CSA Z245.17:22

Cold bends

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Cold bends

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Preface

This is the first edition of CSA Z245.17, *Cold bends*.

This Standard covers the requirements for factory-made steel cold bends intended to be used for transporting fluids as specified in CSA Z662.

As of this edition, induction bends and cold bends have been removed from CSA Z245.11, *Steel fittings*, and are now covered in CSA Z245.16 and Z245.17, respectively.

CSA Group acknowledges that the development of this Standard was made possible, in part, by the valuable dedication of Maros Tropp and the financial support of ATCO Ltd., Benpro Technologies Corp., British Columbia Oil and Gas Commission, Enbridge Inc., FortisBC Energy Inc., TC Energy Corp., and Tectubi Raccordi S.p.A. (Allied Fitting).

This Standard was prepared by the Subcommittee on Materials, under the jurisdiction of the Technical Committee on Petroleum and Natural Gas Industry Pipeline Systems and Materials, and the Strategic Steering Committee on Petroleum and Natural Gas Industry Systems, and has been formally approved by the Technical Committee.

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*
2) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*
3) *This Standard was developed by consensus, which is defined by* CSA Policy governing standardization — Code of good practice for standardization *as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this Standard.*
4) *To submit a request for interpretation of this Standard, please send the following information to* ***inquiries@csagroup.org*** *and include "Request for interpretation" in the subject line:*
   a) *define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;*
   b) *provide an explanation of circumstances surrounding the actual field condition; and*
   c) *where possible, phrase the request in such a way that a specific "yes" or "no" answer will address the issue.*

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   a) *Standard designation (number);*
   b) *relevant clause, table, and/or figure number;*
   c) *wording of the proposed change; and*
   d) *rationale for the change.*

CSA Z245.17:22
Cold bends

1 Scope

1.1 General

This Standard covers the manufacturing of factory-made cold bends, primarily intended for use in oil or gas pipeline systems.

1.2 Size, grade, and category

1.2.1 Size

This Standard covers cold bends from outside diameters (ODs) 21.3 to 1219 mm (NPS 1/2 to NPS 48, see CSA Z245.11 Table A.1).

1.2.2 Grade

For other than sour service, this Standard covers bends from Grade 241 to Grade 690. For sour service, this Standard covers bends from Grade 241 to Grade 483.

Note: *The standard grades are 241, 290, 359, 386, 414, 448, 483, 550, 620, and 690 (see Table 3); however, intermediate grades can be used in accordance with Clause 8.2.2.*

1.2.3 Category

This Standard covers cold bends in the following categories:

a) Category I: Cold bends without requirements for proven notch toughness properties; and
b) Category II: Cold bends with requirements for proven notch toughness properties.

1.3 Terminology

In the Standard, “shall” is used to express a requirement, i.e., a provision that the user is obligated to satisfy in order to comply with the Standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2 Reference publications

This Standard refers to the following publications, and where such reference is made, it shall be to the edition listed below, including all amendments published thereto.

Note: *In cases where the editions listed below are amended, replaced by new editions, or superseded by another standard during the life of this referencing Standard, it is the responsibility of the users of this Standard to investigate the possibility of applying those amendments, new editions, or superseding standards.*

CSA Group

Z245.11:22
Steel fittings

Z245.30:22
Field-applied external coatings for steel pipeline systems

Z662:19
Oil and gas pipeline systems

ASME (American Society of Mechanical Engineers)

BPVC.VIII.1-2021
ASME Boiler and Pressure Vessel Code, Section VIII — Pressure Vessels — Division 1: Rules for Construction of Pressure Vessels

ASTM International

A370-21
Standard Test Methods and Definitions for Mechanical Testing of Steel Products

A751-21
Standard Test Methods and Practices for Chemical Analysis of Steel Products

A1038-19
Standard Test Method for Portable Hardness Testing by the Ultrasonic Contact Impedance Method

E21-20
Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E29-13 (R2019)
Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E110-14
Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers

E140-12B(2019)e1
Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

E165/E165M-18
Standard Test Method for Liquid Penetrant Testing for General Industry

E709-21
Standard Guide for Magnetic Particle Testing

EN (European Standard)
10204:2004
Metallic products — Types of inspection documents

ISO (International Organization for Standardization)
2566-1:2021
Steel — Conversion of elongation values — Part 1: Carbon and low-alloy steels

NACE International (National Association of Corrosion Engineers)
NACE TM0284-2016
Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking

3 Definitions

The following definitions shall apply in this Standard:

Bend angle — amount of directional change through the bend (see Figure 1).

Centreline radius — distance from the centre of curvature to the centreline axis of the bent pipe (see Figure 1).

Cold bending — a bending process that applies a controlled mechanical force on the pipe being bent at ambient temperature.

Defect — an imperfection of sufficient magnitude to warrant rejection based on the requirements of this Standard.

Demonstrate — verify, or describe and explain, by the use of records, measurements, tests, comparison of specimens, experiments, or analysis by a competent person, supported by documentation.

Extrados — outer curved section of the bend arc (see Figure 1).

Grade — a product designation based on strength.
Note: *A grade designation is non-dimensional; however, it is numerically equivalent to the specified minimum yield strength in megapascals.*

Heat-affected zone — that portion of the weldment consisting of base metal that has not been melted but whose microstructure and mechanical properties or microstructure has been altered by the heat of welding.

Heat analysis — the chemical analysis reported by the steel producer as being representative of the heat of steel.

Hoop stress — the tensile stress that is produced by the pressure of the fluid in the pipeline and that acts in the circumferential direction.

Imperfection — a material discontinuity or irregularity that is detectable by inspection in accordance with the requirements of this Standard.

Intrados — inner curved section of the bend arc (see Figure 1).

Material test report (MTR) — a document that presents applicable or quantitative results obtained by applying one or more given test methods in accordance with EN10204 Type 3.1.

Neutral axis — the section of the bend that is 90° from the intrados or extrados (see Figure 1).

Notch toughness — the resistance of the steel to fracture under suddenly applied loads at a notch.

Out-of-round (OOR) — difference between the maximum and minimum outside diameter measured on any radial cross-section.

Product analysis — the chemical analysis made on a sample taken from the finished bend or from material representative of the finished bend.

Stress — the internal force per unit area that resists change in the size or shape of a body acted on by a force or forces external to the body.

Tangent — straight section at the ends of a bend (see Figure 1).

Tensile strength — the stress obtained by dividing the maximum load applied in a conventional tensile test by the original cross-sectional area of the test sample.

Yield strength — the stress at which the steel exhibits either 0.2% offset deviation from the proportionality of stress to strain or 0.5% total elongation under load in a tensile test.

4 General requirements

4.1 Product ordering requirements

4.1.1 Standard requirements

The following information shall be included in the purchase order for bends:

a) CSA Standard designation and year of publication (e.g., Z245.17:22);
b) quantity, size, and description;
c) grade or intermediate grade (see Clause 1.2.2);
d) matching pipe specified wall thickness at each end;
e) matching pipe grade at each end, if different from the bend grade;
f) bend angle, centreline radius, tangent lengths (see Figure 1), and minimum wall thickness after bending (see Clause 4.2.2);
g) the dimensions and grade of any straight pipe supplied by the purchaser for bending;
h) category (see Clause 1.2.3);
i) test temperature for Category II (see Clause 8.3.1.2);
j) end preparation (see Clause 9.4);
k) packaging and shipping instructions; and
l) required delivery date.

4.1.2 Optional requirements

Where applicable, the purchase order shall include information concerning the following items, which are optional for the purchaser:

a) weld seam position (see Clause 5.4.2);

b) post-bend heat treatment (see Clause 5.5.3);
c) increased absorbed energy values (see Clauses 8.3.4.1 and 8.3.4.2);
d) guided bend tests (see Clause 8.5);
e) plant inspection by the purchaser or representative (see Clause 10.3);
f) liquid penetrant or magnetic particle inspection of welds (see Clause 11.2);
g) liquid penetrant or magnetic particle inspection of bends (see Clause 11.2);
h) mechanical test reports; and
i) report of specific sour service items, guided bend tests, and/or hardness tests (see Clause 12).

4.1.3 Additional requirements

Where applicable, the purchase order shall include information concerning the following items, which are subject to agreement between the purchaser and the manufacturer:
a) higher field test pressure (see Clause 4.2.2);
b) use of thermomechanical controlled process (TMCP) material (see Clause 5.3);
c) manufacturing procedure specification (see Clause 5.6);
d) inspection and test plan (see Clause 5.7);
e) test frequency for hardness tests (see Clause 8.4.1);
f) ultrasonic or radiographic inspection of seam welds (see Clause 11.1);
g) alternative requirements for markings (see Clause 14.1); and
h) longitudinal tensile test requirements.

4.2 Pressure rating

4.2.1 Capability

After installation, bends shall be capable of withstanding a pressure test at a pressure level required to develop a hoop stress equal to the specified minimum yield strength for pipe of equivalent grade and wall thickness attached to the bend, or at a higher pressure level specified in the purchase order, without failure, leakage, plastic deformation, or impairment of serviceability or mechanical properties.

4.2.2 Design thickness

The thickness at the neutral axis and on the extrados of the bend shall be no less than the mating pipe design thickness or the purchaser-specified minimum wall thickness. The required internal pressure design thickness at the intrados of the bend shall be determined in accordance with the following equation:

$$T_1 \geq \left[\frac{4(R / NOD) - 1}{4(R / NOD) - 2}\right] t$$

where

NOD = nominal outside diameter

R = bend centreline radius

T_1 = minimum required thickness at the intrados

t = nominal design wall thickness

4.3 Rounding procedure

Except as otherwise required by this Standard, to determine conformance with the specified requirements, observed or calculated values shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of ASTM E29.

4.4 Quality management system

The manufacturer shall have a documented quality management system that complies with the requirements of a nationally or internationally recognized quality management system standard. The quality management system shall specify controls for the manufacturing process, heat treatment process, testing, inspection, material traceability from starting material to final product, and documentation requirements necessary to ensure compliance with this Standard. If applicable, the control and verification of sub-supplier activities (e.g., forming, heat treatment, inspection) shall be the responsibility of the manufacturer.

