API Standard 650
Fifth Edition
July 1973

WELDED STEEL TANKS FOR OIL STORAGE

OFFICIAL PUBLICATION

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AMERICAN PETROLEUM INSTITUTE
Refining Department
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SUPPLEMENT NO. 3
TO
API STANDARD 650 (FIFTH EDITION)
WELDED STEEL TANKS FOR OIL STORAGE

AMERICAN PETROLEUM INSTITUTE
Division of Refining
1801 K Street, N.W.
Washington, D.C. 20006

Price: $1.00

SUPPLEMENT NO. 3
TO
WELDED STEEL TANKS FOR OIL STORAGE
FIFTH EDITION OF
API STANDARD 650

This supplement revises certain information set forth in the fifth edition of *API Standard 650: Welded Steel Tanks for Oil Storage,* issued in July 1973, *Supplement No. 1 to API Standard 650 (Fifth Edition): Welded Steel Tanks for Oil Storage,* issued in October 1973, and *Supplement No. 2 to API Standard 650 (Fifth Edition): Welded Steel Tanks for Oil Storage,* issued in August 1974.

In Supplement 3, the method by which Standard 650 is revised has been changed. Complete pages (with revisions included) are presented on green stock to facilitate the incorporation of additional material and the replacement of corresponding pages of Supplement 2 (printed on pink stock), Supplement 1 (printed on blue stock), and the fifth edition of Standard 650 (printed on white stock).

Some of the pages included have no technical or editorial changes but were merely reprinted to accommodate additions made to previous pages. Any revision or addition of new material will be indicated by an **R** in the margin.

FOREWORD

This standard is based on the accumulated knowledge and experience of purchasers and manufacturers of welded steel oil storage tanks of various sizes and capacities for internal pressures approximating atmospheric. The object of this publication is to provide a purchase specification to facilitate the manufacture and procurement of storage tanks for the petroleum industry.

Provisions for welding and details pertaining thereto, as given herein, were prepared in cooperation with the American Welding Society. These provisions include: definitions of welding and welded joints and fabrication thereof; materials suitable for welding, including electrodes; and inspection requirements for field welding. In all other respects, welding shall be as specified in *Welding Qualifications*, Sect. IX of *ASME Boiler and Pressure Vessel Code.*

If tanks are purchased in accordance with the specifications in this standard, the purchaser is required to specify certain basic requirements. The purchaser may desire to modify, delete, or amplify sections of this standard, but the API monogram shall not be used on tanks that do not fulfill the minimum requirements or **R** that exceed the limitations of this standard. It is strongly recommended that such modifications, deletions, or amplifications be made by supplementing this standard, rather than by rewriting or incorporating sections thereof into another complete standard.

Design rules given herein are minimum requirements. Any more stringent design rules specified by the purchaser or furnished by the manufacturer are acceptable **R** when mutually agreed upon by the purchaser and the manufacturer.

This standard is not intended to cover storage tanks which are to be erected in areas subject to regulations more stringent than the specifications contained herein. In such cases, this standard should be followed, on purchases made under this standard, insofar as it does not conflict with local requirements.

Suggested revisions are invited and should be submitted to the director of the Division of Refining, American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20006.

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CAUTION

Do not use this Standard unless page inserts which were published as API Standard 650 (Fifth Edition), *Welded Steel Tanks for Oil Storage,* Supplement No. 3, March 1975, have been added.

RELATED API PUBLICATIONS

American Petroleum Institute publications pertaining to welded steel tanks as well as other types of tanks are:

API Standard 12A: Specification for Oil Storage Tanks with Riveted Shells

Covers material, design, fabrication, and erection requirements for vertical cylindrical aboveground steel tanks with riveted shells, in nominal capacities of 240 bbl to 255,000 bbl (in standard sizes) for oil field service. It also contains appurtenance requirements.

API Standard 12B: Specification for Bolted Production Tanks

Covers material, design, and erection requirements for vertical cylindrical aboveground bolted steel production tanks in nominal capacities of 100 bbl to 10,000 bbl (in standard sizes) for oil field service. It also contains appurtenance requirements.

