	60 [415]	115 [795]	60 [415]
...	S20400	95 [655]	48 [330]	95 [655]	48 [330]
...	N08367	...	...	...	...
...	t ≤ 0.187	100 [690]	45 [310]	100 [690]	45 [310]
...	t > 0.187	95 [655]	45 [310]	95 [655]	45 [310]
...	S31266	109 [750]	61 [420]	109 [750]	61 [420]

10.1.3 *Alignment (Camber)*—Using a 10-ft [3.0-m] straight-edge placed so that both ends are in contact with the pipe, the camber shall not be more than 3/16 in. [4.8 mm].

11. Lengths

11.1 Unless otherwise specified in the purchase order, pipe of NPS 22 or less will be furnished in random lengths of 9 to 12 ft (Note 3). For outside diameters of over NPS 22, the minimum length will be 5 ft (Note 3).

NOTE 3—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. The corresponding metric value(s) shall be agreed upon between the manufacturer and the purchaser.

11.2 When specified by the purchaser, two or more lengths may be circumferentially welded together to produce longer lengths.

11.3 Circumferentially welded joints shall be of the same quality as the longitudinal joints.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall have a workmanlike finish.

12.2 *Repair of Defects by Machining or Grinding*—Pipe showing moderate slivers or other surface defects may be machined or ground inside or outside to a depth which will

ensure the removal of all defects providing the wall thickness is not reduced below the minimum specified in 9.1.

12.3 *Repair of Defects by Welding*—Defects which violate minimum wall thickness may be repaired by welding, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 5.3 shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than $\frac{1}{4}$ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable non-destructive examination techniques, including any techniques specifically required of the primary weld.

12.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

13. Test Specimens

13.1 Transverse tension and bend test specimens may be taken from a test plate of the same material as the pipe, made by attaching a formed cylinder to the end of the pipe and welding the abutting edges as a continuation and duplication of the seam of the pipe (run-off plate). As an alternative to a formed cylinder, the run-off plate may consist of flat plates with reinforcing bars clamped to the underside to prevent distortion. The run-off plate material shall be of the same heat, preferably shear croppings from the same plate.

13.2 When heat treatment is required, test specimens shall be cut from pipe after the heat treating has been completed, or specimens removed from the pipe prior to heat treating shall be heat treated with the pipe.

14. Transverse Guided-Bend Weld Tests

14.1 Two bend test specimens shall be taken transversely across the weld. One shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

14.2 The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. [3 mm] in any direction are present in

the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing, and that are less than $\frac{1}{4}$ in. [6.5 mm] measured in any direction shall not be considered.

15. Pressure Tests

15.1 Where hydrostatic test equipment is not available, the pipe may be air or gas pressure tested with an internal pressure of 100 psi [700 kPa]. The weld and weld area shall be inspected with the use of soap solution or any other prepared solution which will detect the leakage of air or gas from the inside.

15.2 Instead of a pressure test, when mutually agreed upon between the purchaser and manufacturer, the entire weld area of each pipe, including circumferential welds, may be tested by nondestructive testing methods. These methods shall be capable of detecting both surface and subsurface defects.

16. Inspection

16.1 When specified in the purchase order, the pipe may be inspected at the manufacturer's plant by an inspector representing the purchaser. The inspector shall have entry at all times. The manufacturer shall afford the inspector, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

17. Certification

17.1 Upon request of the purchaser in the contract or order, certification in accordance with the provisions of Specification A999/A999M shall be furnished. When specified on the purchase order or when a specific type of melting has been specified on the purchase order, the type of melting used shall also be reported to the purchaser or the purchaser's representative.

18. Product Marking

18.1 Each length of pipe manufactured in accordance with this specification shall have the following identifying marking within 12 in. [300 mm] of one end: manufacturer's name or trade-mark, specification number, grade number of the alloy, the manufacturer's heat number, size, and schedule number. Additional marking requirements for heat treatment are described in Supplementary Requirement S2.

18.2 Marking shall be legibly stenciled with a suitable paint or permanent marking compound, except when otherwise specified by the purchaser.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 At the request of the purchaser a product analysis of one coupon representing finished sheet or plate from each heat shall be made by the pipe manufacturer. The drillings for product analysis may be taken from shear crop or test specimens. The results of product analysis shall conform to the requirements in Table 1 and shall be reported to the purchaser.

S2. Radiographic Examination

S2.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S3. Corrosion Requirements

S3.1 *Boiling Nitric Acid Test*—Except for Grade TP321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50 % and less molybdenum) shall meet the requirement of the boiling nitric acid test conducted according to Practice C of Practices A262. The condition of the test specimens and the corrosion rates are as follows: Type 347 and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [675 °C]) and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP321, shown in Table 1 shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.04 mm]/month.

S3.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material and Type 321 (over 0.50 % molybdenum) shall meet the requirements of the copper-copper sulfate-sulfuric acid test (intergranular corrosion test) conducted in accordance with Practice E of Practices A262. The condition of the test specimen is as

follows: All molybdenum-bearing types shown in Table 1 shall be tested in the annealed and unsensitized condition. Type 321 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [675 °C]). All specimens shall meet the requirements of the prescribed bend test.

S4. Ferrite Control of Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe may be determined. The procedural details pertaining to this subject (that is, welding, plate and weld deposit chemistry, testing equipment and method, number and location of test sites, and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 5.3, Grades TP321, TP347, and TP348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S6 Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

NOTE S6.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

APPENDIX

(Nonmandatory Information)

X1. Wall Thickness of Schedule 5S and Schedule 10S

TABLE X1.1 Pipe Dimensions

NPS Designator	Wall Thickness			
	Schedule 5S		Schedule 10S	
	in.	mm	in.	mm
14	0.156	3.96	0.188	4.78
16	0.165	4.19	0.188	4.78
18	0.165	4.19	0.188	4.78
20	0.188	4.78	0.218	5.54
22	0.188	4.78	0.218	5.54

TABLE X1.1 *Continued*

NPS Designator	Wall Thickness			
	Schedule 5S		Schedule 10S	
	in.	mm	in.	mm
24	0.218	5.54	0.250	6.35
30	0.250	6.35	0.312	7.92

SPECIFICATION FOR STEEL, SHEET, CARBON, FOR PRESSURE VESSELS



SA-414/SA-414M

(Identical with ASTM Specification A414/A414M-07 except for para. 1.3.)

SPECIFICATION FOR STEEL, SHEET, CARBON, FOR PRESSURE VESSELS



SA-414/SA-414M



(Identical with ASTM Specification A 414/A 414M-07.)

1. Scope

1.1 This specification covers hot-rolled carbon steel sheet for pressure vessels involving fusion welding or brazing. Welding and brazing technique is of fundamental importance and shall be in accordance with commercial practices.

1.2 The following grades are included in this specification:

Grade	Mechanical Requirements			
	Yield Strength, min		Tensile Strength, min	
	ksi	MPa	ksi	MPa
A	25	170	45	310
B	30	205	50	345
C	33	230	55	380
D	35	240	60	415
E	38	260	65	450
F	42	290	70	485
G	45	310	75	515

1.3 Hot-rolled carbon steel sheet is generally furnished in cut lengths and to decimal thickness only. Coils may be furnished, provided tension test specimens are taken to represent the middle of the slab as required by 5.1.3. The purchaser should recognize this may require cutting the coils to obtain test samples and results in half-size coils. The sheet is furnished to the following size limits:

Thickness, in. [mm]	Width, in. [mm]
0.270 to 0.230 [7.0 to 6.0]	Over 12 [Over 300]
Under 0.230 to 0.057 [6.0 to 1.5]	sheet (coils only) sheet

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining

values from the two systems may result in nonconformance with the specification.

1.5 Tolerances are found in General Requirements Specifications A 568/A 568M and A 635/A 635M. The appropriate General Requirements specification is applied based on the thickness and width of the product ordered.

2. Referenced Documents

2.1 ASTM Standards:

A 568/A 568M Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
A 635/A 635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for

3. Ordering Information

3.1 Orders for material under this specification shall include the following information, as required, to describe the material adequately:

3.1.1 Designation or specification number, date of issue, and grade,

3.1.2 Copper bearing steel, when required,

3.1.3 Special requirements, if required,

3.1.4 Condition — pickled (or blast cleaned), if required (material so ordered will be oiled unless ordered dry), and

3.1.5 Dimensions, including type of edges.

3.1.5.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the appropriate standard or restricted

thickness tolerance table shown in Specification A 568/A 568M or Specification A 635/A 635M.

NOTE 1 — Not all producers are capable of meeting all of the limitations of the thickness tolerance tables in Specification A 568/A 568M or Specification A 635/A 635M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

3.1.6 Cast or heat analysis, or test report request, or both, if required.

NOTE 2 — A typical ordering description is as follows: “ASTM A 414, Grade A, Hot-Rolled Sheet, 0.100 in. [2.54 mm] by 36 in. [914.4 mm] by 96 in. [2438 mm], cut edges.

4. Chemical Requirements

4.1 *Cast or Heat Analysis* — The analysis of the steel shall conform to the requirements prescribed in Table 1.

4.1.1 Unspecified elements may be present. Limits on elements shall be as stated in Table 2.

4.1.1.1 Each of the elements listed in Table 2 shall be included in the report of the heat analysis. When the amount of an element present is less than 0.02%, the analysis may be reported as “<0.02%.”

4.2 *Product, Check, or Verification Analysis* — Analyses may be made by the purchaser from finished material representing each heat.

4.3 *Deoxidation* — For all grades, killed steel is required. See Table 1 and footnotes A and B.

5. Mechanical Property Requirements

5.1 *Tensile Strength:*

5.1.1 *Requirements* — Material as represented by the test specimen shall conform to the tensile requirements specified in Table 3.

5.1.2 *Number of Tests* — Two tensile tests shall be made from the product of each slab as rolled.

5.1.3 *Location and Orientation (see Fig. 1):*

5.1.3.1 Tensile test specimens shall be taken at locations representing the middle and back end of each slab as rolled.

5.1.3.2 Tensile test samples shall be taken from the full thickness of the sheet as rolled.

5.1.3.3 Tensile test specimens shall be taken from a location approximately halfway between the center of the sheet and the edge of the material as-rolled.

5.1.3.4 Tensile test specimens shall be taken with the axis of the test specimen perpendicular to the rolling direction (transverse test).

5.1.4 *Test Method* — Yield strength shall be determined by either the 0.2% offset method or by the 0.5% extension under load method, unless otherwise specified.

6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568/A 568M or Specification A 635/A 635M unless otherwise provided herein.

7. Workmanship

7.1 The material shall be free from injurious defects (see Specifications A 568/A 568M or A 635/A 635M, as appropriate due to thickness).

8. Finish and Appearance

8.1 *Surface Finish:*

8.1.1 Unless otherwise specified, the material shall be furnished without removing the hot-rolled oxide or scale.

8.1.2 When required, the material may be specified to be pickled or blast cleaned.

8.2 *Oiling:*

8.2.1 Unless otherwise specified, the material shall be furnished not oiled.

8.2.2 When specified to be pickled or blast cleaned, the material shall be furnished oiled. When required, pickled or blast-cleaned material may be specified to be furnished dry.

8.3 *Edges* — Unless otherwise specified, mill edges shall be furnished on material that has not had the hot-rolled oxide or scale removed and cut edges shall be furnished on material that has had the hot-rolled oxide or scale removed.

9. Certification and Reports

9.1 The manufacturer or processor shall furnish copies of a test report showing the results of the heat analysis and mechanical property tests made to determine compliance with this specification.

9.2 The report shall include the purchase order number, the specification number and year date, product designation, grade, the heat number, and heat analysis and mechanical properties as indicated by the tension test.

9.3 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

9.4 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a

counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard and the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

10. Product Marking

10.1 The name or brand of the manufacturer, heat and slab number, specification designation number, and grade shall be legibly and durably marked on each cut length sheet in two places not less than 12 in. [300 mm] from the edges. Cut length sheets, the maximum lengthwise and crosswise, dimensions of which do not exceed 72 in.

[1800 mm], shall be legibly and durably marked in one place approximately midway between the center and a side edge. The manufacturer's test identification number shall be legibly and durably marked on each test specimen. Steeldie marking of sheets is prohibited on material <0.250 in. [6 mm].

10.2 For coil product, the information required in 10.1 shall be legibly and durably marked both on each coil and on a tag affixed to each coil.