To ensure material traceability, the manufacturer shall follow documented procedures for maintaining the identity throughout the entire supply chain and production process. Such procedures shall provide means for tracing any bend to the appropriate heat and qualification bend, including chemical and mechanical test results, back to and including the starting raw material used for production.

5 Materials and manufacture

5.1 Steel-making process and deoxidation practice

Bends shall be made from open hearth, electric furnace, or basic oxygen-process steel. The steel shall be semi-killed or killed.

5.2 Starting pipe material

Pipe used for bends shall be in accordance with one of the specifications listed in CSA Z662 Table 5.3 and shall comply with the requirements of that applicable material specification.

In addition to the above, pipe used for sour service bends shall also meet the supplemental requirements listed in CSA Z662 Clause 16.4.

5.3 Starting pipe made from thermomechanical controlled process (TMCP)

Pipe formed from TMCP plate can be used with caution, as TMCP plate results in material that loses properties when heated over 260 °C. If the purchaser wishes to use this material, they shall consult with the manufacturer and determine what forming conditions and heat treatments are acceptable for this material’s use.

5.4 Bends containing welds

5.4.1 General

Seam-welded pipe used for bends shall be electric welded (EW) or longitudinal submerged metal arc (SAWL). Helical submerged metal arc (SAWH) pipe may be used for bends when agreed to with the purchaser.

5.4.2 Weld seam position

The seam weld of longitudinally welded pipe shall be located within ±15° of the neutral axis of the finished bend. If agreed, weld seam position (top or bottom) shall be specified by the purchaser.

5.4.3 Girth welds

Circumferential girth welds shall not be permitted within the bend radius.

5.5 Bends

5.5.1 Forming

Cold bending shall be done by roll bending, rotary draw bending, or ram style bending.

5.5.2 Forming and sizing after bending

Hot forming (including spot heating) or hot sizing after bending shall not be permitted.

5.5.3 Heat treatment

Cold bends shall be stress relieved as specified in Clause 7 if the wall thinning due to bending exceeds 10% or when specified in the purchase order. For bends intended for sour service stress, relieving shall be required if the fibre strain exceeds 5%. Fibre strain shall be calculated using the equation

$$\frac{NOD}{2 \cdot R} \times 100$$

where

NOD = outside diameter of the pipe, mm

R = centreline radius of the bend, mm

Where specified by the purchaser, bends shall be subject to post-bend heat treatment as per Clause 7.

5.6 Manufacturing procedure specification (MPS)

When specified by the purchaser, cold bends shall be manufactured in accordance with a documented manufacturing procedure specification. If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable:

a) starting pipe information
   i) pipe grade;
   ii) type of pipe (EW, SMLS, SAWL, SAWH);
   iii) pipe dimensions (i.e., diameter, wall thickness); and
   iv) mechanical properties;
b) testing and inspection requirements for
   i) qualification test bend; and
   ii) production bends;
c) bending process
   i) pipe cleaning method prior to bending (if any);
   ii) method of cold bending; and
   iii) values of bending parameters (see essential variables);
d) details of post-bend heat treatment, if applicable
   i) heating rate, soaking time and temperature, cooling medium and rate; and
   ii) type and location of thermocouples; and
e) additional requirements
   i) end preparation;
   ii) marking; and
   iii) storage and shipping.

5.7 Inspection and test plan

When specified by the purchaser, the manufacturer shall supply the purchaser with summary information or identification of the control documents, as applicable, on the main characteristics of the inspection and test plan (ITP). The ITP shall include, at a minimum, the following information:

a) inspection activity;
b) organization or individuals responsible for performing the inspection activity (including manufacturer, subcontractor, purchaser, or third-party representation);
c) inspection/test practices, as applicable;
d) frequency of inspection;
e) acceptance criteria;
f) result recording, as applicable;
g) identification of processes requiring validation; and
h) witness and hold points.

6 Chemical test requirements

6.1 General

Except as otherwise required by this Standard, the methods, practices, and definitions pertaining to chemical analysis shall be as specified in ASTM A751.

6.2 Heat analysis

The requirements for heat analysis shall be as specified in Table 4.

6.3 Product analysis

Product analyses shall be determined by the bend manufacturer or the pipe manufacturer at a frequency of twice per heat. The requirements for product analysis shall be as specified in Table 4.

6.4 Records

The heat analysis or product analysis values for the elements with listed maximums in Table 4 and the carbon equivalent calculated in accordance with Table 4 shall be reported on the material test report (MTR) as required by Clause 15.1 c).

7 Heat treatment

7.1 General

Where specified by Clause 5.5.3, the bends shall be heat treated using the procedure specified in Clause 7.2. Furnaces shall be surveyed at least annually, controlled within ±15 °C from the set point temperature, and equipped with recording sensors that are calibrated at least quarterly.

The total thickness of the bend and any contact with other objects, such as other bends and supports, shall be considered to ensure uniform temperature through the thickness of the bend. Annex A shall be used for the calibration and survey of heat treating equipment unless another practice can be demonstrated to be equivalent.

7.2 Stress relieving

Cold bends shall be

a) heated to a suitable temperature below the transformation range, but not less than 480 °C;
b) held at this temperature for a minimum of 1 h per 25 mm of maximum thickness, but not less than 0.5 h; and
c) cooled in the furnace or in still air at a maximum rate of 200 °C per hour.

7.3 Procedures and records

7.3.1 Operator training

Heat treating shall be done by trained operators.

7.3.2 Furnace loading

Heat treatment and loading procedures shall be available for review at the facility and shall include requirements for furnace temperatures and soak times at temperature. Furnaces shall be visually inspected at least every three months for scale build-up, burner malfunction, loss of refractory material, or hot spots on the shell of the furnace.

7.3.3 Recording

A record of each heat treatment load shall be recorded and reviewed for consistency to the qualification bend and previous loads of the same heat.

Records for qualification and production bends shall, at a minimum, include furnace number, date, identification of all bends in the load, procedure used, heat treatment charts, order number, and bend descriptions. Manufacturers using third-party services shall maintain copies of heat treatment records from their sub-supplier.

When requested by the purchaser, the manufacturer shall demonstrate, in a manner mutually agreed between the purchaser and the manufacturer, that the requirements in Clause 7 were met.

Note: *Photographic images may be taken of heat treatment loads to augment records.*

8 Mechanical test requirements

8.1 General

8.1.1 Representative specimens

Test specimens for mechanical tests shall be representative of the finished bends.

8.1.2 Defective test specimens

For any of the mechanical tests specified in Clauses 8.2 to 8.5, specimens showing defective preparation or material imperfections unrelated to the intent of the particular mechanical test, whether observed before or after testing, may be discarded, and replacements shall be considered original specimens.

8.1.3 Qualification bend

8.1.3.1 Essential variables

Prior to production bending, a qualification bend shall be made using the same MPS that is intended to be used for the production bends. Changes in any of the essential variables beyond the limits of variation as specified in Table 1 shall require a new qualification bend and MPS.

8.1.3.2 Sampling locations

The location of the test coupons and the frequency of testing shall be in accordance with Table 2. Each qualification bend shall be tested in the final heat-treated condition. The length of the qualification bend shall be sufficient to allow the removal of all required specimens. If helical submerged metal arc (SAWH) pipe is used for bends, then test specimen locations shall be as agreed upon with the purchaser.

Category I bends shall be subject to tension and hardness tests. Category II bends shall be subject to tension tests, notch toughness tests, and hardness tests. Where specified in the purchase order, bends shall be subject to guided bend tests.

8.1.4 Bend inspection

Unless otherwise specified by the purchaser, qualification bends and production bends shall be inspected. The inspections shall consist of wall thickness, ovality, and hardness. Wall thickness measurements shall be performed by ultrasonic testing methods. Out-of-roundness shall be measured by the use of calipers or another practical method, and shall be the difference between the largest diameter and the smallest diameter. Hardness readings shall be performed utilizing the ultrasonic contact impedance (UCI) method or portable testing method agreed upon by the purchaser, and shall be reported in the Brinell scale.

8.2 Tension tests

8.2.1 General

Except as otherwise required by this Standard, test specimens and testing procedures shall be as specified in ASTM A370. Testing shall be conducted with the test specimens at room temperature. Yield strength and tensile strength results shall be rounded to the nearest megapascal. For Grade 241 to Grade 620, the yield strength shall be the tensile stress required to produce a total extension under load of 0.5% of the gauge length.

8.2.2 Requirements

The tensile properties of test specimens representing the body of the bend shall be as specified in Table 3. For NPS 8 and larger welded bends, the tensile strength of test specimens across welds shall be as specified in Table 3. Intermediate grades may be used when approved by the purchaser and tensile properties are determined in accordance with the Note to Table 3. Reporting of yield strength is not required for weld tension tests.

8.2.3 Cold flattening

Round-bar testing pieces machined from unflattened samples are preferred. Cold-flattened transverse specimens may be used when the use of round-bar specimens is not feasible or practical.

8.2.4 Test specimen orientation

Test specimen orientation shall be taken transverse to the major axis for bends NPS 8 and larger, and shall be longitudinal to the major axis for smaller sizes. Round bar test specimen axial location shall be centred at the 1/2 *t* location for thicknesses less than or equal to 38 mm and 1/4 *t* for thicknesses greater than 38 mm. The longitudinal axis of transverse weld specimens shall be perpendicular to the weld axis.

8.2.5 Test specimen dimensions

The strip test specimens shall be as shown in Figure 2. Strip test specimens shall be 38 mm (+3 mm, –6 mm) wide in the reduced section, unless the size of the bend or the character of the material to be tested makes the use of sub-size test specimens necessary. For such cases, the test specimens shall be 19 mm (+3 mm, –6 mm) wide for bends NPS 3 or smaller, and 25 mm (+3 mm, –6 mm) wide for bends larger than NPS 3 up to NPS 6.

8.3 Notch toughness — Category II bends

8.3.1 General

8.3.1.1 Charpy V-notch impact tests

Charpy V-notch impact tests shall be conducted as specified in ASTM A370. An impact test shall consist of testing three adjacent specimens taken from a single test coupon. The result shall be the average of the results of the three test specimens.

The test result is acceptable when the following conditions are met:

a) the test result (average of three specimens) equals or exceeds the specified test minimum value (as specified in Clause 8.3.4);
b) the individual value for not more than one specimen measures less than the specified test minimum value; and
c) the individual value for any specimen measures not less than two-thirds of the specified test minimum value.