API Standard 12D: Specification for Large Welded Production Tanks

Covers material, design, fabrication, and erection requirements for vertical cylindrical aboveground welded steel production tanks in nominal capacities of 500 bbl to 3,000 bbl (in standard sizes) for oil field service.

API Standard 12E: Specification for Wooden Production Tanks

Covers material, design, fabrication, and erection requirements for vertical cylindrical aboveground closed-top wooden production tanks in nominal capacities of 130 bbl to 1,500 bbl (in standard sizes) for oil field service.

API Standard 12F: Specification for Small Welded Production Tanks

Covers material, design, and construction requirements for vertical cylindrical aboveground shop-welded steel production tanks in nominal capacities of 90 bbl to 440 bbl (in standard sizes up to a maximum diameter of 12 ft) for oil field service.

API Standard 620: Recommended Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks

Covers the design and construction of large, welded, field-assembled storage tanks used for petroleum intermediates and finished products operated at a gas pressure of 15 psig and less.

API Standard 2000: Venting Atmospheric and Low-Pressure Storage Tanks

Covers recommended procedure for testing venting devices on low-pressure aboveground storage tanks used for petroleum and petroleum products. It also contains venting-capacity tables.

API Recommended Practice 2003: Protection Against Ignition Arising Out of Static, Lightning, and Stray Currents

Covers some of the conditions which have resulted in oil fires ignited by electrical sparks and arcs from so-called natural causes, as well as the methods which the petroleum industry currently is applying for the prevention of ignition from these sources.

API Recommended Practice 2015: Cleaning Petroleum Storage Tanks

Covers discussion of safe practices in tank cleaning, including use of suitable mechanical equipment and protective clothing, use of proper cleaning methods, elimination of potential ignition hazards, and provision for means of entrance and exit in an emergency. Combines and updates information contained in *Accident Prevention Manual No. 1: Cleaning Petroleum Storage Tanks—Section A, Crude Oil and Unfinished Products Tanks* and *Bulletin 2016: Cleaning Tanks Used for Gasoline or Similar Low-Flash Products.*

API Standard 2550 (ASTM D 1220-65): Measurement and Calibration of Upright Cylindrical Tanks

Covers procedures for calibrating upright cylindrical tanks larger than a barrel or drum, including procedures for making necessary measurements to determine total and incremental tank volumes and the recommended procedure for computing volumes.

API Standard 2555 (ASTM D 1406-65): Liquid Calibration of Tanks

Covers standard procedure for calibrating tanks, or portions of tanks, larger than a barrel or drum by introducing or withdrawing measured quantities of liquid.

Guide for Inspection of Refinery Equipment: Chapter XIII, Atmospheric and Low-Pressure Storage Tanks

Covers inspection of atmospheric storage tanks which have been designed for operation at pressures from atmospheric through 0.5 psig and inspection of low-pressure storage tanks which have been designed for operation at pressures above 0.5 psig but not exceeding 15 psig.

SUGGESTIONS FOR ORDERING TANKS

The purchaser should state on his inquiry or purchase order the following:

- Specification
- Number of tanks
- Nominal capacity, in barrels
- Specific gravity of contents
- Appurtenances (type, size, and location)
- Painting requirements
- Time of completion
- Erection location and facilities
- Tank grade details
- Special provisions (permits, fees, etc.)
- Wind velocity

The purchaser may exercise an option with respect to the following requirements:

- Diameter, in feet
- Height, in feet
- Plate specifications (bottom, shell, and roof)
- Mill test reports
- Shop inspection
- Field inspection
- Bottom test
- Shell test
- Roof test
- Welding procedure qualification
- Sectioning method
- Closure of openings
- Segment ownership
- Radiographic method
- Film ownership
- Bolting
- Bottom plates:
  - Thickness
  - Size and arrangement
  - Joint design and welding procedure
- Shell plates:
  - Thickness
  - Width and number of courses
  - Alignment
  - Horizontal joint penetration and fusion
  - Top-angle orientation
  - Wind girders
- Roof plates:
  - Thickness
  - Slope
- Roof supports
- Roof live load and its distribution
- Appurtenances:
  - Shell manhole design
  - Shell nozzle design
  - Cleanout fitting support
  - Drawoff sump design
  - Roof nozzle flange design
- Stairways, platforms, and walkways
- Freight and hauling

Note: See, also, Appendix L, "Storage Tank Specification Data Sheet."