11. Keywords

11.1 carbon steel sheet; pressure vessel steels; steel sheet

FIG. 1 LOCATION OF TEST SPECIMENS

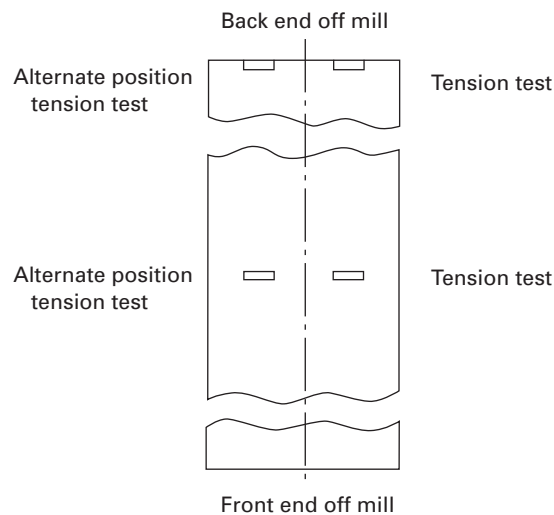


TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition — Weight, % Heat Analysis						
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Carbon, max	0.15	0.22	0.25	0.25	0.27	0.31	0.31
Manganese, max	0.90	0.90	0.90	1.20	1.20	1.20	1.35
Phosphorus, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Aluminum ^A	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08
Silicon ^A	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Copper, when copper steel is specified, min	0.20	0.20	0.20	0.20	0.20	0.20	0.20

^A The steel shall be considered aluminum-silicon killed when the silicon is between 0.15 and 0.30, otherwise it shall be considered aluminum killed.

TABLE 2
LIMITS ON UNSPECIFIED ELEMENTS (See 4.1.1)

Copper, max % ^A	Heat analysis	0.40
	Product analysis	0.43
Nickel, max % ^A	Heat analysis	0.40
	Product analysis	0.43
Chromium, max % ^{A,B}	Heat analysis	0.30
	Product analysis	0.34
Molybdenum, max % ^{A,B}	Heat analysis	0.12
	Product analysis	0.13
Vanadium, max % ^C	Heat analysis	0.03
	Product analysis	0.04
Columbium, max % ^C	Heat analysis	0.02
	Product analysis	0.03

^A The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

^B The sum of chromium and molybdenum shall not exceed 0.32% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

^C By agreement, the heat analysis limits for vanadium or columbium, or both, may be increased up to 0.10% and 0.05%, respectively.

TABLE 3
TENSILE REQUIREMENTS

	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Tensile strength:							
min, ksi [MPa]	45 [310]	50 [345]	55 [380]	60 [415]	65 [450]	70 [485]	75 [515]
max, ksi [MPa]	60 [415]	65 [450]	70 [485]	75 [515]	85 [585]	90 [620]	95 [655]
Yield strength, min, ksi (MPa) ^A	25 [170]	30 [205]	33 [230]	35 [240]	38 [260]	42 [290]	45 [310]
Elongation in 2 in. (50 mm), min, percent:							
Under 0.270 to 0.145 [Under 7.0 to 3.8]	26	24	22	20	18	16	16
Under 0.145 to 0.089 [Under 3.8 to 2.2]	24	22	20	18	16	14	14
Under 0.089 to 0.057 [Under 2.2 to 1.5]	23	21	19	17	15	13	13
Elongation in 8 in. (200 mm), min, percent:							
Under 0.270 to 0.145 [Under 7.0 to 3.8]	20	18	16	14	12	10	10

^A Yield strength determined by the 0.2% offset or 0.5% extension under load methods.

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SPECIFICATION FOR PIPING FITTINGS OF WROUGHT CARBON STEEL AND ALLOY STEEL FOR LOW-TEMPERATURE SERVICE



SA-420/SA-420M



(21)

(Identical with ASTM Specification A420/A420M-19a.)

For products welded with filler metal ordered to Section III, Division 1, Supplementary Requirement S1 is mandatory.

Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service

1. Scope

1.1 This specification covers wrought carbon steel and alloy steel fittings of seamless and welded construction, covered by the latest revision of ASME B16.9, ASME B16.11, MSS SP-79, MSS SP-83, MSS SP-95, and MSS SP-97. Fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A960/A960M. These fittings are for use in pressure piping and pressure vessel service at low temperatures.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements shall be specified in the order.

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 In addition to those Referenced Documents listed in Specification A960/A960M, the following list of standards apply to this specification.

2.2 ASTM Standards:

A350/A350M Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A960/A960M Specification for Common Requirements for Wrought Steel Piping Fittings

A1058 Test Methods for Mechanical Testing of Steel Products—Metric

2.3 ASME Standards:

B16.9 Factory-Made Wrought Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket-Welding Threaded

2.4 ASME Boiler and Pressure Vessel Code:

Section III

Section VIII Division 1, Pressure Vessels

Section IX

2.5 MSS Standards:

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS SP-79 Socket Welding Reducer Inserts

MSS SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS SP-95 Swage(d) Nipples and Bull Plugs

MSS SP-97 Integrally Reinforced Forged Branch Outlet Fittings—Socket Welding, Threaded and Buttwelding Ends

TABLE 1 Chemical Requirements

NOTE 1—All requirements are maximum unless otherwise indicated.

NOTE 2—Where an ellipsis (...) appears in this table, there is no requirement.

Grade ^A	Composition, %										
	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Nb ^E	V
WPL6	0.30	0.50–1.35	0.035	0.040	0.15–0.40	0.40	0.30	0.12	0.40	0.02 ^B	0.08
WPL9	0.20	0.40–1.06	0.030	0.030	...	1.60–2.24			0.75–1.25		
WPL3 ^C	0.20	0.31–0.64	0.05	0.05	0.13–0.37	3.2–3.8			...		
WPL8 ^D	0.13	0.90	0.030	0.030	0.13–0.37	8.4–9.6			...		

^A When fittings are of welded construction, the symbols above shall be supplemented by the letter "W".

^B By agreement, the limit for niobium may be increased up to 0.05 % on heat analysis and 0.06 % on product analysis.

^C Fittings made from plate or forgings may have 0.90 % max manganese.

^D Fittings made from plate may have 0.98 % max manganese.

^E Niobium and columbium are interchangeable names for the same element and both names are acceptable for use in A01.22 specifications.

2.6 ASNT Standards:

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 See Specification A960/A960M.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A960/A960M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A960/A960M constitutes non-conformance with this specification. In case of conflict between the requirements of this specification and Specification A960/A960M, this specification shall prevail.

5. Material

5.1 The starting material for fittings shall be fully killed steel, consisting of forgings, bars, plates, sheet, and seamless or fusion welded tubular products with filler metal added and shall conform to the chemical requirements in Table 1. The steels shall be made using recognized melting practices necessary to produce steels that shall meet the impact requirements of this specification.

6. Manufacture

6.1 Forging or forming operations shall be performed by hammering, pressing, piercing, extruding, upsetting, working, bending, fusion-welding, or machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

6.2 All welds, including welds in tubular products from which fittings are made, shall be (1) made by welders, welding operators and welding procedures qualified under the provisions of ASME Section IX, (2) heat treated in accordance with Section 7 of this specification, and (3) nondestructively examined throughout the entire length of each weld in accordance with Section 15 of this specification. The radiography of welds

shall be done either prior to or after forming at option of manufacturer. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

6.3 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

6.4 All butt-weld tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S52 or S53 of Specification A960/A960M. This examination shall be performed after final heat treatment by NDE personnel qualified under the provisions of SNT-TC-1A. Only the side-wall areas of the tee need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the centerline of the body or run. Internal and external surfaces shall be examined when size permits accessibility. After the removal of any cracks, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6.5 Stubends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 6.2 for qualifications and radiography and 7.1 for post weld heat treatment.

7. Heat Treatment

7.1 All fittings shall be furnished in the normalized, normalized and tempered, annealed, or quenched and tempered condition. All welding shall be completed prior to the austenitizing heat treatment.

7.2 The full thickness of the material from which impact test specimens are to be obtained shall be heat treated with a furnace charge as specified in 10.4.2 or 10.4.3.

7.3 After forming, the fittings shall be allowed to cool below the lower critical before applying one of the heat treatments listed in 7.1.

7.4 When specified in the order, the test specimens shall be subjected to a simulated post-weld heat treatment before testing. The simulated post-weld heat treatment used shall be

as shown in Table 2, unless the purchaser has otherwise specified in the order.

8. Chemical Composition

8.1 The steel shall conform to requirements of chemical composition for the respective material prescribed in Table 1.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it then conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 The chemical composition of weld metal is not required to meet the same limits of the base materials however, the composition of the weld deposit shall be such that it meets the minimum mechanical and impact requirements of this specification. In general, the alloy content shall be similar to that of the base metal but shall not exceed 6 % except in the case of fittings of 9 % nickel steel.

8.4 A product analysis is optional.

9. Tensile Properties

9.1 The tensile properties of the fittings material shall conform to the requirements for the applicable grade of material as listed in Table 3.

9.1.1 Longitudinal or transverse specimens cut from either a fitting or from starting plate or pipe they were manufactured from shall be acceptable for the tension test. For fittings made from forgings, the test specimen shall meet the requirements of Specification A350/A350M for the tension test.

9.1.2 While Table 3 specifies elongation requirements for both longitudinal and transverse specimens, it is not the intent that both requirements apply simultaneously. Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable. Unless specified by the customer, tensile test orientation is at the discretion of the manufacturer.

9.2 At least one tension test shall be made on each heat of material and in the same condition of heat treatment as the finished fittings it represents provided that the wall thickness of the fitting and the representative sample thickness do not vary more than ¼ in. [6 mm]. At least one tension test per heat of weld metal shall be made after heat treatment in the same manner as the base metal. Results of the tension test of the weld metal need not be reported unless Supplementary Requirement S51 of Specification A960/A960M is specified.

TABLE 2 Post-Weld Heat Treatment

Grade	Metal Temperature		Minimum Holding Time
	°F	°C	
WPL6	1100–1200	595–650	1 h/in. [25 mm] ¾ h min
WPL3	1100–1150	540–620	¼ h/in. [25 mm] 1 h min
WPL8	1050–1100	565–595	½ h/in. [25 mm] 1 h min
WPL9 ^a	1025–1085	550–585	1 h/in. [25 mm] 2 h min

^a 2 in. [51 mm] thickness and over. The cooling rate shall not be less than 300 °F [150 °C] per hour down to a temperature of 600 °F [315 °C].

9.3 Records of the tension tests shall be certification that the material of the fitting meets the tensile requirements of this specification.

10. Impact Test Properties

10.1 Properties:

10.1.1 The notched bar impact properties of the base metal and weld metal shall conform to the requirements of Table 4 or Table 5 for the applicable grade of material.

10.1.2 *Retest*—When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedure, a retest shall be allowed.

10.2 Procedures:

10.2.1 All material furnished under this specification shall be tested for impact resistance at the temperature for the respective grade in Table 6. Exceptions to these requirements are permissible when agreed upon between the purchaser and producer and specified in the order, in that the impact test is acceptable when made at temperatures different from those shown in Table 6, provided the test temperature is at least as low as the intended service temperature, and fittings are suitably marked in accordance with Section 19 to identify the reported test temperature.

10.2.2 The notched-bar impact test shall be made in accordance with the procedure for the simple-beam, Charpy-type test of Test Methods and Definitions A370 if the inch-pound units are specified or Test Methods A1058 if the M suffix (SI units) standard is specified. Each impact test shall consist of breaking three specimens.

10.3 Specimens:

10.3.1 Notched-bar impact specimens shall be simple-beam, Charpy-type A with a V-notch in accordance with Test Methods and Definitions A370 if the inch-pound units are specified or Test Methods A1058 if the M suffix (SI Units) standard is specified. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable standard subsize impact specimens shall be used. When the size or shape of the finished fittings is insufficient to permit obtaining the smallest standard subsize impact specimens, an impact test by the fitting manufacturer will not be required. The material from which the specimens are taken shall be heat treated with a furnace charge in accordance with 10.4.2 or 10.4.3. Impact tests shall be made from either the raw material from which the fittings are made or from a finished fitting at the option of the manufacturer.

10.3.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the fitting while the axis of the “V” shall be perpendicular to the surface. On wall thickness over 1 in. [25 mm] the specimens shall be obtained with their longitudinal axis located ½ in. [13 mm] from the outer surface.

TABLE 3 Tensile Requirements

NOTE 1—Where an ellipsis (. . .) appears in this table, there is no requirement.