8.3.1.2 Test temperature

The test temperature shall be as specified in the purchase order, except that a lower test temperature may be used if the specified absorbed energy requirements are met.

8.3.2 Test specimen orientation

8.3.2.1 Body tests

For body tests, the notch shall be perpendicular to the surface of the bend. For sizes NPS 6 and larger, the test specimen orientation shall be transverse to the axis of the bend. For sizes smaller than NPS 6, the test specimen orientation shall be either transverse or parallel to the direction of maximum work, at the option of the manufacturer.

8.3.2.2 Weld tests

Test specimens for weld tests shall be etched prior to notching to enable proper placement of the notches. For weld tests, Charpy V-notch test specimens shall be transverse to the axis of the weld, and the root of the notch shall be located

a) within 0.5 mm of the weld fusion line for bends formed from EW pipe;

b) in the centre of the deposited weld for bends formed from SAWL or SAWH pipe; and
c) as close as practical to the outside edge of the weld bead for bends formed from SAWL or SAWH pipe.

8.3.2.3 Cold flattened specimens

Cold flattened specimens shall not be used.

8.3.3 Test specimen size

8.3.3.1

Except as allowed by Clauses 8.3.3.2 and 8.3.3.4, the test specimen size and type shall be as specified in Table 5.

8.3.3.2

The test specimens shall be full-size specimens unless the test specimen thickness or the testing machine energy capacity dictate the use of subsize specimens. The largest obtainable subsize test specimen from those specified in Table 5 shall be used. If material wall thickness and/or diameter does not allow at least a 1/2-size Charpy specimen, no toughness testing shall be required.

8.3.3.3

Where subsize test specimens are used, the minimum energy absorption value requirement shall be that specified for full-size test specimens multiplied by the applicable reduction ratio, as follows:

Specimen size	Dimensions, mm	Reduction ratio
3/4	10 x 7.5	0.75
2/3	10 × 6.7	0.67
1/2	10 × 5.0	0.50

8.3.3.4

The next smaller test specimens may be substituted in the following cases:
a) where the energy needed to break a test specimen of the required size is expected to exceed 80% of the capacity of the impact testing machine; or
b) the actual wall thickness, within the allowable tolerance, does not permit machining of a sample of the required size.

8.3.4 Requirements

8.3.4.1 Body

For body tests, the absorbed energy (based on full-size test specimens) for each Charpy V-notch impact test shall be greater than or equal to
a) 27 J for bends smaller than NPS 18;
b) 40 J for bends NPS 18 or larger; or
c) a higher value, if specified in the purchase order.

8.3.4.2 Weld

Charpy V-notch impact tests shall be conducted on test specimens taken for

a) bends with a specified test temperature lower than –5 °C; or
b) where specified in the purchase order, bends with a specified test temperature of –5 °C or higher.

The absorbed energy (based on full-size test specimens) for each test shall be equal to or greater than 18 J, or such higher value as is specified in the purchase order.

Note: *A lower toughness value is permitted for weld tests because welds are 100% non-destructively inspected; accordingly, imperfections in the weld are typically smaller than imperfections in the body of the bend.*

8.4 Hardness test

8.4.1 Test locations and frequency

Each qualification bend shall be subject to surface and cross-sectional hardness testing at the locations specified in Table 2.

Production bends shall be subject to surface hardness testing at the same locations as the qualification bend, as specified in Table 2, and every 30° of bend arc.

Inspection locations and frequency may be increased as agreed upon with the purchaser.

All hardness testing shall be conducted in the final heat-treated condition.

8.4.2 Type of hardness tester

The type of portable hardness tester used to perform the surface hardness tests on the qualification bends shall be the same as used on each production bend. Hardness testing shall be performed utilizing ASTM A1038 or ASTM E110, or as agreed upon with the purchaser, and shall be reported in the Vickers scale.

8.4.3 Surface hardness

8.4.3.1

Except as allowed by Clause 8.4.3.2, the following surface hardness test locations shall be assessed and shall not exceed 260 HB or an equivalent value obtained by conversion from another macrohardness scale in accordance with the requirements of ASTM E140:

a) body of seamless bends;
b) body and weld zone of EW bends; and
c) body, deposited weld metal, and heat-affected zone of SAW bends.

For sour service, see Clause 12.

8.4.3.2

For non-sour service Grades 483 and higher, the following surface hardness test locations shall be assessed and shall not exceed 302 HB or an equivalent value obtained by conversion from another macrohardness scale in accordance with ASTM E140:

a) body of seamless bends;
b) body and weld zone of EW bends; and
c) body, deposited weld metal, and heat-affected zone of SAW bends.

8.4.4 Cross-sectional hardness tests

8.4.4.1
The qualification bend shall be subject to a Vickers cross-sectional hardness test using a 10-kg load at each of the locations stated in Table 2. The number and location of the hardness indentations on each specimen shall be as shown in Figures 3a, 3b, and 3c.

8.4.4.2
Except as allowed by Clause 8.4.4.3, the cross-sectional hardness at any location shall not exceed 260 HV10. (For sour service, see Clause 12.)

8.4.4.3
For non-sour service Grades 483 and higher, the cross-sectional hardness of the body and weld zone shall not exceed 302 HV10.

8.5 Guided bend tests

8.5.1 General
Where specified in the purchase order, welds in the bend shall be subjected to guided bend tests as specified in Clauses 8.5.2 and 8.5.3.

8.5.2 Method
Transverse weld test specimens shall be subjected to face and root guided bend tests. The specimens shall be as specified in Figure 4, and shall be bent using a plunger as shown in Figure 5 and a jig that is substantially as shown in Figure 5. For EW material, only root guided bend tests are required.

8.5.3 Criteria
Bend tests shall be acceptable if no cracks or other defects exceeding 3 mm in any direction are present in the weld metal or the heat-affected zone after bending. Cracks that originate at the edges of the specimen and are less than 6 mm long shall not be cause for rejection.

8.6 Retesting
If any of the tension, notch toughness, hardness, or guided bend test specimens from the qualification bend fail to conform to requirements, at the manufacturer’s option the qualification bend may be retested or rejected. Retests shall only be required for the particular test with which the specimen did not comply originally.

The qualification bend shall be retested using test specimens from two additional samples from the same qualification bend and taken immediately adjacent to the original test sample location. If there is insufficient material to complete this, a second qualification bend or portion thereof shall be used for retesting. Where both retests conform to the specified requirements, the qualification bend shall be accepted. If one or both retests fail to conform to the requirements, the qualification bend shall be rejected.

9 Dimensions and tolerances

9.1 Wall thickness tolerances

No location shall have a measured wall thickness less than the values specified in the purchase order by the purchaser.

9.2 Inspection frequency

Each qualification bend shall be subject to wall thickness testing at the locations specified in Table 2.

Production bends shall be inspected as a minimum of 10% per production lot (heat, diameter, wall thickness, radius). The largest angles in each inspection lot should be inspected.

Inspection frequency may be increased as agreed upon with the purchaser.

9.3 Bend tolerances

The tolerances of bends shall be as specified in Table 6.

9.4 Recommended end preparations

The recommended end preparations are shown in Figure 6. The root face/land of the bend shall be machined flat and shall not vary from the plane by more than 0.8 mm. The purchaser shall state the end preparation required. All counterbore end preparations shall be as per Figure 8.

9.5 Design of ends for unequal grades

Weld end configurations for bends with a lower grade than the matching pipe shall be designed as shown in Figure 7.

9.6 Maximum bevel thickness

The maximum bevel thickness at the end of the bend shall be the greater of

a) t_{min} + 4 mm; or

b) $1.10t_D$

where

t_{min} = $0.875t_D$ for bends NPS 18 and smaller and $0.92t_D$ for bends larger than NPS 18

t_D = the nominal wall thickness of the matching pipe when the grade of the bend is equal to or greater than that of the matching pipe

= t_D as defined in Figure 6 when the grade of the bend is less than that of the matching pipe

10 Inspection, work quality, and repair of bends containing defects

10.1 Plant inspection

The internal and external surfaces of the finished bend shall be free of loose mill scale, foreign matter, oil, and grease, and shall be clean and dry for final inspection. Each bend shall be visually inspected to detect defects and to determine compliance with the dimensional and work quality requirements.

10.2 Inspection notice

Where specified in the purchase order that the inspector representing the purchaser intends to inspect the bends or witness the tests at the manufacturer's plant, the manufacturer shall give the purchaser reasonable notice of the production schedule.

10.3 Plant access

While work on the purchaser's order is being performed, the inspector representing the purchaser shall have unrestricted entry at all times to all parts of the manufacturer's plant concerned with the manufacture of the ordered bends. The manufacturer shall afford the inspector all reasonable facilities to allow the inspector to verify that the bends are being manufactured, sampled, tested, and inspected as specified in this Standard and the purchase order. Inspections shall be conducted without unnecessary interference with normal plant operation.

10.4 Work quality

10.4.1 General

Bends shall be smooth and uniform.

10.4.2 Waves

Waves as shown in Figure 9 shall be acceptable provided that the following requirements are met:

a) the wave shapes blend into the bend surface in a gradual manner with a maximum crest-to-valley depth (CVD) of 1% of the nominal outside diameter; and
b) the ratio of the distance between adjacent crests (l) to the CVD is a minimum of 25.

10.4.3 Defects

Defects shall be defined as:

a) sharp notches, scratches, scabs, seams, laps, tears, slivers, arc burns, and cracks;
b) other imperfections, excluding dents and waves, that result in a wall thickness less than that allowed by Clause 9.1;
c) dents described by one or more of the following criteria:
    i) dents that are deeper than 1.5 mm, located in the body of the bend, and contain a stress concentrator such as a gouge, groove, or arc burn;
    ii) dents that are located on a weld and are deeper than 1.5 mm;
    iii) for NPS 12 and smaller bends, plain dents that are deeper than 3.2 mm; and
    iv) for bends larger than NPS 12, plain dents that are deeper than 1% of the nominal bend size; and
d) waves exceeding the tolerances specified in Clause 10.4.2.

The depth of a dent shall be measured as the gap between the lowest point of the dent and the prolongation of the original contour of the bend in any direction. The removal or modification of dents by mechanical means or welding of dents shall be prohibited.