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WELDED STEEL TANKS FOR OIL STORAGE

API specifications [standards] are published as an aid to procurement of standardized equipment and materials. These specifications are not intended to inhibit purchasers and producers from purchasing or producing products made to specifications other than API, and nothing in any API specification is intended to in any way inhibit the purchase of products from companies not authorized to use the API monogram.*

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WELDED STEEL TANKS FOR OIL STORAGE

1. SCOPE

1.1 GENERAL

a. This specification covers material, design, fabrication, erection, and testing requirements for vertical cylindrical aboveground, closed and open-top, welded steel storage tanks in various sizes and capacities for internal pressures approximating atmospheric pressures, except that a small internal pressure is permitted when the additional requirements of Appendix F are met.

b. This specification is designed to provide the oil industry with tanks of adequate safety and reasonable economy for use in the storage of petroleum and its products and those other liquid products commonly handled and stored by the various branches of the industry. It does not present, nor is it contemplated to establish, a fixed series of allowable tank sizes; but rather it is intended to permit the selection by the purchaser of whatever size of tank may be required to best meet his particular needs. This specification is for the convenience of purchasers and manufacturers in ordering, fabricating, and erecting tanks and is not intended to prohibit purchasers and manufacturers from purchasing and fabricating tanks meeting specifications other than those contained herein; nor is it intended in any way to prohibit purchasers from purchasing tanks from companies not authorized to use the API monogram.

c. Appendix A to this specification presents for ready reference design data relating to tanks which may be built according to specifications contained herein. The data presented in Appendix A are for convenience and are not required in order to comply with this specification.

d. Stressed components in this specification (shell plates, reinforcing pads, etc.) excluding flanges shall be limited to a maximum of ½-in. nominal thickness unless the provisions of Appendix D or G are followed. R

Appendix D to this specification presents an alternative design basis for tanks with improved design, materials, and inspection. Appendix G provides a special design basis for high-strength steels with improved notch toughness. Appendix K presents an alternative procedure for calculating the thickness of the plate courses in tank shells.

e. Appendixes C and H to this specification present rules for special types of roofs for storage tanks. Appendix C provides requirements for pan-type, pontoon-type, and double-deck-type floating roofs. Appendix H provides requirements for a floating roof in a tank having a fixed roof at the top of the tank shell.

f. Appendix J to this specification presents rules covering the complete shop assembly of tanks not exceeding 20 ft. in diameter.

1.2 COMPLIANCE

The manufacturer is responsible for complying with all of the provisions of this specification. The purchaser may make any investigation necessary to satisfy himself of compliance by the manufacturer, and he may reject any material that does not comply with this specification. It is urged that the purchaser avail himself of this right and furnish his own inspection independently of any supervisory inspection furnished by the manufacturer, and that the purchaser's inspector follow closely all of the details of field construction and testing herein specified which affect the integrity and safety of the completed structure.

2. MATERIALS

2.1 PLATES

a. Plates purchased shall conform to the latest edition of one of the following specifications, subject to the modifications and limitations indicated in this standard. Material produced to specifications other than those listed in this paragraph may be employed provided the material is certified to meet all the requirements of a material specification listed herein and its use is approved by the purchaser.

R *ASTM * Standards*

A 36: Structural Steel †

A 283: Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality—grades C and D only

A 285: Low and Intermediate Tensile Strength Carbon Steel Plates for Pressure Vessels—grade C only

CSA ‡ Standard

G40.21: Structural Quality Steel—grade 44W only R
(Elements added for grain refining or strengthening shall be restricted in accordance with Table G-2.)