Requirement	Grade							
	WPL6		WPL9		WPL3		WPL8	
Tensile strength, min ksi [MPa]	60 [415] – 95 [655]		63 [435] – 88 [610]		65 [450] – 90 [620]		100 [690] – 125 [865]	
Yield strength, min ksi [MPa]	35 [240]		46 [315]		35 [240]		75 [515]	
Elongation Requirements	Grades							
	WPL6		WPL9		WPL3		WPL8	
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
Standard round specimen, or small proportional specimen, min % in 4 D	22	12	20	...	22	14	16	...
Rectangular specimen for wall thickness $\frac{5}{16}$ in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. or 50 mm	30	16.5	28	18	30	20	22	...
Rectangular specimen for wall thickness less than $\frac{5}{16}$ in. [7.94 mm]; min % in 2 in. or 50 mm ($\frac{1}{2}$ -in. [12.7-mm] wide specimen)	A	A	A	A	A	A	A	...

^A For each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.94 mm], a deduction of 1.5 % (grades WPL6, WPL9, and WPL3) or 1.25 % (WPL8) for longitudinal and 1.0 % (grades WPL6, WPL9 and WPL3) for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses:

Wall Thickness		Grades							
in.	[mm]	WPL6		WPL9		WPL3		WPL8	
		Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
$\frac{5}{16}$ (0.312)	[7.94]	30.0	16.5	28.0	18.0	30.0	20.0	22.0	...
$\frac{9}{32}$ (0.281)	[7.14]	28.5	15.5	26.5	17.0	28.5	19.0	20.75	...
$\frac{1}{4}$ (0.250)	[6.35]	27.0	14.5	25.0	16.0	27.0	18.0	19.5	...
$\frac{7}{32}$ (0.219)	[5.56]	25.5	...	23.5	...	25.5	...	18.25	...
$\frac{3}{16}$ (0.188)	[4.76]	24.0	...	22.0	...	24.0	...	17.0	...
$\frac{5}{32}$ (0.156)	[3.97]	22.5	...	20.5	...	22.5	...	15.75	...
$\frac{1}{8}$ (0.125)	[3.17]	21.0	...	19.0	...	21.0	...	14.5	...
$\frac{3}{32}$ (0.094)	[2.38]	19.5	...	17.5	...	19.5	...	13.25	...
$\frac{1}{16}$ (0.062)	[1.59]	18.0	...	16.0	...	18.0	...	12.0	...

Note—The preceding table gives the computed minimum elongation value for each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test	Equations			
	WPL6	WPL9	WPL3	WPL8
Longitudinal	$E = 48t + 15.00$	$48t + 13.00$	$E = 48t + 15.00$	$40t + 9.50$
Transverse	$t = 32t + 6.50$	$32t + 8.00$	$E = 32t + 10.00$	...

where:

E = elongation in 2 in. or 50 mm, %, and
 t = actual thickness of specimen, in.

TABLE 4 Charpy Impact Requirements for WPL6, WPL9, and WPL3^A

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Three Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft-lbf	J	ft-lbf	J
	10 by 10.0	13	17.6	10	13.6
10 by 7.5	10	13.6	8	10.8
10 by 5.0	7	9.5	5	7.0
10 by 2.5	4	5.4	3	4.1

^A Straight-line interpolation for intermediate values is permitted.

TABLE 5 Charpy Impact Requirements for WPL8

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft-lbf	J	ft-lbf	J
	10 by 10.0	25.0	33.9	20.0	27.1
10 by 7.5	21.0	28.5	17.0	23.1
10 by 5.0	17.0	23.1	14.0	19.0
10 by 2.5	8.0	10.8	6.0	8.1

10.3.3 When testing welds, the notch of the specimen shall be in the welded joint and, where the diameter and wall thickness permit, the longitudinal axis of the specimen shall be

transverse to the longitudinal axis of the weld. The axis of the notch shall be perpendicular to the surface.

10.4 Number of Tests:

TABLE 6 Impact Test Temperature

Grade	Impact Test Temperature, °F [°C]
WPL6	-50 [-45]
WPL9	-100 [-75]
WPL3	-150 [-100]
WPL8	-320 [-195]

10.4.1 A notched-bar impact test, consisting of breaking three specimens shall be made. Each test shall represent only such fittings from a heat that do not vary from the thickness of the material from which the test specimens are taken by more than ¼ in. [6 mm].

10.4.2 When heat treatment is performed in furnaces not equipped with calibrated recording pyrometers, one impact test shall be made for each heat in each heat-treatment load. Test specimens shall be included with each furnace charge. If this heat treatment is conducted in continuous-type furnaces not equipped with calibrated recording pyrometers, then one test per heat shall be conducted for each 5000 lb or 2550 kg (or less) of product.

10.4.3 When heat treatment is performed in furnaces controlled within a 50 °F [28 °C] range and equipped with calibrated recording pyrometers so that records of heat treatment are available, then one impact test from each heat is required, provided that all other heat treatments are conducted at the same temperatures and within the same 50 °F [28 °C] range as the furnace charge that contained the test specimens.

10.4.4 On fittings of welded construction, additional impact tests of the same number as required in 10.4.1 or 10.4.2 shall be made to test the weld metal.

10.4.5 Specimens showing defects while being machined or prior to testing shall be discarded, and replacements shall be considered as original specimens.

10.5 Retreatment:

10.5.1 If the results of impact tests conducted in accordance with 10.4.2 and 10.4.3 fail to conform to the test requirements specified in 10.1, that group of fittings shall be retreated and submitted for test. No group of fittings shall be retreated more than twice.

11. Hydrostatic Tests

11.1 Hydrostatic testing of fittings is not required by this specification.

11.2 All fittings shall be capable of withstanding without failure, leakage, or impairment of their serviceability, a hydrostatic test pressure equal to that prescribed for the specified matching pipe of equivalent material.

12. Dimensions

12.1 Butt-welding fittings and butt-welding short-radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ASME B16.9 or MSS SP-95. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ASME B16.11, MSS SP-79, or MSS SP-83. Swage(d) Nipples,

Bull Plugs, and Integrally Reinforced Forged Branch Outlet Fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of MSS SP-95 or MSS SP-97.

12.2 Fittings of size or shape differing from these standards, but meeting all other requirements of the specification, shall be furnished in accordance with Supplementary Requirement S58 of Specification A960/A960M only by agreement with the purchaser.

13. Surface Finish, Appearance, and Corrosion Protection

13.1 The requirements of Specification A960/A960M apply.

14. Repair by Welding

14.1 The requirements of Specification A960/A960M apply except as follows:

14.1.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ASME or equivalent standards.

14.1.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's dimensional requirements.

14.1.3 Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short circuit gas metal arc welding is permissible only with the approval of the purchaser.

14.1.4 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

14.1.5 After weld repair, material shall be heat treated in accordance with 7.1.

14.1.6 Tension and impact testing of representative deposited weld metal for each heat shall meet the requirements of 9.2 and 10.1.

15. Radiographic Examination

15.1 All fusion-welded butt joints shall be radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. Instead of radiographic examination, welds made by the manufacturer may be ultrasonically examined in accordance with Appendix 12 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. In general, radiography or ultrasonic examination shall be performed after all forming operations have been completed. Fittings made from fusion-welded pipe need not be radiographed if the pipe has been radiographed, provided the fitting forming process does not materially affect the weld.

16. Inspection

16.1 All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

16.2 Other tests, when required by agreement shall be made from materials of the lots covered in the order.

17. Rejection and Rehearing

17.1 Material that fails to conform to the requirements of this specification shall be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier shall make claim for a rehearing.

17.2 Fittings that develop defects in shop working or application operations shall be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

18. Certification

18.1 Test reports are required for all fittings covered by this specification. Each test report shall meet the requirements for certification in Specification A960/A960M as well as include the following information specific to this specification:

18.1.1 Chemical analysis results, Section 8 (Table 1), reported results shall be to the same number of significant figures as the limits specified in Table 1 for that element,

18.1.2 Tensile property results, Section 9 (Table 3) report yield strength and tensile strength in ksi [MPa] and elongation in percent, and tensile test orientation,

18.1.3 Impact test results, Section 10 (Table 4 and Table 5),

18.1.4 Type heat treatment, Section 7,

18.1.5 Statement regarding radiographic or ultrasonic examination of welds, Section 15, and

18.1.6 Any supplementary testing required by the purchase order.

19. Product Marking

19.1 In addition to marking requirements of Specification A960/A960M, the following additional marking requirements shall apply:

19.1.1 Fittings shall be marked by any method which will identify the fittings and not result in sharp discontinuities. Stamping, when used, shall be done with blunt-nosed continuous or blunt-nosed interrupted dot stamps.

19.1.2 When agreed upon between the purchaser and producer, and specified in the order, the markings shall be painted or stenciled on the fitting or stamped on a metal or plastic tag which shall be securely attached to the fitting.

19.1.3 Fittings containing welds that have been ultrasonically examined instead of radiography shall be marked U after heat identity.

19.1.4 Threaded or socket welding fittings shall be marked with the pressure class. Plugs and bushings furnished to ASME B16.11 requirements are not required to be marked.

19.1.5 The impact test temperature shall also be shown if it is different from the standard test temperature specified in Table 6, for example: WPL-6-60 or WPL3-176.

19.2 *Bar Coding*—In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

20. Keywords

20.1 pipe fittings; piping applications; pressure containing parts; pressure vessel service; temperature service applications, low

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements appearing in Specification A960/A960M may be included in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. ASME Section III Construction

S1.1 Products welded with filler metal furnished under this specification that are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code shall be manufactured by holders of the appropriate ASME Certificate of Authorization and Certification Mark. The product is subject to all applicable requirements of Section III, including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

S1.2 The applicable ASME Partial Data Report form, signed by an Authorized Nuclear Inspector, and a material test report shall be furnished for each lot of pipe.

S1.3 The material used to fabricate the pipe fitting shall conform to the applicable SA specification in ASME Boiler and Pressure Vessel Code, Section II. The welded joints shall be full penetration butt welds as obtained by double welding or by other means that will obtain the same quality of deposited weld metal on the inside and outside. Welds using metal backing strips that remain in place are prohibited.

S1.4 Each piece of pipe fitting shall be so marked as to identify each such piece of pipe fitting with the lot and the material test report.

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SPECIFICATION FOR SEAMLESS AND ELECTRIC-WELDED LOW-ALLOY STEEL TUBES



SA-423/SA-423M



(21)

(Identical with ASTM Specification A423/A423M-95(2004).)

SPECIFICATION FOR SEAMLESS AND ELECTRIC-WELDED LOW-ALLOY STEEL TUBES



SA-423/SA-423M



[Identical with ASTM Specification A 423/A 423M-95(2004).]

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless and electric-resistance welded, low-alloy steel tubes for pressure containing parts such as economizers or other applications where corrosion resistance is important.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm] inclusive, in minimum wall thicknesses. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{4}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 ASTM Standard:

- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing
- A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. Ordering Information

3.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately;

- 3.1.1** Quantity (feet, metres, or number of lengths),
- 3.1.2** Name of material (seamless or electric-resistance welded tubes),
- 3.1.3** Grade (Table 1),
- 3.1.4** Manufacture (hot finished or cold finished),
- 3.1.5** Size (outside diameter and minimum wall thickness)
- 3.1.6** Length (specific or random),
- 3.1.7** Optional requirements (hydrostatic or electric test, 13.7),
- 3.1.8** Test report required (see Certification Section of Specification A 450/A 450M),
- 3.1.9** Specification designation, and
- 3.1.10** Special requirements and any supplementary requirements selected.

4. Manufacture

4.1 Tubes made by the seamless process may be hot finished or cold finished.

5. Heat Treatment

5.1 All tubes shall be normalized or given such heat treatment as may be necessary to conform to the requirements of this specification.

6. Chemical Composition

6.1 The steel shall conform to requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 An analysis of either one billet, one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each billet, length of flat-rolled stock or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1—For flattening, flaring, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 2—For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 170 HB or 87 HRB.

10. Forming Operations

10.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws.

11. Mechanical Tests Required

11.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension

tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

11.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring or flanging test, from each lot (Note 1).

11.3 Flaring Test (Seamless Tubes) — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.4 Flange Test (Welded Tubes) — One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.5 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

11.6 Reverse Flattening Test — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

11.7 Hydrostatic or Nondestructive Electric Test — Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. General Requirements

12.1 Material furnished under this specification should conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether hot finished or cold finished, and whether seamless or welded.