10.5 Repair of bends containing defects

10.5.1 Defect repair

Other than wave defects, bends containing defects shall be given either or both of the following dispositions:

a) the defect shall be removed by grinding, provided that the remaining wall thickness is verified to be within the limits specified in Clause 9.1; or
b) the bend shall be rejected.

Bends containing wave defects shall be rejected.

10.5.2 Grinding repair

Where grinding is performed, it shall be done in a competent manner to ensure no damage to the surrounding area, and to provide gradual transitions not resulting in a stress concentrator.

10.6 Bending of pre-coated pipe

After inspection, all areas with damaged or missing coating shall be repaired in accordance with CSA Z245.30.

11 Non-destructive inspection

11.1 Radiography or ultrasonic inspection

Where specified in the purchase order, or where welds have not been radiographically or ultrasonically inspected by the pipe manufacturer, welds shall be inspected throughout their entire length after bending and shall comply with Paragraph UW 51 or Appendix 12, whichever is applicable, of ASME BPVC.VIII.1.

11.2 Liquid penetrant or magnetic particle inspection

Where specified in the purchase order, liquid penetrant per ASTM E165 or magnetic particle inspection per ASTM E709 shall be performed on both the intrados and extrados. The mill scale shall be removed from the areas to be inspected. Bends so inspected shall comply with Appendix 6 or 8, whichever is applicable, of ASME BPVC.VIII.1.

12 Sour service

12.1

Where sour service is specified in the purchase order, the requirements of Clauses 1 to 11, 14, and 15 shall apply, except where such requirements are modified by the requirements of Clause 12.

12.2

The type and frequency of additional inspection and post-bend heat treatment shall be specified by the purchaser for sour service bends.

12.3
The macrohardness at any location in the bend shall not exceed 22 HRC or an equivalent value obtained by conversion from another macrohardness scale in accordance with the requirements of ASTM E140.

12.4
The microhardness at any location in the body or weld zone of bends formed from electric welded pipe and in the body, deposited weld metal, and heat-affected zones of other welds shall not exceed 248 HV 0.5.

12.5
Bends formed from electric-welded pipe NPS 2 or larger shall be subjected to the root guided bend test in accordance with the applicable requirements of Clause 8.5.

12.6
Where hydrogen-induced cracking testing is specified in the purchase order, such testing shall be performed in accordance with the requirements of NACE TM0284, with the test solution, test frequency, and acceptance criteria as specified in the purchase order.

12.7
The tensile strength shall not exceed 625 MPa for Grades 386 and lower, 650 MPa for grades higher than Grade 386 but lower than Grade 483, and 665 MPa for Grade 483.

Note: *For sour service, grades higher than Grade 483 are not within the scope of this Standard.*

12.8
Any lamination in the body of the bend shall be considered a defect if its non-destructively determined dimensions exceed

a) a width of 20 mm; and
b) an area of 500 mm^2.

12.9
The nickel content at any location, including any deposited weld metal, shall not exceed 1.0%.

12.10
Bends with a fibre strain of 5% or greater shall be subject to a post-bend heat treatment in accordance with Clause 7.2.

13 Elevated temperature service

13.1
Where a bend for elevated temperature service is specified in the purchase order, the requirements of Clauses 1 to 11, 14, and 15 shall apply, as well as Clause 12 when sour service is applicable, except where modified by the requirements of Clause 13.

Note: *Materials (including welding consumables) and manufacturing procedures should be selected so that specified elevated temperature properties are maintained at the elevated test temperature for welds, heat-affected zones, and parent metal.*

13.2

In addition to the standard requirements specified in Clause 4.1.1, the purchase order shall include the following:

a) elevated test temperature(s);
b) elevated temperature tension test
   i) frequency;
   ii) specimen type, size, location, and orientation;
   iii) required properties for bend body and weld seam (if present); and
   iv) retesting procedures.

Note: *Elevated temperature tension test requirements and impact property requirements at the minimum design temperature may be derived from CSA Z662, Clause 14 and Annex I.*

13.3

In addition to the requirements specified in Clause 8.2.1, elevated temperature tension tests shall be conducted in accordance with the requirements of ASTM E21 at the specified elevated test temperature. Round cross-section specimens shall be used unless otherwise agreed upon by the manufacturer and the purchaser.

Note: *The relationship between tensile properties and test temperatures can be non-linear.*

13.4

For submerged arc welded bends, each bend grade and combination of welding flux and electrode classifications shall be considered essential variables.

13.5

Unless otherwise agreed upon by the purchaser, in addition to the requirements specified in Clause 8.2.1, all-weld-metal tension testing shall be conducted at room temperature at the frequency specified by the purchaser [see Clause 13.2 b) i)] in accordance with the requirements of ASTM A370.

Unless otherwise agreed upon by the purchaser, in addition to the requirements specified in Clause 13.3, all-weld-metal tension testing shall be conducted at the specified elevated test temperature in accordance with ASTM E21.

The results of both room temperature and elevated temperature tension tests shall be included in the qualification record. Test specimens shall be all-weld-metal standard or subsize round tensile specimens in accordance with the requirements of ASTM A370 or equivalent standard agreed to by the purchaser.

The room temperature all-weld-metal yield strength shall be no less than the bend body specified minimum yield strength at room temperature. The elevated temperature all-weld-metal yield strength shall be no less than the specified minimum body elevated temperature yield strength.

14 Markings

14.1 General

Unless otherwise agreed upon by the purchaser and the manufacturer, the manufacturer shall mark the bends as specified in Clause 14.2. Additional markings desired by the manufacturer or requested by the purchaser may be used.

Die-stamping other than described in Clause 14.3 shall not be permitted.

14.2 Required markings

The following markings shall be placed on the bends in the following sequence and separated by dashes or adequate spaces:

a) manufacturer's name or mark;
b) CSA Standard designation and year of publication (e.g., Z245.17:22);
c) grade: the numerical portion of the bend grade designation;
d) category;
e) test temperature for Category II. The notch toughness test temperature shall be marked using the designation "MXC" or "PXC", where "M" and "P" signify minus and plus, respectively, and "X" signifies the numerical value of the test temperature in degrees Celsius (e.g., "M45C" for –45 °C);
f) "SS" for sour service, if applicable;
g) identification designation. A manufacturer's identification designation shall be used on bends and shall be traceable to pertinent material certificates, test reports, and inspection reports;
h) matching pipe grade, where different from the bend grade;
i) size (the numerical portion of the NPS designation);
j) wall thickness (the nominal thickness of the pipe used);
k) angle of the bend; and
l) radius (the centreline radius of the bend in mm).

14.3 Die-stamped markings

For other than required markings, the manufacturer may die-stamp bend end faces with prior approval from the purchaser, provided that such markings are applied

a) at least 25 mm from any weld;
b) at temperatures less than 100 °C; and
c) with round, blunt, or low-stress stamps or dies.

14.4 Omission of markings

Where the size of the bend does not permit all markings specified in Clause 14.2 to be marked on the bend, one or more of such markings may be omitted as needed, in the reverse order to that specified in Items h) to j).

15 Certification

15.1

The manufacturer shall furnish a material test report (MTR) and a bend report listing the following:

a) statement that the product was manufactured, sampled, tested, and inspected as specified in this Standard and the purchase order, and was found to have met such requirements;
b) name and address of the manufacturer;
c) results of the chemical composition heat and product analysis, including carbon equivalency (see Clause 6);
d) mechanical properties of each qualification bend, test orientation, test specimen size, and tensile strength of weld, if applicable (see Clause 8.2);
e) notch toughness properties of each qualification bend to include size, orientation, temperature, and actual results for each specimen (see Clause 8.3);
f) notification of number of retests and reason for retesting (e.g., two heat lot retests for low body yield strength);
g) heat treatment used, including temperatures and hold times (see Clause 7);

h) non-destructive examination results, as applicable (see Clause 11);
i) part description that agrees with the marking on the bend (see Clause 14.2);
j) statement if bends are seamless or welded, including type of weld if applicable;
k) CSA designation and effective year date (e.g., Z245.17:22);
l) name and location of the starting pipe manufacturer with heat number;
m) name and location of all entities used to perform forming operations or heat treatment for the bend;
n) hardness tests shall include the test method used and the test results (see Clause 8.4);
o) results of any sour service items specified by the purchaser (see Clause 12);
p) minimum measured wall thickness;
q) dimensional report for production and test bends;
r) name and manufacturing location of the starting raw material manufacturer with heat number; and
s) name and manufacturing location of all entities used to perform any forming operation, welding, or heat treatment for the fitting.

15.2

Where specified in the purchase order, the manufacturer shall provide the following:
a) results of the guided bend tests (see Clause 8.5);
b) heat treatment charts;
c) starting material test certificate from the pipe mill; and
d) any special or supplemental test required by the purchase order.

15.3

Where elevated temperature service is specified in the purchase order, elevated test temperature and the elevated temperature tension test properties (i.e., yield strength, tensile strength, and elongation) shall be reported, as applicable (see Clause 13.2).

15.4

15.4.1

Material test reports and bend reports shall be retained by the manufacturer for a period of not less than 10 years from the date of manufacture.

15.4.2

Supporting data for the mill test and bend reports shall be retained by the manufacturer for a period of not less than five years from the date of manufacture, and should include information detailing
a) chemical and mechanical test data;
b) product compliance non-destructive inspection reports;
c) heat treat records;
d) product compliance NDE and mechanical testing machine calibration reports;
e) furnace survey reports; and
f) product compliance NDE and mechanical testing machine procedures.

15.4.3

Radiographs shall be kept for a period of not less than two years from the date of manufacture.

Note: *Interpretation reports of radiographs are considered supporting data and are retained as described in Clause 15.4.2*

15.4.4

Manufacturers shall take reasonable and prudent care to store records in a manner that prevents loss, damage, or degradation.

Table 1
Essential variables and permissible variables
(See Clause 8.1.3.1.)