* American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

† None of the specifications for the appurtenant materials listed in Table 1 of ASTM A 36 are to be deemed acceptable for tanks constructed under these rules unless expressly so provided in this standard.

‡ Canadian Standards Association specifications may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

R *ISO* Recommendation R630*

Fe 42 and Fe 44: Structural Steels—grade B, non-rimming only

b. When the severity of the service conditions warrants the use of premium materials, the following alternative specifications for plates may be used, subject to the modifications and limitations indicated in this standard. Material produced to specifications other than those listed in this paragraph may be employed provided the material is certified to meet all the requirements of a material specification listed herein and its use is approved by the purchaser.

R *ASTM Standards*

A 131: Structural Steel for Ships—structural quality only

A 442: Carbon Steel Plates with Improved Transition Properties for Pressure Vessels

A 516: Carbon Steel Plates for Pressure Vessels for Moderate and Lower Temperature Service

A 537: Carbon-Manganese-Silicon Steel Plates, Heat Treated, for Pressure Vessels—grade A only

Note: ASTM A 537 plates may be furnished without impact tests.

A 573: Structural Carbon Steel Plates of Improved Toughness—grade 70

A 662: Carbon-Manganese Steel Plates for Pressure Vessels for Moderate and Lower Temperature Service—grade B only

CSA Standards

G40.8: Structural Steels with Improved Resistance to Brittle Fracture

R G40.21: Structural Quality Steel—grade 44T only (Elements added for grain refining or strengthening shall be restricted in accordance with Table G-2.)

R *ISO Recommendation R630*

Fe 42, Fe 44, and Fe 52: Structural Steels—grades C and D

c. The manufacturer shall state in his proposal the plate specification which he intends to use.

d. All plates shall be manufactured by the open-hearth, electric-furnace, or basic oxygen processes only. Copper-bearing steel shall be used if specified by the purchaser.

e. Plate specification on an edge-thickness basis is required for all shell plates, the thicknesses of which are determined by design computations. Shell plates for which minimum thicknesses have been computed may be purchased on a weight basis, provided they are ordered sufficiently heavier than the nominal weight corresponding to the specified minimum thickness to insure that plates furnished by the mill will not underrun the computed thickness by more than 0.01 in. Shell plates for which minimum thicknesses have been fixed for practical reasons (greater than required by computation) and which will not underrun the required computed thickness by more than 0.01 in., as well as all roof and bottom plates, may be purchased on a weight basis. The plate thicknesses or weights, as stipulated herein, are minimum; thicker or heavier material may be required on the order at the option of the purchaser.

2.2 SHEETS

Sheets shall conform to the latest revision of ASTM A 570, grade C, open-hearth process and basic oxygen process. Copper-bearing steel shall be used if so specified on the purchase order. Sheets may be ordered on a weight or thickness basis, at the option of the tank manufacturer.

2.3 WELDING ELECTRODES

Manual arc-welding electrodes shall conform to the E 60 and E 70 Series of Classification (suitable for the electric current characteristics, the position of welding, and other conditions of intended use) in the latest edition of AWS† A5.1: *Specification for Mild Steel Covered Arc-Welding Electrodes.* R

2.4 STRUCTURAL SHAPES

Structural shapes shall be of open-hearth, electric-furnace, or basic oxygen process and shall conform to the latest edition of one of the following specifications:

ASTM Standards

A 36: Structural Steel
A 131: Structural Steel for Ships

CSA Standard

G40.12: General Purpose Structural Steel

* International Organization for Standardization recommendations may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

† American Welding Society, 2501 Northwest 7th Street, Miami, Fla. 33125.

ISO Recommendation R630

Fe 42 and Fe 44: Structural Steels—grades B, C, and D

Copper-bearing steel shall be used if so specified on the purchase order.

2.5 CASTINGS

Castings shall conform to the latest edition of ASTM A 27, grade 60-30, fully annealed.