14. Keywords

14.1 Seamless steel tube; steel tube; alloy; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %	
	Grade 1	Grade 2
Carbon, max	0.15	0.15
Manganese, max	0.55	0.50–1.00
Phosphorus	0.06–0.16	0.04 max
Sulfur, max	0.060	0.05
Silicon, min	0.10	...
Copper	0.20–0.60	0.30–1.00
Chromium	0.24–1.31	...
Nickel	0.20–0.70	0.40–1.10
Molybdenum, min	...	0.10

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY
THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

Tensile strength, min, ksi [MPa]	60 [415]
Yield strength, min, or 50 mm, ksi [MPa]	37 [255]
Elongation in 2 in. or 50 mm, min, %	25
For longitudinal strip tests a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{3}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.25 ^A

^A Calculated elongation requirements shall be rounded to the nearest whole number.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of this supplemental requirement shall be agreed upon by the manufacturer and the purchaser.

S1. Surface Condition

S1.1 If pickling or shot-blasting, or both, are required, this shall be specifically stated in the order and shall be done at the purchaser's expense.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered unless specified in the order and the necessary tests shall be made at the mill.

S2. Additional Testing of Welded Tubing per ASME Request

S2.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S2.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 450/A 450M.

S2.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S2.4 In addition to the marking prescribed in Specification A 450/A 450M, "S2" shall be added after the grade designation.

SPECIFICATION FOR CENTRIFUGALLY CAST FERRITIC ALLOY STEEL PIPE FOR HIGH-TEMPERATURE SERVICE



SA-426/SA-426M



(Identical with ASTM Specification A426/A426M-13.)

Standard Specification for Centrifugally Cast Ferritic Alloy Steel Pipe for High- Temperature Service

1. Scope

1.1 This specification covers centrifugally cast alloy steel pipe intended for use in high-temperature, high-pressure service.

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary Requirements S1 through S12 are provided. The supplementary requirements provide for additional tests of an optional nature and when desired shall be so stated in the order (Section 4).

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4.1 Within the text, the SI units are shown in brackets.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A609/A609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E94 Guide for Radiographic Examination

E165 Practice for Liquid Penetrant Examination for General Industry

E186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (50.8 to 114-mm)) Steel Castings

E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings

E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness

E709 Guide for Magnetic Particle Testing

2.2 ANSI Standard:

B46.1 Surface Texture

2.3 ASME Boiler and Pressure Vessel Code:

Section IX Welding and Brazing Qualifications

3. Ordering Information

3.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (centrifugally cast pipe),

3.1.3 Specification number,

3.1.4 Grade (Table 1),

3.1.5 Size (outside or inside diameter and minimum wall thickness),

3.1.6 Length (specific or random) (Section on Permissible Variations in Length of Specification A999/A999M),

3.1.7 End finish (Section on Ends of Specification A999/A999M),

TABLE 1 Chemical Requirements^A

Composition, %								
Grade	UNS Number	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum
CP1	J12521	0.25 max	0.30-0.80	0.030	0.025	0.10-0.50	...	0.44-0.65
CP2	J11547	0.10-0.20	0.30-0.61	0.030	0.025	0.10-0.50	0.50-0.81	0.44-0.65
CP5	J42045	0.20 max	0.30-0.70	0.030	0.025	0.75 max	4.00-6.50	0.45-0.65
CP5b	J51545	0.15 max	0.30-0.60	0.030	0.025	1.00-2.00	4.00-6.00	0.45-0.65
CP9	J82090	0.20 max	0.30-0.65	0.030	0.025	0.25-1.00	8.00-10.00	0.90-1.20
CP11	J12072	0.05-0.20	0.30-0.80	0.030	0.025	0.60 max	1.00-1.50	0.44-0.65
CP12	J11562	0.05-0.15	0.30-0.61	0.030	0.025	0.50 max	0.80-1.25	0.44-0.65
CP15	J11522	0.15 max	0.30-0.60	0.030	0.025	1.15-1.65	...	0.44-0.65
CP21	J31545	0.05-0.15	0.30-0.60	0.030	0.025	0.50 max	2.65-3.35	0.80-1.06
CP22	J21890	0.05-0.15	0.30-0.70	0.030	0.025	0.60 max	2.00-2.75	0.90-1.20
CPCA15	J91150	0.15 max	1.00 max	0.030	0.025	1.50 max	11.5-14.0	0.50 max

^A Where ellipses appear in this table, there is no requirement.

3.1.8 Optional Requirements S1 through S12 and Section 14.1,

3.1.9 Test report required (Section on Certified Test Report of Specification A999/A999M),

3.1.10 Service temperature if over 1000°F [540°C] (Note 1), and

3.1.11 Special requirements or additions to specification.

4. General Requirements for Delivery

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

5. Materials and Manufacture

5.1 *Heat-Treatment*—The pipe shall be furnished in the austenitized and tempered condition (Note 1) according to the requirements of Table 2.

5.1.1 Heat treatment shall be performed after the pipe has been allowed to cool below the transformation range. Definition of heat-treatment terms shall be as given in Terminology A941.

NOTE 1—It is recommended that the temperature for tempering should be at least 100°F [55°C] above the intended service temperature. The purchaser shall advise the manufacturer of the service temperature when it is over 1000°F [540°C]. (See 3.1.10.)

5.2 *Machining*—The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250 μ in. [6.35 μm] arithmetical average deviation (AA) from the mean line unless otherwise specified as in ANSI B46.1.

6. Chemical Analysis

6.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test

sample taken preferable during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements of Table 1.

7. Tensile and Hardness Requirements

7.1 Steel used for the castings shall conform to the tensile and hardness requirements specified in Table 3.

8. Permissible Variations in Dimensions

8.1 *Thickness*—The wall thickness shall not vary over that specified by more than 1/8 in. [3 mm]. There shall be no variation under the specified wall thickness.

9. Number of Tests

9.1 One tension and one hardness test shall be made from each heat.

9.2 If a specimen is machined improperly or if flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

10. Retests

10.1 If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be re-austenitized more than twice.

11. Test Specimens

11.1 Test coupons from which tension test specimens are prepared shall be removed from heat-treated casting prolongations.

TABLE 2 Heat Treatment Requirements

Grade	Austenitizing Treatment	Tempering Temperature, min, unless a range is shown, °F [°C]
CP1	Normalized or Liquid Quenched	1100 [595]
CP2	Normalized or Liquid Quenched	1100 [595]
CP5	Normalized or Liquid Quenched	1250 [675]
CP5b	Normalized or Liquid Quenched	1250 [675]
CP9	Normalized or Liquid Quenched	1250 [675]
CP11	Normalized or Liquid Quenched	1100 [595]
CP12	Normalized or Liquid Quenched	1100 [595]
CP15	Normalized or Liquid Quenched	1100 [595]
CP21	Normalized or Liquid Quenched	1250 [675]
CP22	Normalized or Liquid Quenched	1250 [675]
CPCA15	Normalized or Liquid Quenched	1250 [675]

11.2 When agreed upon between the manufacturer and the purchaser, test coupons from which test specimens are prepared shall be cast attached to separate blocks from the same heat as the casting represented. The test blocks shall be heat treated in the same manner as the casting represented.

11.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A370.

12. Hydrostatic Test

12.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A999/A999M.

12.2 When agreed to between the manufacturer and the purchaser and so stated in the order, the hydrostatic test may be deferred and shall be performed later by the purchaser. Pipe furnished without the hydrostatic test shall include with the

TABLE 3 Tensile Properties and Hardness Requirements

Tensile strength, min:	psi [MPa]
Grade CP1	65 000 [450]
Grades CP11, CP22	70 000 [485]
Grades CP5, CP9, CPCA15	90 000 [620]
All other grades	60 000 [415]
Yield strength, min:	psi [MPa]
Grade CP1	35 000 [240]
Grades CP11, CP22	40 000 [275]
Grades CP5, CP9	60 000 [415]
Grade CPCA15	65 000 [450]
All other grades	30 000 [205]
Elongation, min:	% ^A
Grade CP1	24
Grades CP11, CP22	20
Grades CP5, CP9, CPCA15	18
All other grades	22
Reduction of area, min:	%
Grades CP1, CP2, CP11, CP12, CP15, CP21, CP22, CP5, CP5b, CP7, CP9	35
Grade CPCA15	30
Hardness:	HBW
Grades CP5, CP5b, CP9, CPCA15, max	225
All other grades, max	201

^A Elongation in 2 in. [50 mm] using a standard round specimen, in either the transverse or longitudinal direction.

mandatory marking the letters “NH.” The manufacturer is responsible for the satisfactory performance of the casting when it is tested.

12.3 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state “not hydrostatically tested.” The specification number and material grade shown on the certification shall be followed by the letters “NH.”

13. Visual Inspection

13.1 The surface of the casting shall be free from cracks and hot tears as determined by visual examination. Other surface imperfections shall be judged in accordance with visual acceptance criteria which may be specified in the order.

14. Rework and Retreatment

14.1 Defects as defined in Section 13 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects that are located by inspecting with supplementary requirements S6, S7, S8, or S9 shall be removed or reduced to an acceptable size.

14.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

14.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchaser’s approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

14.3.1 Only welders and procedures qualified in accordance with *ASME Boiler and Pressure Vessel Code*, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

14.4 Local or full heat treatment in accordance with tempering temperatures specified in 5.1 shall follow welding.

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

16. Product Marking

16.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number and

grade. In addition, heat numbers or serial numbers that are traceable to heat numbers shall be marked on each length of pipe.

17. Keywords

17.1 alloy steel; centrifugal; ferritic; high-temperature service; pipe; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon between the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between the purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A999/A999M, that length shall be rejected.

S3. Photomicrographs

S3.1 The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in each heat-treatment lot. Such photomicrographs shall be suitable identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photomicrographs for the individual pieces purchased shall be required except as specified in Section S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E186, E280, or E446. The extent of the examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Practice E165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, or as agreed upon between the manufacturer and purchaser.

S8. Magnetic Particle Inspection

S8.1 The castings shall be examined by magnetic particle inspection. The inspection procedure used shall be in accordance with Practice E709. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S9. Ultrasonic Inspection

S9.1 The castings shall be examined ultrasonically in accordance with Practice A609/A609M. The extent of the examination and the basis of acceptance shall be subject to agreement between the manufacturer and the purchaser.

S10. Residual Elements

S10.1 An analysis for the elements specified in Table S1.1 shall be included in those analyses specified in Section 6. The chemical composition thus determined shall conform to the requirements of Table S1.1.

TABLE S1.1 Residual Elements

Grade	Copper, max	Nickel, max	Chromium, max	Tungsten, max	Total Contents of These Unspecified Elements, max, %
CP1	0.50	0.50	0.35	0.10	1.00
CP2	0.50	0.50	...	0.10	1.00
CP5	0.50	0.50	...	0.10	1.00
CP5b	0.50	0.50	...	0.10	1.00
CP7	0.50	0.50	...	0.10	1.00
CP9	0.50	0.50	...	0.10	1.00
CP11	0.50	0.50	...	0.10	1.00
CP12	0.50	0.50	...	0.10	1.00
CP15	0.50	0.50	0.35	0.10	1.00
CP21	0.50	0.50	...	0.10	1.00
CP22	0.50	0.50	...	0.10	1.00
CPCA15	0.50	1.00	...	0.10	1.50

S11. Charpy Impact Test

S11.1 Charpy impact test properties shall be determined on each heat from a set of three Charpy V-notch specimens. The test coupons shall be taken as specified for tension specimens in Section 11 and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed or lateral expansion or percent

shear area, and shall be that agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A370.

S11.2 *Absorbed Energy Value*, of three specimens shall not be less than that agreed upon by the manufacturer and purchaser, with no more than one value permitted below the minimum average specified and no value permitted below the minimum specified for a single specimen.

S11.3 *Lateral Expansion Value*, shall be agreed upon by the manufacturer and purchaser.

S11.4 *Percent Shear Area*, shall be agreed upon by the manufacturer and purchaser.

S12. Drop Weight Test

S12.1 Drop weight test properties shall be determined by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E208. The test coupons shall be taken as specified for tension specimens in Section 11. The crack starter weld shall be deposited on the surface of the specimen which was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit a “no break” performance.

SPECIFICATION FOR STAINLESS AND ALLOY-STEEL TURBINE-TYPE BOLTING SPECIALLY HEAT TREATED FOR HIGH-TEMPERATURE SERVICE



SA-437/SA-437M



(Identical with ASTM Specification A437/A437M-12.)

Standard Specification for Stainless and Alloy-Steel Turbine-Type Bolting Specially Heat Treated for High-Temperature Service

1. Scope

1.1 This specification covers stainless and alloy-steel bolting specially heat treated for high-temperature service, such as steam turbine, gas turbine, and similar uses. See Specification A962/A962M for the definition of bolting. This material requires special processing and should not be used in general-purpose applications. Bolting furnished as bars shall be hot wrought and may be further processed by centerless grinding or by cold drawing.