Essential variable	Maximum permissible variation-cold bends
Heat of steel	None
Nominal pipe diameter	None
Nominal pipe wall thickness	± 3 mm
Centreline radius diameter	All larger radii (but not smaller) inside the following ranges a) up to and including 3D; b) 3D up to and including 5D; c) 5D up to and including 10D; or d) greater than 10D.
Cold bend method	None
Weld seam location	15° from neutral axis
Post-bend heat treatment	Soaking temperature: ±15 °C (± 25 °F) in holding temperature Method, machine and tooling: no change Soaking Time: 0–15 min Heating and cooling rates: By agreement

Table 2
Test sampling locations
(See Clauses 8.1.3.2, 8.4.1, 8.4.4.1, and 9.2.)

Test locations
Mid bend intrados
Mid bend extrados
Mid bend weld seam
Tangent (180° from weld seam)

Notes:
1) *New sets of tests, as described in Clause 8.1.3.1, shall be required for changes in grade, wall thickness, outside diameter, or heat number.*
2) *Where a post-bend heat treatment is performed, the bends represented by a qualification bend shall be heat treated in the same manner as the qualification test bend.*
3) *Testing of tangents shall not be required if a post-bend heat treatment is not performed.*
4) *Impact testing of weld seams shall be as per Clause 8.3.2.2.*

Table 3
Tensile requirements
(See Clauses 1.2.2 and 8.2.2.)

	Yield strength (*Y*), MPa		Tensile strength (*T*), MPa		*Y*/*T*, Maximum*		
Grade	Mini-mum	Maxi-mum†	Minimum	Maxi-mum†	Flattened strip specimen	Other than flattened strip specimen	Body elongation in 50 mm, minimum, %
241	241	495	414	760	0.93	0.93	20
290	290	495	414	760	0.93	0.93	20
359	359	530	455	760	0.93	0.93	20
386	386	540	490	760	0.93	0.93	20
414	414	565	517	760	0.93	0.93	20
448	448	600	531	760	0.93	0.93	18
483	483	620	565	760	0.93	0.93	16
550	550	690	620	830	0.93	0.93	16
620	620	760	690	900	0.93	0.95	16
690	690	825	760	970	0.93	0.97	16

* *Limits are not applicable to bends smaller than NPS 14.*
† *Limits are not applicable to bends smaller than NPS 8.*

Notes:
1) *The yield strength, tensile strength, and elongation requirements for intermediate grades shall be obtained by interpolation between the values specified for the standard listed grades, with the results for minimum yield and minimum tensile strength rounded to the nearest 1 MPa and results for minimum % elongation rounded to the nearest 1%.*
2) *For test specimens having a specified gauge length less than 50 mm, the measured elongation after fracture shall be converted to a percentage elongation in 50 mm in accordance with ISO 2566-1.*

Table 4
Chemical composition limits for heat and product analyses
(See Clauses 6.2, 6.3, and 6.4.)

Grades	Carbon equivalent*, maximum
All	0.40
Element	**Maximum permitted, %**
Carbon	0.26
Manganese	2.00
Phosphorus	0.030
Sulphur	0.035
Silicon	0.50
Niobium	0.11
Titanium	0.11
Vanadium	0.11
Boron	0.001

** The carbon equivalent shall be determined from the product analysis using the following formula:*

$$C.E. = C + F\left(\frac{Mn}{6} + \frac{Si}{24} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{Cr + Mo + V + Nb}{20} + 5B\right)$$

where

F = a compliance factor that is dependent on carbon content and is as specified in the following table

Carbon content, %	***F***	***Carbon content, %***	***F***	***Carbon content, %***	***F***
< 0.06	*0.53*	*0.11*	*0.70*	*0.17*	*0.94*
0.06	*0.54*	*0.12*	*0.75*	*0.18*	*0.96*
0.07	*0.56*	*0.13*	*0.80*	*0.19*	*0.97*
0.08	*0.58*	*0.14*	*0.85*	*0.20*	*0.98*
0.09	*0.62*	*0.15*	*0.88*	*0.21*	*0.99*
0.10	*0.66*	*0.16*	*0.92*	*> 0.21*	*1.00*

Notes:

1) *The chemical requirements specified in this Table are not intended to represent the composition of any heat of steel but to record the maximum permissible amounts of individual elements.*
2) *Niobium (Nb) is also known as columbium (Cb).*

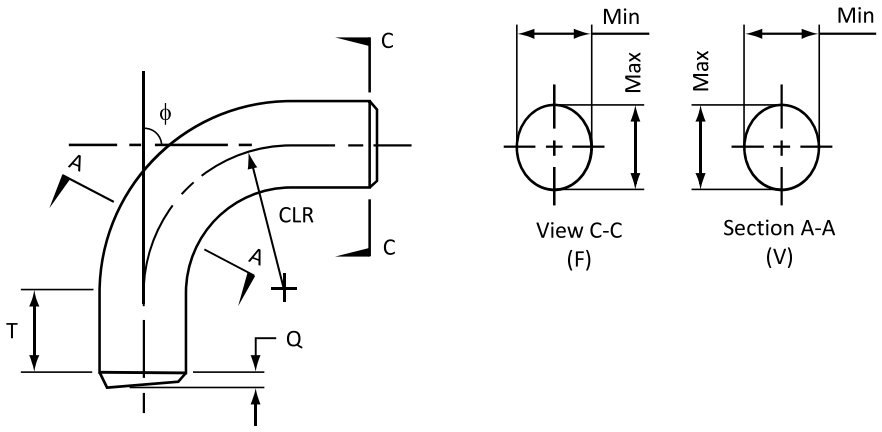
Table 5
Charpy test specimens
(See Clauses 8.3.3.1 and 8.3.3.2.)

Note: *Notch toughness impact testing is not required on bends below NPS 4.*

Specified outside diameter, mm	Material wall thickness, mm				
	Full non-flattened	3/4 non-flattened	2/3 non-flattened	1/2 non-flattened	1/2 flattened*
114.3–141.2	> 12.5	11.3–12.5	10.9–11.2	10.1–10.8	6.0–10.0
141.3–168.2	> 11.8	9.8–11.8	9.4–9.7	8.6–9.3	6.0–8.5
168.3–219.0	> 11.6	9.2–11.6	8.5–9.1	7.6–8.4	6.0–7.5
219.1–273.0	> 11.3	8.9–11.3	8.1–8.8	6.5–8.0	6.0–6.4
273.1–323.8	> 11.2	8.6–11.2	7.9–8.5	6.2–7.8	6.0–6.1
323.9–355.5	> 11.0	8.6–11.0	7.8–8.5	6.1–7.7	6.0
355.6–406.3	> 11.0	8.6–11.0	7.7–8.5	6.1–7.6	6.0
406.4–2032	> 10.9	8.5–10.9	7.7–8.4	6.0–7.6	—

* *This column is not applicable to weld or heat-affected zone Charpy tests.*

Table 6
Bend tolerances
(See Clause 9.3.)



$$F = \frac{\text{Max} - \text{Min}}{\text{NOD}} \times 100$$

$$V = \frac{\text{Max} - \text{Min}}{\text{NOD}} \times 100$$

F = end out-of-roundness

Q = end squareness

(Continued)

Table 6 (Concluded)

CLR = centreline radius
T = tangent
V = bend zone out-of-roundness
ϕ = bend angle
NOD = nominal outside diameter
NID = nominal inside diameter

Item	Tolerances	
Bend angle (ϕ)	±1° for CLR ≤ 4500 mm	±2° for CLR > 4500 mm
Centreline radius (CLR)	±1%	
Bend zone out-of-roundness (V)	8% max for CLR ≤ 5 × NOD	5% max for CLR > 5 × NOD
End out-of-roundness (F)	2% max for T ≥ 1.5 × NOD	Tolerance to be specified by purchaser for T < 1.5 × NOD
End squareness (Q)	3 mm max	
Minimum internal diameter	95% min for CLR ≤ 5 × NID	97% min for CLR > 5 × NID Bends to be drift pigged if requested by purchaser.

Figure 1
Bend diagram
(See Clauses 3 and 4.1.1.)

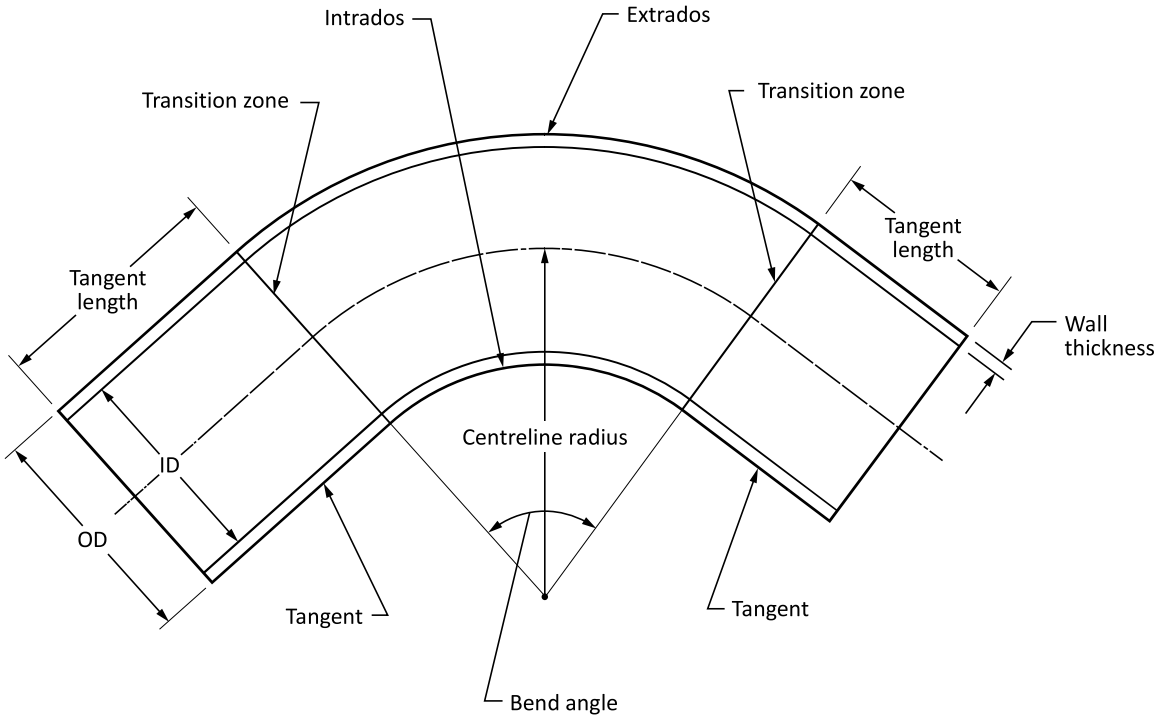
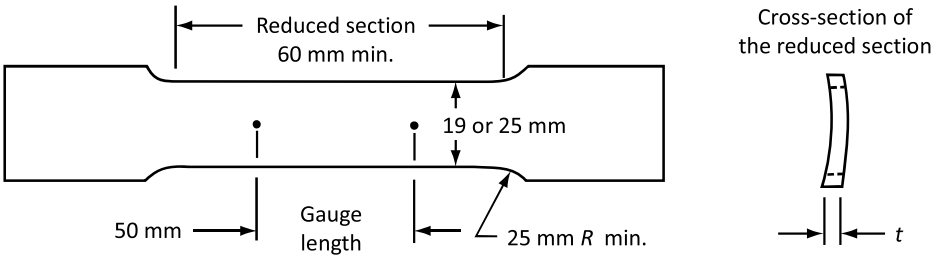
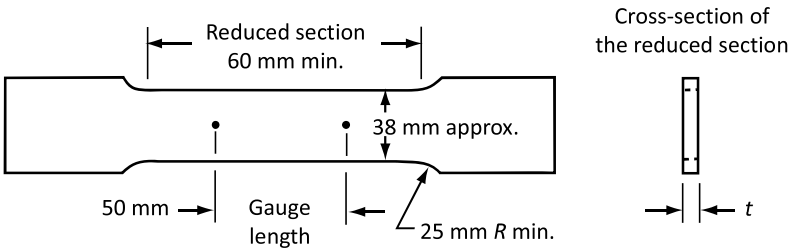