2.6 PIPING

Except as otherwise specified herein, pipe and pipe couplings shall conform to the latest edition of API Standard 5L; ASTM A 53; ASTM A 524; or ASTM A 106, grades A and B. By agreement between the purchaser and the manufacturer, couplings for threaded connections may be supplied without recesses. When so supplied, the couplings in all other respects shall conform to API Standard 5L. Pipe used for structural purposes shall conform to API Standard 5L, grade B, or API Standard 5LX, with respect to physical properties of the material.

2.7 FLANGES

Hub slip-on welding and welding-neck flanges shall conform to the material requirements for forged carbon steel flanges as specified in ANSI B16.5. Plate-ring flanges shall conform to the requirements of Table D-1. **R**

2.8 BOLTING

Bolting shall conform to the latest edition of ASTM A 307. Purchasers should specify on their orders the desired shape of bolt heads and nuts, and whether regular or heavy dimensions are desired.

3. DESIGN

3.1 JOINT DESIGN

3.1.1 Definitions

The following definitions shall apply to tank joint designs:

1. Double-welded butt joint: A joint between two abutting parts lying in approximately the same plane and welded from both sides.

2. Single-welded butt joint with backing: A joint between two abutting parts lying in approximately the same plane, welded from one side only with the use of a strip, bar, or other suitable backing material.

3. Double-welded lap joint: A joint between two overlapping members in which the overlapped edges of both members are welded with fillet welds.

4. Single-welded lap joint: A joint between two overlapping members in which the overlapped edge of one member is welded with a fillet weld.

5. Butt weld: A weld placed in a groove between two abutting members. Grooves may be square, V (single or double), or U (single or double), and may be either single- or double-beveled.

6. Fillet weld: A weld of approximately triangular cross-section joining two surfaces approximately at right angles to each other, as in a lap joint, tee joint, or corner joint.

7. Full-fillet weld: A fillet weld whose size is equal to the thickness of the thinner member joined.

8. Tack weld: A weld made to hold parts of a weldment in proper alignment until the final welds are made.

3.1.2 Size of Weld

The size of a weld shall be based on the following dimensions:

a. Groove weld: The joint penetration (depth of chamfering plus the root penetration when specified).

b. Fillet weld: For equal-leg fillet welds, the leg length of the largest isosceles right triangle which can be inscribed within the fillet weld cross-section. For unequal-leg fillet welds, the leg lengths of the largest right triangle which can be inscribed within the fillet weld cross-section.

3.1.3 Joint Restrictions

The following restrictions on type and size of joints or welds shall apply:

a. Tack welds may not be considered as having any strength value in the finished structure.

b. The minimum size of fillet welds shall be as follows: plates $\frac{3}{16}$ in. thick, full-fillet welds; plates over $\frac{3}{16}$ in. thick, not less than one-third the thickness of the thinner plate at the joint, with a minimum of $\frac{3}{16}$ in.

c. Single-welded lap joints are permissible only on bottom plates and roof plates.

d. Lap-welded joints, as tack-welded, shall be lapped not less than five times the nominal thickness of the thinner plate joined; but in the case of double-welded lap joints the lap need not exceed 2 in., and in the case of single-welded lap joints the lap need not exceed 1 in.

3.1.4 Welding Symbols

Welding symbols used on drawings shall be those of the American Welding Society.

3.1.5 Typical Joints

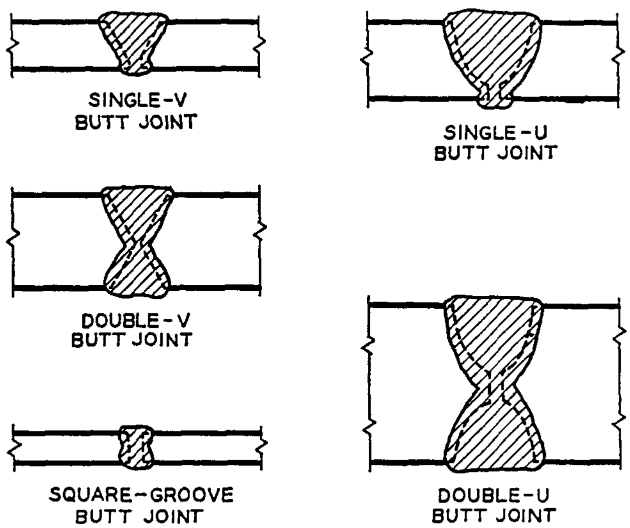
Typical tank joints are shown in Fig. 3-1, 3-2, and 3-3.