1.2 The high-temperature properties of the bolting covered by this specification are dependent upon special heat treatment, which is required. Although the high-temperature properties are not specified, they are implied by control of the chemistry, heat treatment, and room-temperature properties of the material.

1.3 Three levels of bolting strength are covered, designated Grades B4B, B4C, and B4D.

1.4 The following referenced general requirements are indispensable for application of this specification: Specification A962/A962M.

1.5 Supplementary requirements are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

1.6 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable *M* specification designation (SI units), the inch-pound units shall apply.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each

system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials

E112 Test Methods for Determining Average Grain Size

3. Ordering Information

3.1 It shall be the responsibility of the purchaser to specify all requirements necessary for product under this specification. Such requirements to be considered include, but are not limited to, the following:

3.1.1 Specification designation, grade, issue date, and revision letter,

3.1.2 Quantity (weight or number of pieces),

3.1.3 Description (bars, bolts, nuts, etc.),

3.1.4 Dimensions,

3.1.5 Finish, and

3.1.6 Impact testing of nuts, if required (see Section 8).

4. Common Requirements

4.1 Bolting supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, macroetch (Grade B4D only), marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A962/A962M, this specification shall prevail.

5. Heat Treatment

5.1 Grades B4B and B4C shall be heated to a temperature range of 1875 to 1925 °F [1025 to 1050 °C] and liquid quenched to below 600 °F [316 °C]. The material Grades B4B and B4C shall then be uniformly reheated for tempering at a tempering temperature at least 100 °F [55 °C] higher than the proposed operating temperature but not less than 1150 °F [620 °C], then air or furnace cooled to room temperature. The material shall be at the tempering temperature for a minimum of 2 h. Double tempering may be used to enhance properties.

5.2 Grade B4D shall be heated to a temperature range of 1700 to 1750 °F [925 to 954 °C] and oil quenched. The material shall then be uniformly reheated or tempered at a temperature of 1200 °F [650 °C] minimum, followed by air or furnace cooling to room temperature.

5.3 Stress relieving treatment of the bar material is required after any stretcher, roller, or rotary-straightening or cold-finishing operations performed after heat treatment for mechanical properties. Local gagging or press straightening to correct camber limitations in excess of 1/4 in. in any 5 ft [6 mm in any 1.5 m] shall be followed by a stress relieving heat treatment. The minimum stress relieving temperature shall be 100 °F [55 °C] below the minimum tempering temperature as shown in 5.1 for Grades B4B and B4C or in 5.2 for Grade B4D.

6. Chemical Composition

6.1 Material shall conform to the requirements as to chemical composition specified in Table 1.

7. Tensile Requirements

7.1 Material shall conform to the requirements as to tensile properties prescribed in Table 2 at room temperature after heat treatment.

7.2 The longitudinal axis of the test specimen shall be parallel to the direction of rolling.

TABLE 1 Chemical Requirements^A

Element	Grades B4B, B4C ^B		Grade B4D	
	Range, %	Product Variation, %, Over or Under	Range, %	Product Variation, %, Over or Under
Carbon	0.20–0.25	0.02	0.36–0.44	0.02
Manganese	0.50–1.00	0.03	0.45–0.70	0.03
Phosphorus, max	0.025	0.005 over	0.04	0.005 over
Sulfur, max	0.025	0.005 over	0.04	0.005 over
Silicon	0.20–0.50	0.05	0.20–0.35	0.02
Nickel	0.50–1.00	0.03	...	...
Chromium	11.0–12.5	0.15	0.80–1.15	0.05
Molybdenum	0.90–1.25	0.05	0.50–0.65	0.03
Vanadium	0.20–0.30	0.03	0.25–0.35	0.03
Tungsten	0.90–1.25	0.05	...	...
Aluminum, max ^C	0.05	...	0.015	...
Titanium, max	0.05	...	...	...
Tin, max	0.04	...	...	...

^A Steel to which lead has been added shall not be used.

^B UNS S42200.

^C Total, Soluble + Insoluble

TABLE 2 Tensile Requirements

Grade	Diameter, in. [mm]	Tensile Strength, min, ksi	Yield Strength (0.2% offset) min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
		[MPa]			
B4B	...	145 [1000]	105 [720]	13	30
B4C	...	115 [790]	85 [585]	18	50
B4D	2½ [65] and under	125 [860]	105 [720]	18	50
	over 2½ to 4 [65 to 100]	110 [760]	95 [655]	17	45
	over 4 to 7 [100 to 180]	100 [690]	85 [585]	16	45

8. Impact Requirements

8.1 Grades B4B, B4C, and B4D shall conform to the requirements as to impact properties prescribed in Table 3 at room temperature after heat treatment.

9. Hardness Tests

9.1 Grades B4B, B4C, and B4D shall conform to the requirements as to hardness as prescribed in Table 4 and Table 5 at room temperature after heat treatment.

10. Nuts

10.1 When specified by the purchaser, nuts shall be subject to the impact and tension requirements of this specification. The tests shall be made on test specimens taken from the bar or plate used in the manufacture of the nuts.

11. Threads

11.1 All threads shall be formed after heat treatment.

12. Nondestructive Inspection

12.1 Each bar or forged blank of starting material shall be subjected to NDE following final heat treatment. The method used shall be either the Eddy Current (EC), the Magnetic Particle (MPI) (wet or dry), the Liquid Penetrant (LPI), the Ultrasonic (UT), or the Visual Testing (VT), at the option of the producer. For LPI or MPI, linear indications (those indications longer than 1/16 in. [1.5 mm] with a length greater than three times their width) are unacceptable. For UT or ET, reject levels for linear indications shall be based on the alarm response from a surface notch with a maximum depth of 0.012 in. [0.30 mm] in a calibration bar. Product being subjected to VT shall be pickled prior to inspection. VT indications longer than 1/8 in. [3.2 mm] are prohibited.

TABLE 3 Impact Requirements

Grade	Minimum Impact Value, ft-lbf [J]
B4B	10 [14]
B4C	25 [34]
B4D ^A	25 [34]

^A For bars over 5-in. [127-mm] diameter only.

TABLE 4 Hardness Requirements for Bolts and Studs

Grade	Brinell Hardness Number, max
B4B	331
B4C	277
B4D	302

13. Certification

13.1 Certification is required. See Specification A962/A962M.

14. Product Marking

14.1 Use the grade symbol shown in Table 4. See Specification A962/A962M.

TABLE 5 Hardness Requirements for Nuts and Washers

Grade	Brinell Hardness Number	Rockwell Hardness Number
B4B	293–341	C 31–37
B4C	229–277	C 21–29
B4D	263–311	C 27–33

15. Keywords

15.1 bolts—steel; chromium alloy steel; fasteners—steel; marking on fasteners; nuts—steel; stainless steel; steel bars—alloy; steel bolting material; temperature service applications—high; turbine materials

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order; in which event the specified tests shall be made before shipment of the product.

S1. Non-Destructive Examination

S1.1 NDE is required following all machining and threading. The acceptance criteria of 12.1 shall apply.

S2. Stress Rupture Testing—Grade B4B

S2.1 Stress rupture testing shall be conducted at 1200 °F [650 °C] and 26 000 psi [180 MPa] using a combination test bar in accordance with Test Methods E292. Rupture shall occur in the smooth section of each test specimen. The test may be

discontinued after 25 h provided the certification so notes. Stress rupture testing is not required on bars less than ½ in. [12.7 mm] in diameter or thickness.

S3. Grain Size—Grades B4B and B4C

S3.1 The average grain size shall be 4 or finer. The maximum size of individual grains, distributed at random, shall be a 2. When the average grain size is 5 or finer, only the average size need be reported. Grain size determination shall be performed in accordance with Test Methods E112.

**SPECIFICATION FOR HEX CAP SCREWS, BOLTS AND
STUDS, STEEL, HEAT TREATED, 120/105/90 ksi
MINIMUM TENSILE STRENGTH, GENERAL USE**



SA-449

(Identical with ASTM Specification A449-10 except for requiring that all mating fastener components be coated by the same zinc-coating process in 5.1.4, the removal of reference to bolts in 6.4, and the deletion of the term "private label distributor" in 16.1 and 16.3.2.)

Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/ 105/90 ksi Minimum Tensile Strength, General Use

1. Scope

1.1 This specification covers quenched and tempered steel hex cap screws, bolts, and studs having a minimum tensile strength of 120 ksi for diameters 1.0 in. and smaller; 105 ksi for diameters over 1.0 in. to 1½ in.; and 90 ksi for diameters 1¾ in. to 3.0 in. inclusive. The term "fasteners" in this specification denotes hex cap screws, bolts, and studs.

1.2 The fasteners are intended for general engineering use.

1.3 The fasteners are furnished in diameters ¼ to 3.0 in. inclusive. They are designated by type denoting chemical composition as follows:

Type	Description
Type 1	Plain carbon steel, carbon boron steel, alloy steel, or alloy boron steel
Type 2	Withdrawn 2003
Type 3	Weathering steel

1.4 Terms used in this specification are defined in Terminology F1789 unless otherwise defined in this specification.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A563 Specification for Carbon and Alloy Steel Nuts
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- D3951 Practice for Commercial Packaging
- F436 Specification for Hardened Steel Washers
- F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
- F788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
- F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F1789 Terminology for F16 Mechanical Fasteners
- F2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners
- G101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 ASME Standards:

- B 1.1 Unified Screw Threads
- B 18.2.1 Square and Hex Bolts and Screws
- B 18.24 Part Identifying Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for fasteners under this specification shall include the following:

- 3.1.1 Quantity (number of pieces),
- 3.1.2 Size, including nominal diameter and length,
- 3.1.3 Name of product,

- 3.1.4 Type, that is, Type 1, or Type 3 as required,
 3.1.5 ASTM designation and year of issue, and
 3.1.6 Other components such as nuts and washers if required.
 3.1.7 *Hot-Dip or Mechanically Deposited Zinc Coatings*—For hot-dip or mechanically deposited zinc coatings covered by 5.1 and requiring over-tapped nuts, specify the zinc coating process required, that is, hot-dip, mechanically deposited, or no preference (see 5.1).
 3.1.8 *Other Coatings*—Specify other protective coating if required (see 5.2).
 3.1.9 Specify if inspection at point of manufacture is required.
 3.1.10 Test reports if required.
 3.1.11 Supplementary or special requirements.
 3.1.12 For establishment of a part identifying system, see ASME B18.24.

NOTE 1—A typical ordering description follows: 1000 pieces 1/8 in. diameter × 4.0 in. long hex cap screw, Type 1, ASTM A449-XX, each with one finished hex nut ASTM A563, Grade DH. Each component mechanically zinc coated in accordance with B695, Class 5, Type II.

3.2 *Suitable Nuts and Washers:*

3.2.1 Suitable nuts are covered in Specification A563. Unless otherwise specified, the grade and style of nut shall be as follows:

Fastener Size and Surface Finish	Nut Grade and Style ^A
1/4 to 1 1/2 in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	B, hex
Over 1 1/2 to 3 in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	A, heavy hex
1/4 to 3 in., zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex
1/4 to 3 in., Type 3	C3, DH3, heavy hex

^A Nuts of other grades and styles having specified proof load stresses (Specification A563, Table 3) greater than the specified grade and style of nut are suitable.

3.2.2 Unless otherwise specified, washers ordered with fasteners shall be furnished to the requirements of Specification F436, Type 1 or Specification F436, Type 3. Washers for A449 Type 3 fasteners shall conform to Specification F436 Type 3.

4. Materials and Manufacture

4.1 *Heat Treatment:*

4.1.1 Type 1 fasteners produced from medium carbon steel shall be quenched in a liquid medium from the austenitizing temperature.

4.1.2 Type 1 fasteners produced from medium carbon steel to which chromium, nickel, molybdenum, or boron were intentionally added, and Type 3 fasteners, shall be quenched in oil from the austenitizing temperature.

4.1.3 Type 1 and Type 3 fasteners, regardless of the steel used, shall be tempered by reheating to not less than 800°F.

4.2 *Threading*—Threads shall be rolled, cut, or ground.

4.3 *Secondary Processing*—If any processing which can affect the mechanical properties of the fasteners is performed after the initial testing, the fasteners shall be retested for all specified mechanical properties affected by the reprocessing.

5. Protective Coatings

5.1 *Zinc, Hot Dip, and Mechanically Deposited Requiring Over-tapped Nuts:*

5.1.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, such as, hot-dip, mechanically deposited, or no preference.

5.1.2 When hot dip is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Specification F2329.

5.1.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 55 of Specification B695.