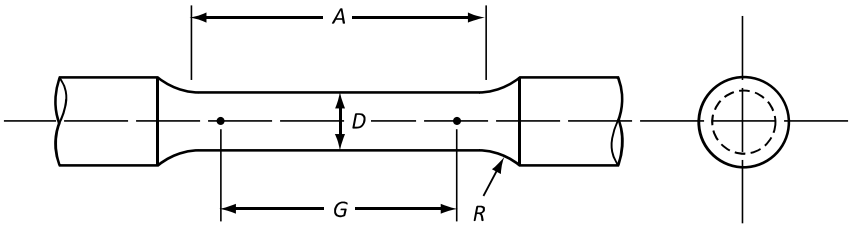
Figure 2
Tension test specimens
(See Clause 8.2.5.)



Longitudinal body strip test specimen



Transverse body strip test specimen

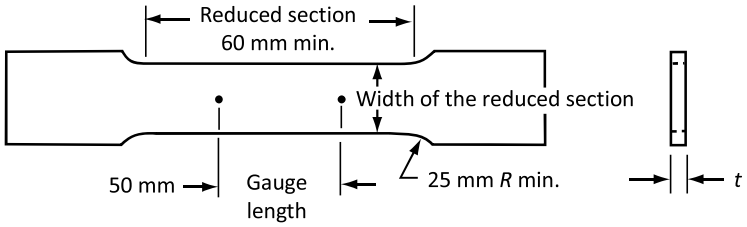


Round tension test specimen

	Nominal diameter of round tension test specimen, mm		
	12.7	**8.9**	**6.4**
G — Gauge length	50.0 ± 0.1	35.0 ± 0.1	25.0 ± 0.1
D — Diameter	12.7 ± 0.2	8.9 ± 0.2	6.4 ± 0.1
R — Radius of fillet, min.	10	6	5
A — length of reduced section, min.	60	45	32

(Continued)

Figure 2 (Concluded)



Transverse weld strip test specimen

Legend:

t = wall thickness, mm

Figure 3a
Vickers hardness transverse across body
(See Clause 8.4.4.1.)

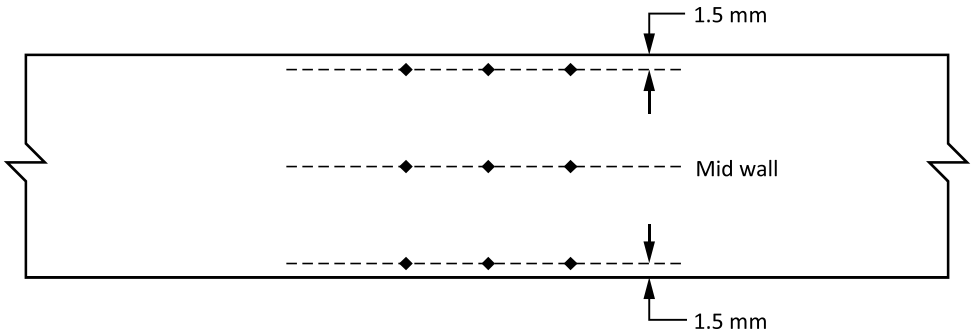
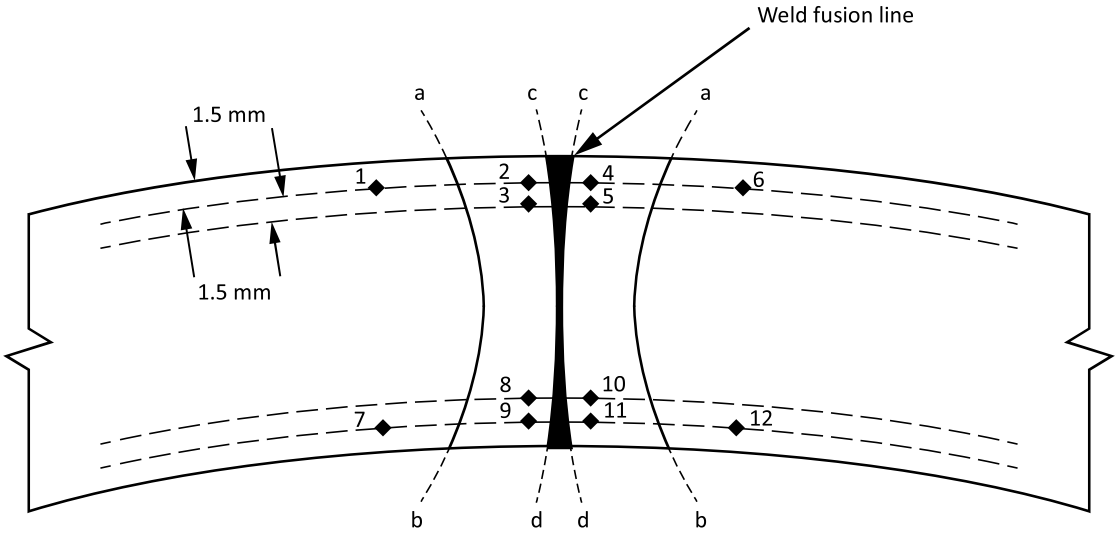
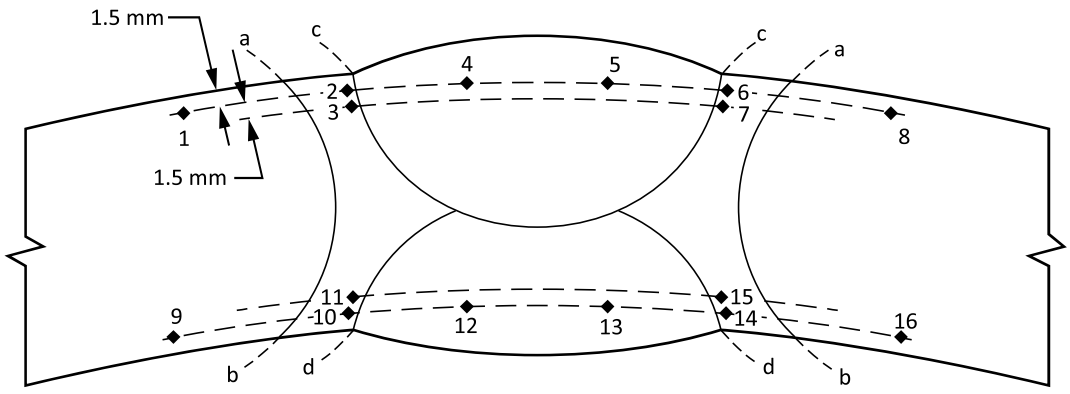


Figure 3b
Vickers hardness traverse across weld for electric welded pipe
(See Clause 8.4.4.1.)



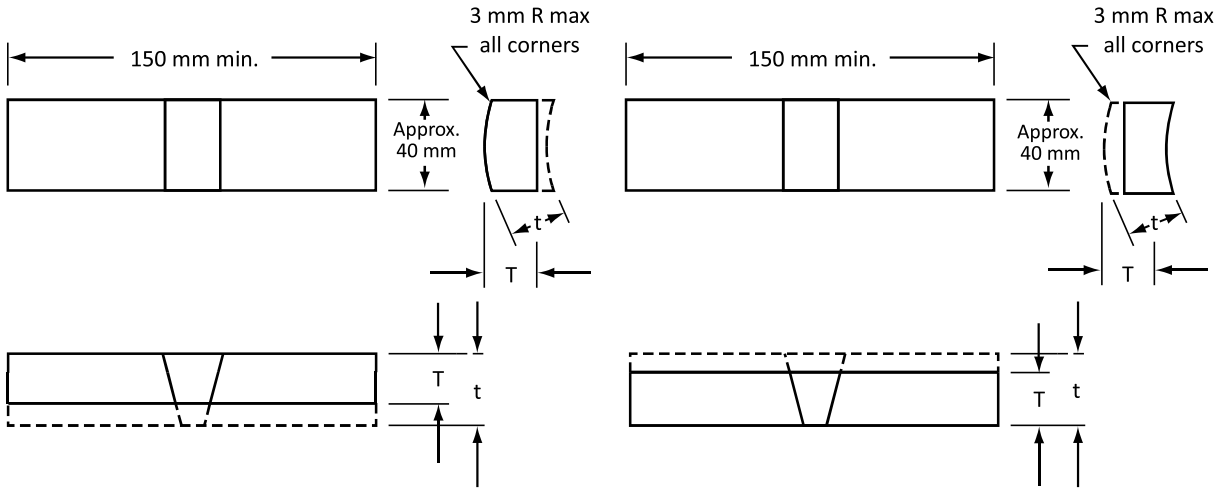
Notes:
1) *Maximum load = 10 kg*
2) *a to b = boundary between the visible weld heat-affected zone and the parent metal*
3) *c to d = fusion line*

Figure 3c
Vickers hardness traverse across weld for SAWL pipe
(See Clause 8.4.4.1.)