Note: The types of joints required for various parts of the tank are specified in Sect. 3.2, "Bottom Design"; Sect. 3.3, "Shell Design"; Sect. 3.4, "Wind Girder Design for Open-Top

Tanks"; Sect. 3.5, "Roof Design"; and Sect. 3.6, "Tank Connections and Appurtenances." For details of welding refer to Sect. 5.2.

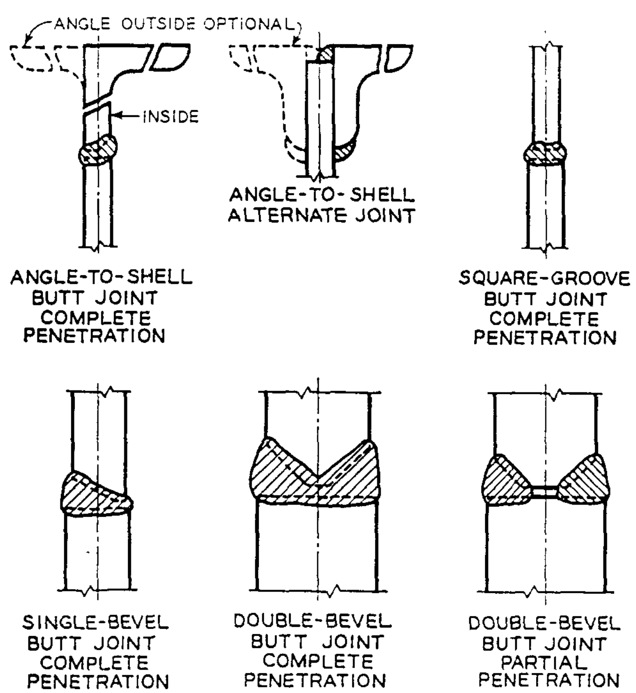
3.2 BOTTOM DESIGN

Note: Storage tanks, particularly in the larger sizes, impose appreciable bearing loads on the subgrade. The purchaser shall make provision to assure an adequate foundation. Details of recommended foundations are given in Appendix B.



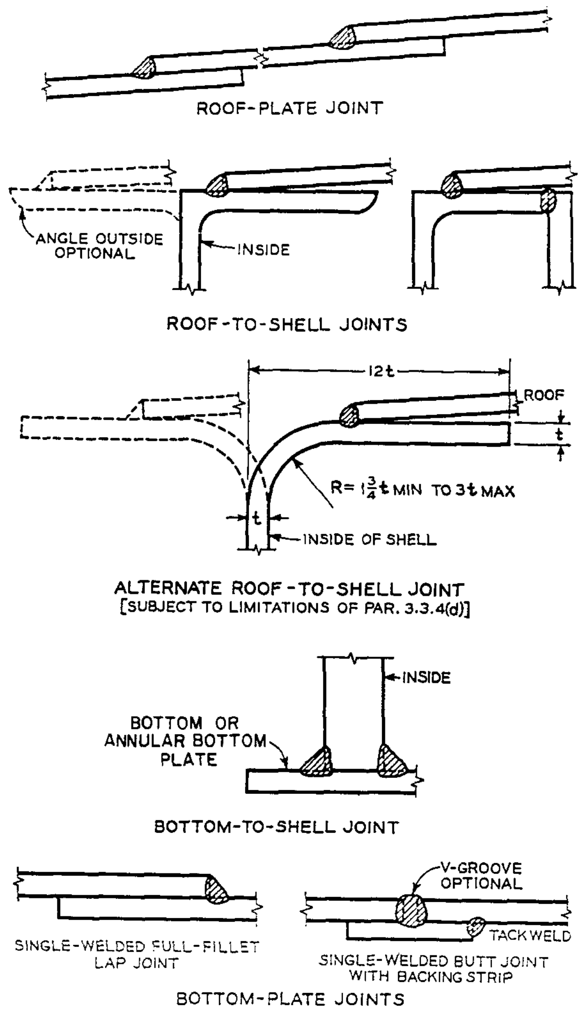
Note: See Par. 3.3.5 for specific requirements on vertical shell joints.