5.1.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification F2329, or a mechanically deposited zinc coating in accordance with Specification B695, Class 55. All mating components shall be coated by the same zinc coating process, and the suppliers' option shall be limited to one process per item with no mixed processes in a lot.

NOTE 2—When the intended application requires that assembled tension exceeds 50 % of minimum bolt or stud proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A563 and should be specified when required.

5.2 *Other Coatings:*

5.2.1 When other coatings are required, the purchaser shall specify the coating specification, including the classification codes or grade numbers to identify the coating material, thickness, supplemental treatments, or other requirements to define the coating. The fasteners shall be coated in accordance with and conform to the specified coating specification.

5.2.2 When a specification does not apply, the purchaser shall specify the desired coating, coating thickness, supplemental treatments, or other requirements to define the coating.

6. Chemical Composition

6.1 Type 1 fasteners shall be plain carbon steel, carbon boron steel, alloy steel, or alloy boron steels, at the manufacturers option, conforming to the requirements in Table 1.

6.2 Type 3 fasteners shall be weathering steel and shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition, A, B, C, D, E or F, shall be a the option of the manufacturer. See Guide G101 for methods of estimating the atmospheric corrosion resistance of low alloy steel.

6.3 Product analyses made on finished fasteners representing each lot shall conform to the product analysis requirements specified in Table 1 or Table 2, as applicable.

6.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts. Compliance shall be based on certification that heats of steel having any of the listed elements intentionally added were not used.

6.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A751.

TABLE 1 Chemical Requirements for Type 1 Fasteners

Element	Carbon Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.15–0.30	0.13–0.32
Element	Boron Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.10–0.30	0.08–0.32
Boron	0.0005–0.003	0.0005–0.003
Element	Alloy Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Alloying Elements	A	A
Element	Alloy Boron Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Boron	0.0005–0.003	0.0005–0.003
Alloying Elements	A	A

^A Steel, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 % or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

7. Mechanical Properties

7.1 *Hardness*—The fasteners shall conform to the hardness specified in Table 3. See Table 3, Note A.

7.2 Tensile Properties:

7.2.1 Except as permitted in 7.2.2 for long fasteners and 7.2.3 for short fasteners, hex cap screws and hex and square head bolts in sizes 1.00 in. and smaller having a length of $2\frac{1}{4}$ D and longer and sizes $1\frac{1}{8}$ to $1\frac{1}{2}$ in. inclusive having a length of 3D and longer shall be wedge tested full size. Bolts with heads other than hex or square shall be axially tested. Both wedge and axially tested hex cap screws and bolts shall conform to the proof load or alternative proof load, and minimum wedge tensile load in Tables 4 and 5, as applicable. The load applied during proof load testing shall be equal to or greater than the proof load in Table 4 or Table 5 as applicable.

7.2.2 Hex cap screws and square head bolts larger than $1\frac{1}{2}$ in. diameter, other than those excepted in 7.2.3, shall preferably be tested full size and when so tested shall conform to the tensile strength and either the specified proof load or yield strength requirements in Tables 4 and 5, as applicable. When equipment of sufficient capacity for full size testing is not available, or when the length of the bolt makes full size testing

impractical, machined specimens shall be tested and shall conform to the requirements of Table 6.

7.2.3 Sizes 1.00 in. and smaller having a length shorter than $2\frac{1}{4}$ D down to 2D inclusive, which cannot be wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load or alternate proof load specified in Tables 4 and 5. Sizes 1.00 in. and smaller having a length shorter than 2D which cannot be axially tension tested shall be qualified on the basis of hardness.

7.2.4 Studs 3D and longer shall be axially tension tested full size and shall conform to the tensile and proof load or alternate proof load specified in Table 4 and Table 5, as applicable. When equipment for full size testing is not available, or when the studs are too long for full size testing, machined specimens shall be tested and shall conform to the tensile requirements in Table 6.

7.2.5 If fasteners are subjected to both hardness and tensile tests, the tensile test results shall take precedence in the event of low hardness test results.

7.2.6 If fasteners are subjected to both full size and machined specimen tests, the full size test results shall take precedence if the results of the two methods differ.

8. Dimensions

8.1 Head and Body:

8.1.1 *Hex Cap Screws*—Unless otherwise specified, hex cap screws shall be furnished with dimensions conforming to ASME B18.2.1.

8.1.2 *Bolts*—When styles other than specified in 8.1.1 are required, they shall have dimensions conforming to those specified by the purchaser.

8.1.3 *Studs*—Studs shall have dimensions conforming to those specified by the purchaser.

8.2 Threads:

8.2.1 *Uncoated*—Unless otherwise specified, uncoated threads shall be the Unified Coarse Thread Series as specified in the latest issue of ASME B1.1, and shall have Class 2A tolerances.

8.2.2 *Coated*—Unless otherwise specified, zinc-coated bolts, to be used with zinc-coated nuts or tapped holes, which are tapped oversize in accordance with Specification A563, shall have UNC Class 2A threads before hot-dip or mechanically deposited zinc-coating. After zinc coating, the pitch diameter and major diameter shall not exceed the Class 2A limits by more than the following amounts:

Nominal Diameter, in.	Oversize Limit, in. ^A	
	Hot-Dip Zinc	Mechanical Zinc
$\frac{1}{4}$	0.016	0.012
$\frac{5}{16}$, $\frac{3}{8}$	0.017	0.012
$\frac{7}{16}$, $\frac{1}{2}$	0.018	0.012
$\frac{9}{16}$, $\frac{5}{8}$, $\frac{3}{4}$	0.020	0.013
$\frac{7}{8}$	0.022	0.015
1.0 to $1\frac{1}{4}$	0.024	0.016
$1\frac{3}{8}$, $1\frac{1}{2}$	0.027	0.018
$1\frac{3}{4}$ to 3.0, incl	0.050	0.033

^A Hot-dip zinc nuts are tapped oversize after coating and mechanical zinc coated nuts are tapped oversize before coating.

TABLE 2 Chemical Requirements for Type 3 Fasteners^A

Element	Composition, %					
	Type 3 Fasteners ^A					
	A	B	C	D	E	F
Carbon:						
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25
Product analysis	0.31–0.42	0.36–0.50	0.14–0.25	0.14–0.25	0.18–0.27	0.19–0.25
Manganese:						
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24
Phosphorus:						
Heat analysis	0.035 max	0.06–0.12	0.035 max	0.035 max	0.035 max	0.035 max
Product analysis	0.040 max	0.06–0.125	0.040 max	0.040 max	0.040 max	0.040 max
Sulfur:						
Heat analysis	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max
Product analysis	0.045 max	0.045 max	0.045 max	0.045 max	0.045 max	0.045 max
Silicon:						
Heat analysis	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35
Product analysis	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37
Copper:						
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.53	0.17–0.43
Nickel:						
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43
Chromium:						
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65
Product analysis	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68
Vanadium:						
Heat analysis	<i>B</i>	<i>B</i>	0.020 min	<i>B</i>	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	<i>B</i>	0.010 min	<i>B</i>	<i>B</i>	<i>B</i>
Molybdenum:						
Heat analysis	<i>B</i>	0.06 max	<i>B</i>	0.10 max	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	0.07 max	<i>B</i>	0.11 max	<i>B</i>	<i>B</i>
Titanium:						
Heat analysis	<i>B</i>	<i>B</i>	<i>B</i>	0.05 max	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	<i>B</i>	<i>B</i>	0.06 max	<i>B</i>	<i>B</i>

^AA,B,C,D, E and F are classes of material used for Type 3 fasteners. Selection of a class shall be at the option of the bolt manufacturer.

^BThese elements are not specified or required.

TABLE 3 Hardness Requirements for Hex Cap Screws, Bolts, and Studs

Nominal Diameter, in.	Length, in.	Brinell		Rockwell C	
		Min	Max	Min	Max
¼ to 1, inclusive	Less than 2D ^A	253	319	25	34
	2D and over	...	319	...	34
Over 1 to 1½, inclusive	Less than 3D ^A	223	286	19	30
	3D and over	...	286	...	30
Over 1½ to 3, inclusive	Less than 3D ^A	183	235	...	...
	3D and over	...	235	...	...

^A Hex cap screws and bolts larger than 1.00 in. diameter and shorter than 3D and all studs shorter than 3D are subject only to minimum and maximum hardness.
D = Nominal diameter or thread size

8.2.3 Unless otherwise specified, fasteners electroplated or mechanically coated to 0.0005 in. or less, threads prior to plating shall conform to ASME B1.1 Class 2A and after plating shall not exceed the Class 3A maximum limits, that is, Class 2A plus the allowance.

9. Workmanship, Finish, and Appearance

9.1 Surface discontinuity limits, inspection, and evaluation shall be in accordance with Specification F788/F788M.

10. Number of Tests and Retests

10.1 Testing Responsibility:

10.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 10.2-10.5.

10.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party as defined in 15.1 shall be responsible for assuring all tests have been performed and the fasteners comply with the requirements of this specification (see 4.3).

10.2 *Purpose of Lot Inspection*—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

10.3 *Lot Processing*—All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors

TABLE 4 Tensile Load Requirements for Coarse-Thread Full-Size Hex Cap Screws, Bolts and Studs

Bolt or Stud Diameter, in.	Threads per in. ^A	Stress Area, ^B in. ²	Tensile Load, min, lbf ^C	Proof Load, Length Measurement Method, lbf ^C	Alternative Proof Load, Yield Strength Method (0.2 % Offset), lbf ^C
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/4	20	0.0318	3 800	2 700	2 900
5/16	18	0.0524	6 300	4 450	4 800
3/8	16	0.0775	9 300	6 600	7 100
7/16	14	0.1063	12 750	9 050	9 800
1/2	13	0.1419	17 050	12 050	13 050
9/16	12	0.182	21 850	15 450	16 750
5/8	11	0.226	27 100	19 200	20 800
3/4	10	0.334	40 100	28 400	30 700
7/8	9	0.462	55 450	39 250	42 500
1	8	0.606	72 700	51 500	55 750
1 1/8	7	0.763	80 100	56 450	61 800
1 1/4	7	0.969	101 700	71 700	78 500
1 3/8	6	1.155	121 300	85 450	93 550
1 1/2	6	1.405	147 500	104 000	113 800
1 3/4	5	1.90	171 000	104 500	110 200
2	4 1/2	2.50	225 000	137 500	145 000
2 1/4	4 1/2	3.25	292 500	178 750	188 500
2 1/2	4	4.00	360 000	220 000	232 000
2 3/4	4	4.93	443 700	271 150	286 000
3	4	5.97	537 300	328 350	346 200

^A For 8 threads per in., sizes 1 1/8 to 1 1/2 in., inclusive, stresses of 105 000 psi, 74 000 psi, and 81 000 psi shall be used for calculating the values in columns 4, 5, and 6 respectively.

^B The stress area is taken from ASME B1.1 which uses the equation below to calculate the values:

$$A_s = 0.7854 [D - (0.9743/n)]^2$$

where:

A_s = stress area,

D = nominal diameter, and

n = threads per in.

^C Values tabulated are based on the following:

Bolt Size, in.	Column 4, psi	Column 5, psi	Column 6, psi
1/4 to 1, incl.	120 000	85 000	92 000
1 1/8 to 1 1/2, incl.	105 000	74 000	81 000
1 3/4 to 3, incl.	90 000	55 000	58 000

shall identify and maintain the integrity of each lot from raw material selection through all operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

10.4 Lot Definition:

10.4.1 *Standard Lot*—A lot shall be a quantity of uniquely identified fasteners of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same processor in the same manner so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

10.5 *Number of Tests*—The minimum number of tests from each lot for the tests specified below shall be as follows:

Tests	Number of Tests in Accordance With
Hardness, tensile strength, proof load	Guide F1470
Coating weight/thickness	The referenced coating specification ^A
Surface discontinuities	Specification F788/F788M
Dimensions and thread fit	ASME B18.2.1

^A Guide F1470 if the coating specification does not specify a testing frequency.