Notes:
1) *Maximum load = 10 kg*
2) *a to b = boundary between the visible weld heat-affected zone and the parent metal*
3) *c to d = fusion line*

Figure 4
Guided bend test specimen
(See Clause 8.5.2.)

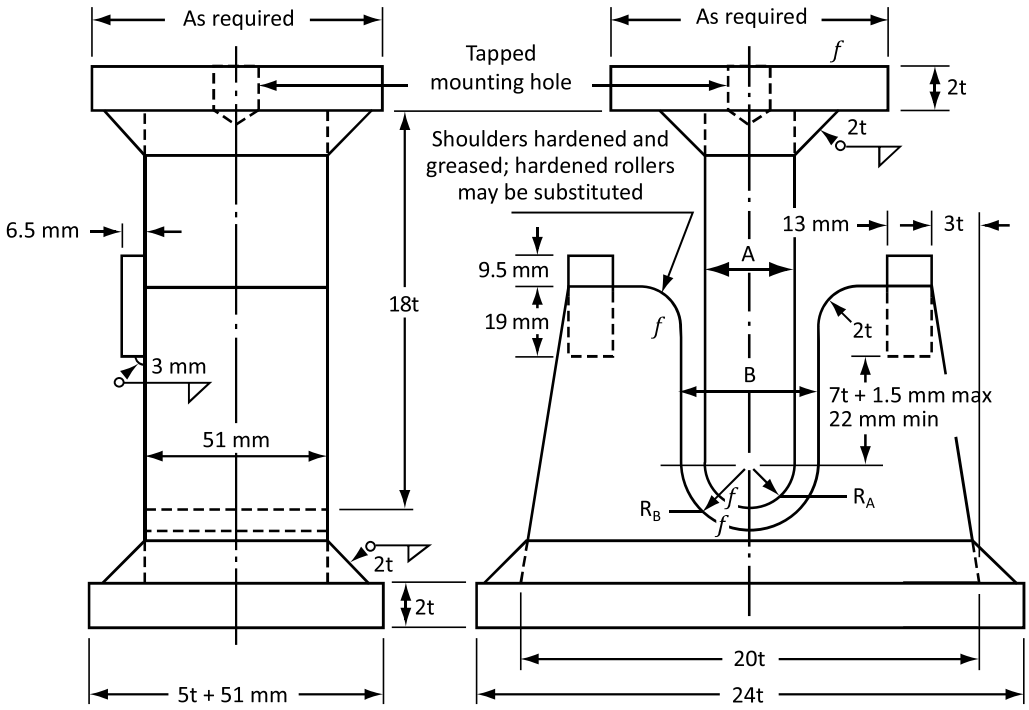


Face guided-bend test specimen **Root guided-bend test specimen**

Bend wall thickness *t*, mm	Test specimen thickness *T*, mm
Up to 9.5	*t*
Over 9.5	9.5

Notes:
1) *Weld reinforcement shall be removed from both faces.*
2) *Specimen edges may be oxygen-cut and may also be machined.*

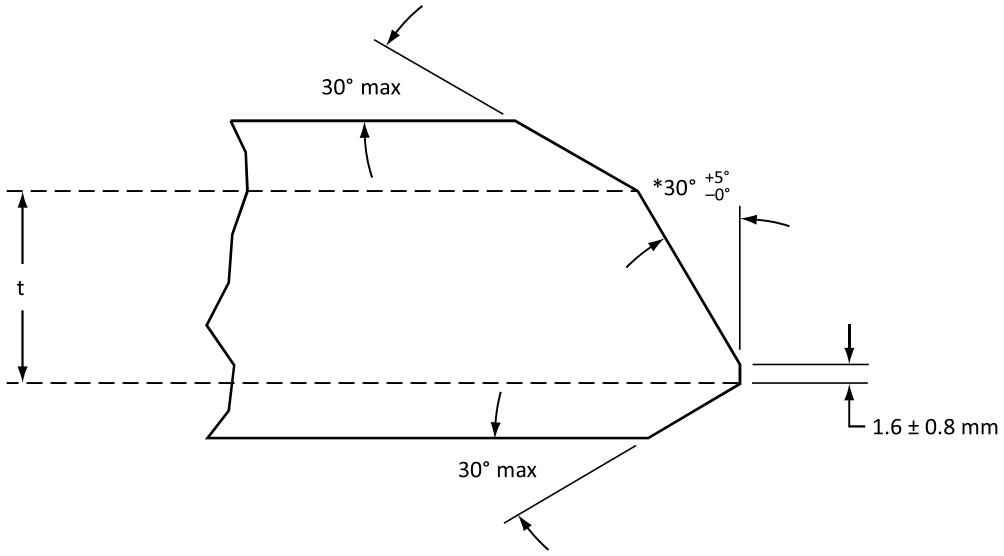
Figure 5
Guided bend test jig dimensions
(See Clause 8.5.2.)



	Test jig dimension, mm			
	Grade 290 or lower	**Over Grade 290 to less than Grade 331**	**Grade 331 to less than Grade 414**	**Grade 414 or higher**
Radius of male member, R_A	3t	3.5t	4t	4.5t
Radius of female member, R_B	4t + 1.6	4.5t + 1.6	5t + 1.6	5.5t + 1.6
Width of male member, A	6t	7t	8t	9t
Width of groove in female member, B	8t + 3.2	9t + 3.2	10t + 3.2	11t + 3.2

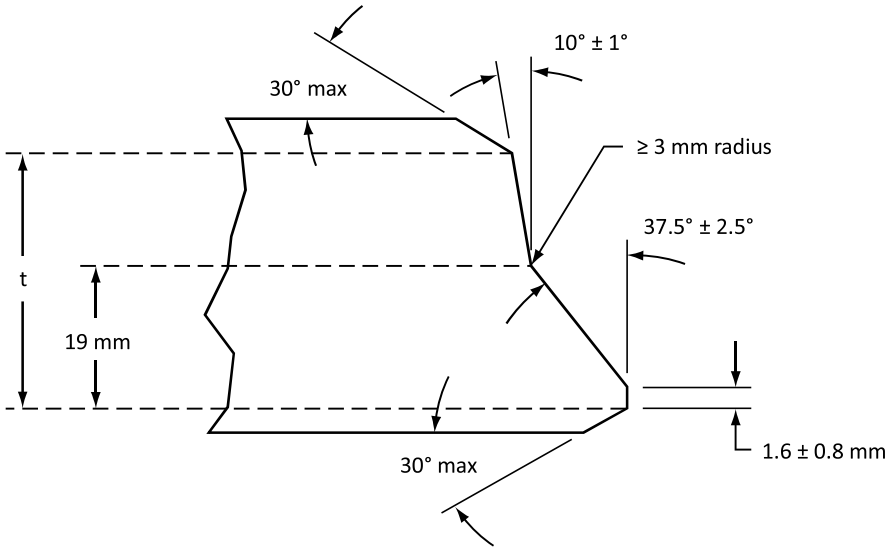
Note: *t = test specimen thickness*

Figure 6
Recommended end preparations
(See Clauses 9.4 and 9.6, and Figure 7.)



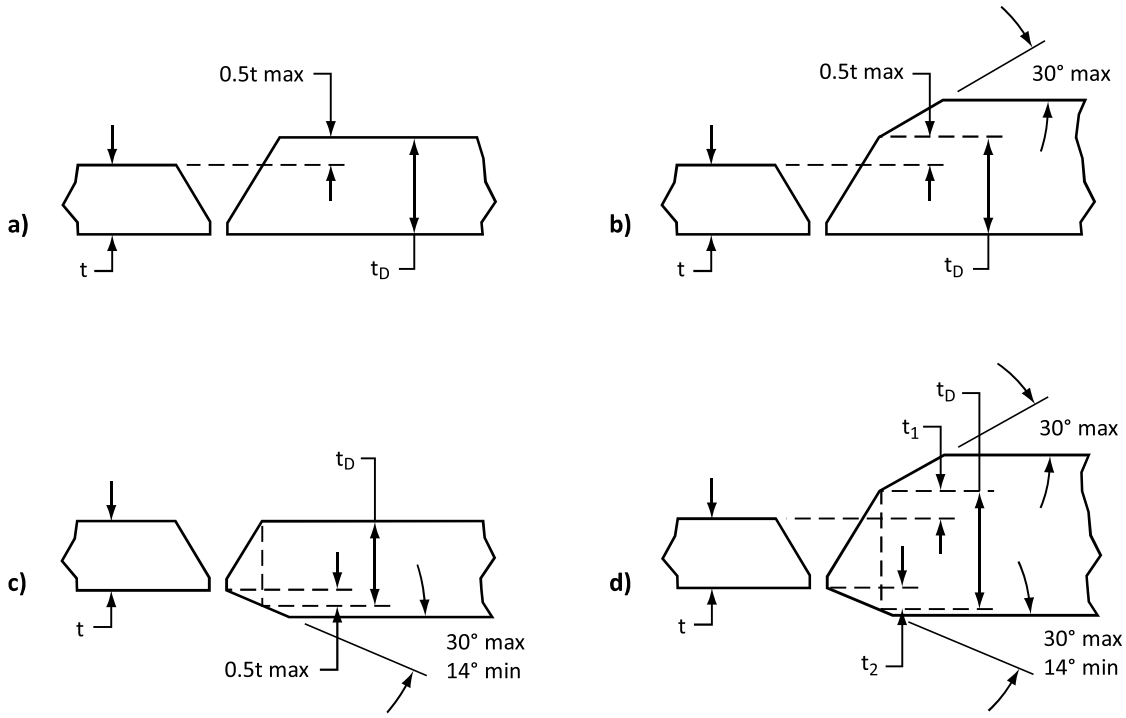
**At the option of the manufacturer, NPS 24 and smaller fittings may be furnished with a 37.5° ± 2.5° bevel.*

Recommended end preparation for wall thickness at end of fitting (t) ≤ 22 mm



Recommended end preparation for wall thickness at end of fitting (t) > 22 mm

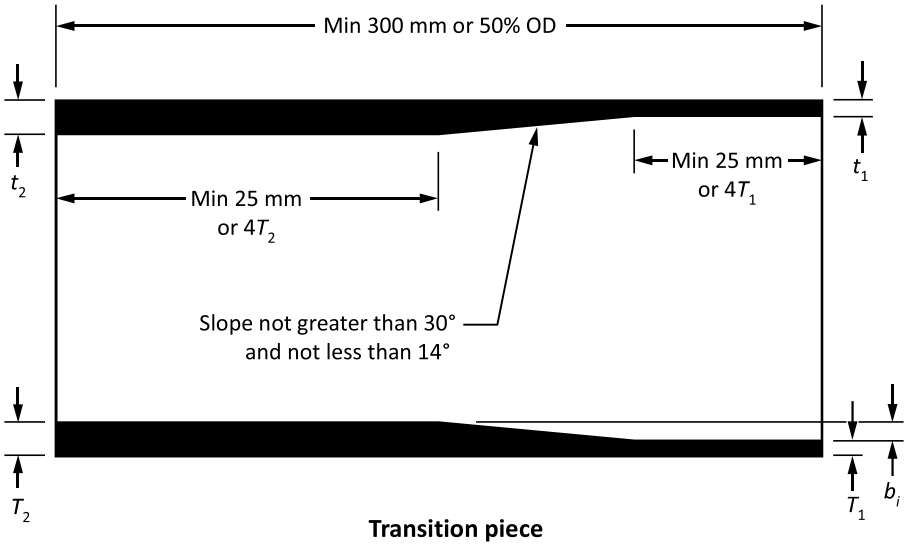
Figure 7
Design of ends for unequal grades
(See Clause 9.5.)



Notes:

1) *t = specified wall thickness of the matching pipe.*
   t_D = design thickness of the bend.
2) *t_D shall be at least equal to t times the ratio of the specified minimum yield strength of the matching pipe to that of the bend.*
3) *Neither t_1, t_2, nor their sum shall exceed 0.5t.*
4) *Any internal taper on (a) and (b) shall not exceed 30°.*
5) *t_D shall not be less than t.*
6) *Angles and dimensions not shown shall be as shown in Figure 6.*

Figure 8
Counterbore transition dimensions
(See Clause 9.4.)



where

b_i = nominal internal offset of the weld bevels, mm

t_1 = design thickness of thinner item, mm

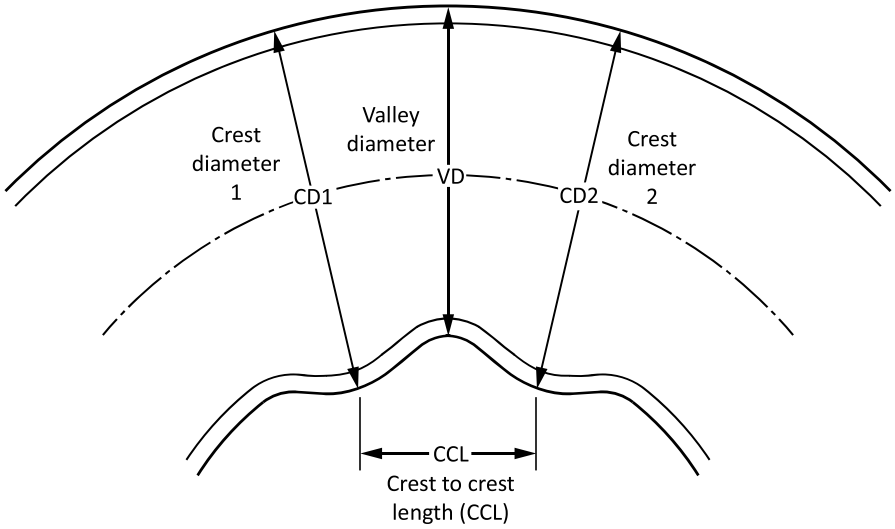
t_2 = design thickness of thicker item, mm

T_1 = nominal thickness of thinner item, mm

T_2 = nominal thickness of thicker item, mm

Note: *This transition may be machined into the tangent section or welded on as a separate transition piece.*

Figure 9
Waves
(See Clause 10.4.2.)



where

$$CVD = \left(\frac{CD1 + CD2}{2}\right) - VD$$

Annex A (normative)
Requirements for the calibration and survey of heat treating equipment

Note: *This Annex is a mandatory part of this Standard.*

A.1 Furnace calibration and survey

A.1.1
A temperature survey within each furnace working zone shall be performed on each furnace at the maximum and minimum temperatures of the range for which the furnace is qualified for use.

A.1.2
The total number of thermocouple test locations in the working zone of a furnace shall be not fewer than four for furnace working zones of 2 m^3 or less. The location of the thermocouples shall be at the manufacturer's discretion.

A.1.3
Furnace working zones greater than 2 m^3 and equal to or less than 10 m^3 shall use not fewer than nine thermocouples. The location of the thermocouples shall be as shown in Figure A.1.

A.1.4
Furnace working zones greater than 10 m^3 shall use a minimum of nine thermocouples, plus one additional thermocouple for each 3 m^3 of working zone exceeding 10 m^3. Furnace working zones greater than 43 m^3 shall use a minimum of 20 thermocouples. Additional thermocouples may be used. The location of the first nine thermocouples shall be as shown in Figure A.1. The placement of additional thermocouples shall be at the manufacturer's discretion and shall be recorded on the survey records.

A.1.5
After the thermocouples have been installed, readings shall be taken at least once every 3 min to determine when the temperature of the furnace working zone approaches the bottom of the temperature range being surveyed.

A.1.6
Once the furnace temperature has reached the set point temperature, the temperature of each thermocouple shall be recorded at maximum intervals of 2 min for at least 10 min. Readings shall then be taken at maximum intervals of 5 min for a sufficient time to determine the recurrent temperature pattern of the working zone for at least 30 min.

A.1.7
After the furnace control set point temperature is reached, the temperature at any point in the working zone shall not vary by more than 15 °C from the set point temperature.

A.1.8
Furnaces that have been subjected to a change in burner quantity or location, or both, shall be surveyed, and the requirements of Clause A.1.7 shall be met.

A.1.9
Furnaces that have been subjected to a change in the type of lining shall be surveyed, and the requirements of Clause A.1.7 shall be met.

Note: *An example of a change in the type of lining is from brick to fibre.*

A.1.10
Except as required by Clauses A.1.8 and A.1.9, furnaces that have been repaired or rebuilt shall be surveyed if deemed necessary by the manufacturer. For any such surveys, the requirements of Clause A.1.7 shall be met.

A.2 Instruments

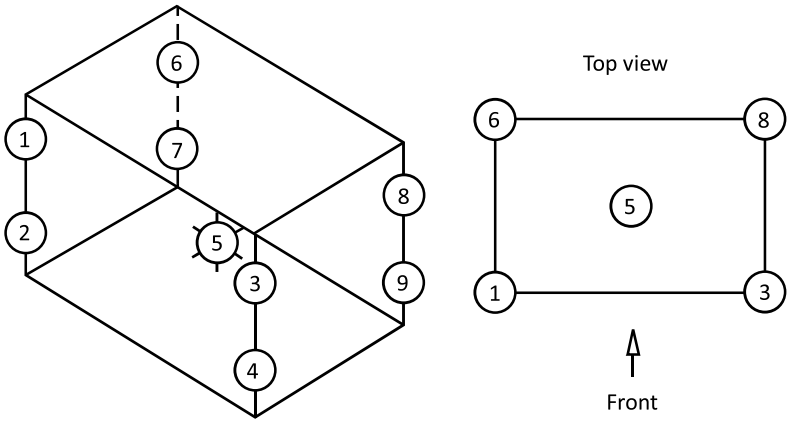
A.2.1 Accuracy of production instruments
The production instruments (thermocouples, controllers, and recorders) used for the heat treatment process shall be accurate to within ±1% over the heat treatment range.

A.2.2 Calibration of production instruments
Equipment used to calibrate production instruments shall be accurate to within ±0.25% of their full-scale range.

A.2.3 Calibration of production instruments
Furnace equipment shall be calibrated annually. Recording equipment shall be calibrated quarterly.

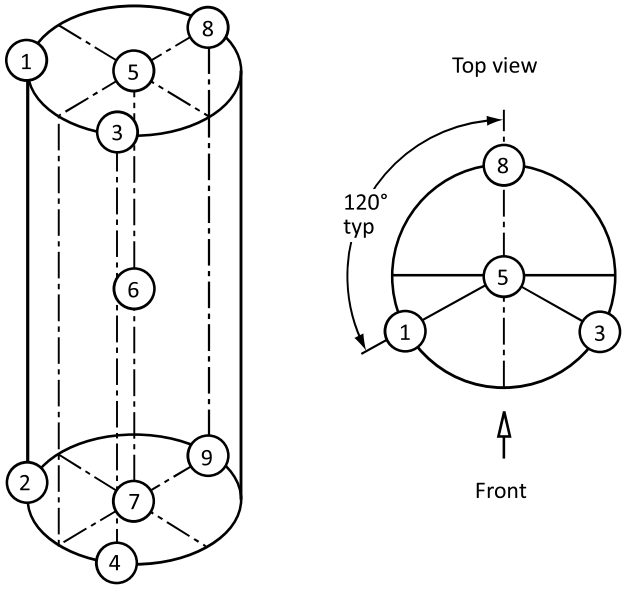
A.3 Records
Records of furnace calibration and surveys shall be maintained for at least five years.

Figure A.1
Thermocouple locations
(See Clauses A.1.3 and A.1.4.)



1) Front/left/top
2) Front/left/bottom
3) Front/right/top
4) Front/right/bottom
5) Centre/centre
6) Back/left/top
7) Back/left/bottom
8) Back/right/top
9) Back/right/bottom

Rectangular furnace



1) Front/left/top
2) Front/left/bottom
3) Front/right/top
4) Front/right/bottom
5) Centre/top
6) Centre/centre
7) Centre/bottom
8) Back/centre/top
9) Back/centre/bottom

Cylindrical furnace

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