11. Test Methods

11.1 Tensile, proof load, and hardness tests shall be conducted in accordance with Test Methods F606.

11.2 Tensile strength for hex cap screws and hex and square bolts shall be determined using the wedge or axial tension testing method of full size product method or the machined test specimens method depending on size and length as specified in 7.2.2-7.2.6. Bolts with heads other than hex or square shall be

TABLE 5 Tensile Load Requirements for Fine-Thread Full-Size Hex Cap Screws, Bolts, and Studs

Bolt or Stud Diameter, in.	Threads per in.	Stress Area, ^A in. ²	Tensile Load, min, lbf ^B	Proof Load, Length Measurement Method, lbf ^B	Alternative Proof Load, Yield Strength Method (0.2 % Offset), min, lbf ^B
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/4	28	0.0364	4 350	3 100	3 500
5/16	24	0.0580	6 950	4 950	5 350
3/8	24	0.0878	10 550	7 450	8 100
7/16	20	0.1187	14 250	10 100	10 900
1/2	20	0.1599	19 200	13 600	14 700
9/16	18	0.203	24 350	17 250	18 700
5/8	18	0.256	30 700	21 750	23 500
3/4	16	0.373	44 750	31 700	34 300
7/8	14	0.509	61 100	43 250	46 800
1	12	0.663	79 550	56 350	61 000
1 1/8	12	0.856	89 900	63 350	69 350
1 1/4	12	1.073	112 650	79 400	86 900
1 3/8	12	1.315	138 100	97 300	106 500
1 1/2	12	1.581	166 000	117 000	128 000

^A See footnote B in Table 4.

^B See footnote C in Table 4.

TABLE 6 Tensile Strength Requirements for Specimens Machined from Hex Cap Screws, Bolts, and Studs

Nominal Diameter, in.	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 4D, min, %	Reduction of Area, min, %
1/4 to 1, incl.	120 000	92 000	14	35
Over 1 to 1 1/2, incl.	105 000	81 000	14	35
Over 1 1/2 to 3, incl.	90 000	58 000	14	35

axially tested. Fracture on full size tests shall be in the body or threads of the fastener without a fracture at the junction of the head and body.

11.3 Studs shall be tested by the axial tension method as described in the second paragraph of axial tension testing of full size products in the Test Methods section of Test Methods F606.

11.4 Proof load shall be determined using Method 1, length measurement, or Method 2, yield strength, at the option of the manufacturer.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The purchaser's representative shall have free entry to all parts of the manufacturer's works or supplier's place of business that concern the manufacture or supply of the fasteners. The manufacturer shall afford the purchaser's representative all reasonable facilities to satisfy him that the fasteners are being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unneces-

sarily with the operation of the manufacturer's works or supplier's place of business.

13. Rejection and Reheating

13.1 Disposition of nonconforming fasteners shall be in accordance with the section on Disposition of Nonconforming Lots of Guide F1470.

14. Certification

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 15, shall furnish the purchaser test reports which include the following:

14.1.1 Heat analysis, heat number, and a statement certifying that heats having the elements listed in 6.4 intentionally added were not used to produce the fasteners,

14.1.2 Results of hardness, tensile, and proof load tests,

14.1.3 Zinc coating measured coating weight/thickness for coated fasteners,

14.1.4 Statement of compliance with dimensional and thread fit requirements,

14.1.5 Lot number and purchase order number,

14.1.6 Complete mailing address of responsible party, and

14.1.7 Title and signature of the individual assigned certification responsibility by the company officers.

14.2 Failure to include all the required information on the test report shall be cause for rejection.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

16. Product Marking

16.1 *Manufacturers Identification*—All hex cap screws and bolts and one end of studs 3/8 in. and larger, and whenever

feasible studs smaller than $\frac{3}{8}$ in., shall be marked by the manufacturer with a unique identifier to identify the manufacturer.

16.2 Type Identification:

16.2.1 Type 1 hex cap screws and bolts and one end of Type 1 studs $\frac{3}{8}$ in. and larger, and whenever feasible studs smaller than $\frac{3}{8}$ in., shall be marked “A449.”

16.2.2 All Type 3 hex cap screws, bolts, and studs shall be marked to indicate that they are produced from weathering steel. Heads of type 3 hex cap screws and bolts shall be marked “A449” underlined. Type 3 studs $\frac{3}{8}$ in. and larger, and whenever feasible studs smaller than $\frac{3}{8}$ in., shall be marked “A449” underlined on at least one end. Studs under $\frac{3}{8}$ in. not marked “A449” underlined, shall be marked with the use of additional marks to indicate that they are produced from weathering steel.

16.3 Marking Location and Methods:

16.3.1 All markings shall be located on the top of a hex cap screw and bolt heads and on one end of studs and shall be either raised or depressed at the manufacturer’s option.

16.3.2 Type and manufacturer’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

16.4 *Acceptance Criteria*—Fasteners which are not marked in accordance with these provisions shall be considered non-conforming and subject to rejection.

17. Packaging and Package Marking

17.1 Packaging:

17.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D3951.

17.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

17.2 Package Marking:

17.2.1 Each shipping unit shall include or be plainly marked with the following information:

17.2.1.1 ASTM designation and type,

17.2.1.2 Size,

17.2.1.3 Name and brand or trademark of the manufacturer,

17.2.1.4 Number of pieces,

17.2.1.5 Lot number,

17.2.1.6 Purchase order number, and

17.2.1.7 Country of origin.

18. Keywords

18.1 bolts; carbon steel; hex cap screws; steel; studs

SUPPLEMENTARY REQUIREMENTS

S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking required by Section 16.

S1.2 Marking small sizes (customarily less than 0.375 in.) may not be practical. Consult the producer for the minimum size that can be marked.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR CARBON AND LOW ALLOY STEEL TUBES



SA-450/SA-450M



(Identical with ASTM Specification A450/A450M-10.)

Standard Specification for General Requirements for Carbon and Low Alloy Steel Tubes

1. Scope

1.1 This specification covers a group of requirements which, with the exceptions of 5.3 and Sections 6, 7, 18, 19, 20, 21, 22, 23, and 24, are mandatory requirements to the following ASTM tubular product specifications:

Title of Specification	ASTM Designation ^A
Electric-Resistance-Welded Carbon Steel and Carbon Manganese Steel Boiler Tubes	A178/A178M
Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes	A179/A179M
Seamless Carbon Steel Boiler Tubes for High-Pressure Service	A192/A192M
Seamless Medium-Carbon Steel Boiler and Superheater Tubes	A210/A210M
Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	A214/A214M
Seamless and Electric-Welded Low-Alloy Steel Tubes	A423/A423M
Specification for Seamless and Welded Carbon Steel Heat-Exchanger Tubes with Integral Fins	A498
Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	A556/A556M
Seamless, Cold-Drawn Carbon Steel Tubing for Hydraulic System Service	A822/A822M

^A These designations refer to the latest issue of the respective specifications.

1.2 One or more of Sections 5.3, 6, 7, 18, 19, 20, 21, 21.1, 23, and 24 apply when the product specification or purchase order has a requirement for the test or analysis described by these sections.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification only the requirement of the product specification need be satisfied.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the

SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A178/A178M Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes
- A179/A179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
- A192/A192M Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service
- A210/A210M Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes
- A214/A214M Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A423/A423M Specification for Seamless and Electric-Welded Low-Alloy Steel Tubes
- A498 Specification for Seamless and Welded Carbon Steel Heat-Exchanger Tubes with Integral Fins
- A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- A556/A556M Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes
- A700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment
- A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A822/A822M Specification for Seamless Cold-Drawn Carbon Steel Tubing for Hydraulic System Service

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferrous Alloys

A1047/A1047M Test Method for Pneumatic Leak Testing of Tubing

D3951 Practice for Commercial Packaging

E92 Test Method for Vickers Hardness of Metallic Materials (Withdrawn 2010)

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

E309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 Federal Standard:
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.3 Military Standards:
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage
MIL-STD-271 Nondestructive Testing Requirements for Metals
MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment

2.4 ASME Boiler and Pressure Vessel Code:
Section IX Welding Qualifications

2.5 Steel Structures Painting Council:
SSPC-SP 6 Surface Preparation Specification No. 6 Commercial Blast Cleaning

2.6 Other Document:
SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification.

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 remelted heat—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.2 thin-wall tube—a tube meeting the specified outside diameter and specified wall thickness set forth as follows:

Specified Outside Diameter	Specified Wall Thickness
2 in. [50.8 mm] or less	2 % or less of specified outside diameter
Greater than 2 in. [50.8 mm]	3 % or less of specified outside diameter
Any	0.020 in. [0.5 mm] or less

3.2 Other defined terms—The definitions in Test Methods and Definitions A370, Test Methods, Practices, and Terminology A751, and Terminology A941 are applicable to this specification and to those listed in 1.1.

4. Process

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

5. Chemical Composition

5.1 Samples for chemical analysis, and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

5.2 Heat Analysis—If the heat analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the manufacturer may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the specified elements that were not reported by the steel producer, provided that product analysis tolerances are not applied and the heat analysis is not altered.

5.3 Product Analysis—Product analysis requirements and options, if any, are contained in the product specification.

6. Tensile Properties

6.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specification.

6.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load shall be determined.

6.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than 3/4 in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

7. Standard Weights

7.1 The calculated weight per foot, based upon a specified minimum wall thickness, shall be determined by the following equation:

$$W = C(D - t)t \tag{1}$$

where:

- C = 10.69 [0.0246615],
- W = weight, lb/ft [kg/m],
- D = specified outside diameter, in. [mm], and
- t = specified minimum wall thickness, in. [mm]

7.2 The permissible variations from the calculated weight per foot [kilogram per metre] shall be as prescribed in Table 1.

8. Permissible Variations in Wall Thickness

8.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 2.

8.2 For tubes 2 in. [50.8 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

- Seamless tubes ± 10 %
- Welded tubes ± 5 %

8.3 When cold-finished tubes as ordered require wall thicknesses 3/4 in. [19.1 mm] or over, or an inside diameter 60 % or less of the outside diameter, the permissible variations in wall thickness for hot-finished tubes shall apply.

9. Permissible Variations in Outside Diameter

9.1 Except as provided in 9.2, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 3.

9.2 Thin-wall tubes usually develop significant ovality (out of roundness) during final annealing, or straightening, or both. The diameter tolerances of Table 3 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the *mean* of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the *difference* in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

TABLE 2 Permissible Variations in Wall Thickness^A

Outside Diameter, in. [mm]	Wall Thickness, %							
	0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl		Over 0.150 to 0.180 [3.8 to 4.6], incl		Over 0.180, [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [101.6] and under	40	0	35	0	33	0	28	0
Over 4 [101.6]	...	...	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
	Over				Under			
1 1/2 [38.1] and under	20				0			
Over 1 1/2 [38.1]	22				0			
Welded Tubes								
All sizes	18				0			

^A These permissible variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

TABLE 3 Permissible Variations in Outside Diameter^A

Outside Diameter, in. [mm]	Permissible Variations, in. [mm]	
	Over	Under
Hot-Finished Seamless Tubes		
4 [101.6] and under	1/64 [0.4]	1/32 [0.8]
Over 4 to 7 1/2 [101.6 to 190.5], incl	1/64 [0.4]	3/64 [1.2]
Over 7 1/2 to 9 [190.5 to 228.6], incl	1/64 [0.4]	1/16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25.4]	0.004 [0.1]	0.004 [0.1]
1 to 1 1/2 [25.4 to 38.1], incl	0.006 [0.15]	0.006 [0.15]
Over 1 1/2 to 2 [38.1 to 50.8], excl	0.008 [0.2]	0.008 [0.2]
2 to 2 1/2 [50.8 to 63.5], excl	0.010 [0.25]	0.010 [0.25]
2 1/2 to 3 [63.5 to 76.2], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [76.2 to 101.6], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7 1/2 [101.6 to 190.5], incl	0.015 [0.38]	0.025 [0.64]
Over 7 1/2 to 9 [190.5 to 228.6], incl	0.015 [0.38]	0.045 [1.14]

^A Except as provided in 9.2, these permissible variations include out-of-roundness. These permissible variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

Outside Diameter	Ovality Allowance
1 in. [25.4 mm] and under	0.020 in. [0.5 mm]
Over 1 in. [25.4 mm]	2.0 % of specified outside diameter

10. Permissible Variations in Length

10.1 Variations from the specified length shall not exceed the amounts prescribed in Table 4.

11. Permissible Variations in Height of Flash on Electric-Resistance-Welded Tubes

11.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

11.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.4 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically

TABLE 1 Permissible Variations in Weight Per Foot^A

Method of Manufacture	Permissible Variation in Weight per Foot, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished:		
1 1/2 in. [38.1 mm] and under OD	12	0
Over 1 1/2 in. [38.1 mm] OD	13	0
Welded	10	0

^A These permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 4 Permissible Variations in Length^A

Method of Manufacture	Outside Diameter, in. [mm]	Cut Length, in. [mm]	
		Over	Under
Seamless, hot-finished	All sizes	3/16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]
Welded	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]

^A These permissible variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by 1/8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or 1/2 in. [13 mm], whichever is the lesser.

removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

12. Straightness and Finish

12.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. Surface imperfections (see Note 1) may be removed by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

NOTE 1—An imperfection is any discontinuity or irregularity found in the tube.

13. Repair by Welding

13.1 Repair welding of base metal defects in tubing is permissible only with the approval of the purchaser and with the further understanding that the tube shall be marked “WR” and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be tested hydrostatically as required by the product specification.

13.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

14. Retests

14.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

15. Retreatment

15.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be retreated and resubmitted for test. Not more than two reheat treatments shall be permitted.

16. Test Specimens

16.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

16.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

17. Method of Mechanical Testing

17.1 The specimens and mechanical tests required shall be made in accordance with Annex A2 of Test Methods and Definitions A370.

17.2 Specimens shall be tested at room temperature.

17.3 Small or subsize specimens as described in Test Methods and Definitions A370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

18. Flattening Test

18.1 A section of tube not less than 2 1/2 in. [63 mm] in length for seamless and not less than 4 in. [100 mm] in length for welded shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 18.4, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1+e)t}{e+t/D} \quad (2)$$

where:

H = distance between flattening plates, in. [mm],
 t = specified wall thickness of the tube, in. [mm],
 D = specified outside diameter of the tube, in. [mm], and
 e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for low alloy steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

18.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

18.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

18.4 When low D -to- t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably

high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D to t ratio is less than 10.

19. Reverse Flattening Test

19.1 A 5 in. [100 mm] in length of finished welded tubing in sizes down to and including ½ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

20. Flaring Test

20.1 A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

21. Flange Test

21.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6.

22. Hardness Test

22.1 For tubes 0.200 in. [5.1 mm] and over in wall thickness, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load, or a 5-mm ball with 750-kg load may be used, at the option of the manufacturer.

22.2 For tubes less than 0.200 in. [5.1 mm] to and including 0.065 in. [1.7 mm] in wall thickness, the Rockwell hardness test shall be used.

22.3 For tubes less than 0.065 in. [1.7 mm] in wall thickness, the hardness test shall not be required.

22.4 The Brinell hardness test may be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a specimen cut from the

TABLE 5 Flaring Test Requirements

Ratio of Inside Diameter to Outside Diameter ^A	Minimum Expansion of Inside Diameter, %	
	Carbon Steels	Low Alloy Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

^A In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

TABLE 6 Flange Requirements

Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15 % of OD
Over 2½ to 3¾ [63.5 to 95.2], incl	12½ % of OD
Over 3¾ to 8 [95.2 to 203.2], incl	10 % of OD

tube at the option of the manufacturer. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

22.5 The Rockwell hardness test may be made on the inside surface, on the wall cross section, or on a flat on the outside surface at the option of the manufacturer.

22.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 22.1 and 22.2 on the outside of the tube near the end after the forming operation and heat treatment.

22.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

22.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E92.

23. Hydrostatic Test

23.1 Except as provided in 23.2 and 23.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$\text{Inch - Pound Units: } P = 32000 t/D \quad (3)$$

$$\text{SI Units: } P = 220.6t/D$$

where:

P = hydrostatic test pressure, psi or MPa,

t = specified wall thickness, in. or mm, and

D = specified outside diameter, in. or mm.

23.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending or other forming operations, or both.

23.2 Regardless of the determination made by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed the values given in Table 7. This

TABLE 7 Hydrostatic Test Pressures

Outside Diameter of Tube, in. [mm]	Hydrostatic Test Pressure, psi [MPa]
Under 1 [25.4]	1000 [7]
1 to 1½ [25.4 to 38.1], excl	1500 [10]
1½ to 2 [38.1 to 50.8], excl	2000 [14]
2 to 3 [50.8 to 76.2], excl	2500 [17]
3 to 5 [76.2 to 127], excl	3500 [24]
5 [127] and over	4500 [31]

does not prohibit testing at higher pressures at manufacturer's option or as provided in 23.3.

23.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 23.2 or 23.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \quad (4)$$

where:

S = tube wall stress, psi or MPa, and all other symbols as defined in 23.1.1.

23.4 The test pressure shall be held for a minimum of 5 s.

23.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

23.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

24. Air Pressure Test

24.1 *Air Underwater Test*—When this test is employed, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well-lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

24.2 *Pneumatic Leak Test*—When this test is employed, each tube shall be subjected to a pneumatic leak test in accordance with Specification A1047/A1047M.

Acceptance criteria shall be as follows:

Tube O.D. in [mm]	Calibration Hole, max. in [mm]
≤1.5 [≤40]	0.003 [0.076]
>1.5≤2.0 [>40≤50]	0.004 [0.162]
>2.0≤2.5 [>50≤65]	0.005 [0.127]
>2.5≤3.0 [>65≤75]	0.006 [0.152]
>3.0 [>75]	by agreement

25. Nondestructive Examination

25.1 When nondestructive examination is specified by the purchaser or the product specification, each tube shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309 (for ferromagnetic materials), Practice E426 (for non-magnetic materials), or Practice E570. Upon agreement, Practice E273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

25.2 The following information is for the benefit of the user of this specification.

25.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, etc., the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

25.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 25.4. The examination may not detect circumferentially oriented imperfections or short, deep defects.

25.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E309 and E426 contain additional information regarding the capabilities and limitations of eddy-current examination.

25.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

25.2.5 The hydrostatic test referred to in Section 22 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

25.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

25.3 *Time of Examination*—Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

25.4 Surface Condition:

25.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

25.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

25.5 Extent of Examination:

25.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in 25.5.2.

25.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

25.6 Operator Qualifications:

25.6.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

25.7 Test Conditions:

25.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.0 MHz, and the maximum transducer size shall be 1.5 in. (38 mm).

25.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

25.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness	Maximum Frequency
<0.050 in.	100 KHz
0.050 to 0.150	50
>0.150	10

25.8 Reference Standards:

25.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish and heat treatment condition as the tubing to be examined.

25.8.2 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

25.8.2.1 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. (0.8 mm) in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

25.8.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼ in. (6.4 mm) diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater.

25.8.2.3 *Longitudinal Notch*—A notch 0.031 in. (0.8 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

25.8.3 For ultrasonic testing, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The

depth of the notches shall not exceed 12½ % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater. The width of the notch shall not exceed two times the depth. For welded tubing, the notches shall be placed in the weld, if the weld is visible.

25.8.4 For flux leakage testing, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed 12½ % of the specified wall thickness or 0.004 in. (0.1 mm), whichever is greater. Notch length shall not exceed 1 in. (25.4 mm), and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

25.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

25.9 Standardization Procedure:

25.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

25.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.

25.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the tube to be tested, except that, at the manufacturer's discretion, the tubes may be tested at a higher sensitivity.

25.9.4 The signal-to-noise ratio for the reference standard shall be 2.5:1 or greater, and the reference signal amplitude for each discontinuity shall be at least 50 % of full scale of the display. In establishing the noise level, extraneous signals from identifiable surface imperfections on the reference standard may be ignored. When reject filtering is used during UT testing, linearity must be demonstrated.

25.9.5 If, upon any standardization, the reference signal amplitude has decreased by 29 % (3.0 dB), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s), or sensor(s) adjusted, and the unit restandardized, but all tubes tested since the last acceptable standardization must be retested.

25.10 Evaluation of Imperfections :

25.10.1 Tubing producing a test signal to or greater than the lowest signal produced by the reference standard shall be designated suspect, shall be clearly marked or identified, and shall be separated from the acceptable tubing.

25.10.2 Such suspect tubing shall be subject to one of the following three dispositions:

25.10.2.1 The tubes may be rejected without further examination, at the discretion of the manufacturer.

25.10.2.2 If the test signal was produced by imperfections such as scratches, surface roughness, dings, straightener marks,

loose ID bead and cutting chips, steel die stamps, stop marks, tube reducer ripple, or chattered flash trim, the tubing may be accepted or rejected depending on visual observation of the severity of the imperfection, the type of signal it produces on the testing equipment used, or both.

25.10.2.3 If the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections, the tubing shall be rejected.

25.10.3 Any tubes with imperfections of the types in 25.10.2.2 and 25.10.2.3, exceeding 0.004 in. (0.1 mm) or 12½ % of the specified minimum wall thickness (whichever is greater) in depth shall be rejected.

25.10.4 Rejected tubes may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. If grinding is performed, the outside diameter in the area of grinding may be reduced by the amount so removed. To be accepted, reconditioned tubes must pass the nondestructive examination by which they were originally rejected.

26. Certified Test Report

26.1 When specified in the purchase order or contract, the producer or supplier shall furnish a certified test report certifying that the material was manufactured, sampled, tested and inspected in accordance with the specification, including year date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that specification, the supplementary requirements and the other requirements. A signature or notarization is not required on the certified test report, but the document shall be dated and shall clearly identify the organization submitting the report.

NOTE 2—Notwithstanding the absence of a signature or notarization, the organization submitting the report is responsible for the contents of the report.

26.2 In addition, the certified test report shall include the following information and test results, when applicable:

- 26.2.1 Heat Number,
- 26.2.2 Heat Analysis,
- 26.2.3 Product Analysis, when specified,
- 26.2.4 Tensile Properties,
- 26.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,
- 26.2.6 Flattening Test acceptable,
- 26.2.7 Reverse Flattening Test acceptable,
- 26.2.8 Flaring Test acceptable,
- 26.2.9 Flange Test acceptable,
- 26.2.10 Hardness Test values,
- 26.2.11 Hydrostatic Test pressure,
- 26.2.12 Non-destructive Electric Test method,
- 26.2.13 Impact Test results, and
- 26.2.14 Other test results or information required to be reported by the product specification.

26.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported, but may be reported in a separate document.

26.4 The certified test report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 29.2), when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

26.5 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

27. Inspection

27.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

28. Rejection

28.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

28.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

29. Product Marking

29.1 Each length of tube shall be legibly stenciled with the manufacturers' name or brand, the specification number, and grade. The marking need not include the year date of the specification. For tubes less than 1¼ in. [31.8 mm] in diameter and tubes under 3 ft. [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

29.2 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification

number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in Section 26.

29.3 Bar Coding—In addition to the requirements in 29.1 and 29.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

30. Packaging, Marking, and Loading

30.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A700.

31. Government Procurement

31.1 Scale Free Pipe:

31.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

31.1.2 Tube shall be ordered to outside diameter (OD) and wall thickness.

31.1.3 *Responsibility for Inspection*— Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

31.1.4 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

31.1.5 *Sampling for Chemical Analysis*— One sample for chemical analysis shall be selected from each of two tubes chosen from each lot. A lot shall be all material poured from one heat.

31.1.6 *Sampling for Tension and Bend Test*— One sample shall be taken from each lot. A lot shall consist of all tube of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

31.1.7 *Hydrostatic and Ultrasonic Tests*— Each tube shall be tested by the ultrasonic (when specified) and hydrostatic tests.

31.1.8 Tube shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel tube shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

31.1.9 In addition to the marking in Specification A530/A530M, each length of tube $\frac{1}{4}$ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with Fed. Std. No. 183 and MIL-STD-792. (a) Outside diameter, wall thickness, and length (b) Heat or lot identification number.

31.1.10 Tube shall be straight to within the tolerances specified in Table 8:

31.1.11 When specified, each tube shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5 % of the wall thickness or 0.005 in., whichever is greater. Any tube which produces an indication equal to or greater than 100 % of the indication from the calibration standard shall be rejected.

31.1.12 The tube shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the tube as determined by visual and ultrasonic examination, or alternate tests, as specified.

31.1.13 Tube shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality tubing. Surface imperfections such as handling marks,

TABLE 8 Straightness Tolerances

Specified OD (in.)	Specified Wall Thickness (in.)	Maximum Curvature in Any 3 ft (in.)	Maximum Curvature in Total Length (in.)
Up to 5.0, incl	Over 3 % OD to 0.5, incl	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl	Over 4 % OD to 0.75, incl	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4 % OD to 1.0, incl	0.060	0.020 × length, ft

straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

31.1.14 No weld repair by the manufacturer is permitted.

31.1.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level

A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A700 or Practice D3951.

32. Keywords

32.1 alloy steel tube; austenitic stainless steel; carbon steel tube; general delivery; stainless steel tube; steel tube

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AN INTERNATIONAL CODE

The ASME Boiler and Pressure Vessel Code (BPVC) is a globally recognized and trusted source of technical requirements and guidance for the design and construction of boilers, pressure vessels, and nuclear components. With each new edition, the Code continues to evolve, introducing new technologies and processes to promote safety across pressure equipment applications and disciplines. Developed through a rigorous consensus process and fueled by the foresight of leading industry experts from around the world, the ASME BPVC is an ever-evolving set of standards that meets the needs of a changing world.

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