FIG. 3-1—Typical Vertical Joints in Shell.



Note: See Par. 3.3.6 for specific requirements on horizontal shell joints.

FIG. 3-2—Typical Horizontal Joints in Shell.



Note: See Par. 3.2.2 for specific requirements on bottom-plate joints; Par. 3.2.3 for specific requirements on bottom-to-shell joints; Par. 3.5.2, 3.5.4, and 3.5.7 for specific requirements on roof-plate joints and roof-to-top angle joints.

FIG. 3-3—Typical Roof and Bottom Joints.

3.2.1 Plate Sizes

a. All bottom plates shall have a minimum nominal thickness of ¼ in.* (10.2 lb per sq ft; see Sect. 2.1) exclusive of any corrosion allowance specified by the purchaser for the bottom plates. All rectangular plates should preferably have a minimum width of 72 in. All sketch plates (bottom plates upon which the shell rests), which have one end rectangular, should also preferably have a minimum width of 72 in. for the rectangular end. R

b. Bottom plates shall be ordered of sufficient size so that, when trimmed, at least a 1-in. width will project beyond the outside edge of the weld attaching the bottom to the shell plate.

* 6.0-mm. minimum thickness, with no under-tolerance, acceptable when specified by the purchaser.

3.2.2 Methods of Construction

Bottoms shall be built in accordance with either or both of the following methods of construction:

a. Lap-welded bottom plates shall be reasonably rectangular and square-edged. Three-plate laps in tank bottoms shall not be closer than 12 in. from each other and also from the tank shell. Bottom plates need be welded on the top side only, with a continuous full-fillet weld on all seams. The plates under the bottom-ring shell connection shall have the outer ends of the joints fitted and lap-welded to form a smooth bearing for the shell plates, as shown in Fig. 3-4.

b. Butt-welded bottom plates shall have the parallel edges prepared for butt welding with either square or V-grooves. If square grooves are employed, the root opening shall be not less than ¼ in. The butt welds shall be made by applying a backing strip ⅛ in. thick or heavier by tack welding to the underside of the plate. A metal spacer shall be used, if necessary, to maintain the root opening between the adjoining plate edges. The manufacturer may submit other methods of butt welding the bottom for the purchaser's approval. Three-plate joints in tank bottoms shall not be closer than 12 in. from each other and also from the tank shell.

3.2.3 Shell-to-Bottom Attachment

The attachment between the bottom edges of the lowest course shell plate and the bottom plate shall be a continuous fillet weld laid on each side of the shell plate. The size of each weld shall be not greater than ½ in. and not less than the nominal thickness of the thinner of the two plates joined (i.e., the shell plate or the bottom plate immediately under the shell), nor less than the following values:

Max. Thickness of Shell Plate (Inches)	Min. Size of Fillet Weld (Inches)
3/16	3/16
Over 3/16 to ¾	¼
Over ¾ to 1¼	5/16
Over 1¼ to 1½	⅜

Note: Refer to Sect. 3.1, "Joint Design," for description of, and information and certain restrictions on, the foregoing types of joints. Refer to Sect. 5.2 for details of welding.

3.3 SHELL DESIGN

See Appendix A for typical tank sizes and shell-plate thicknesses.

3.3.1 Working Stresses

The following maximum allowable working stresses shall be used in design:

a. The maximum tensile stress before applying the factor for efficiency of joint shall be 21,000 lb per sq in.

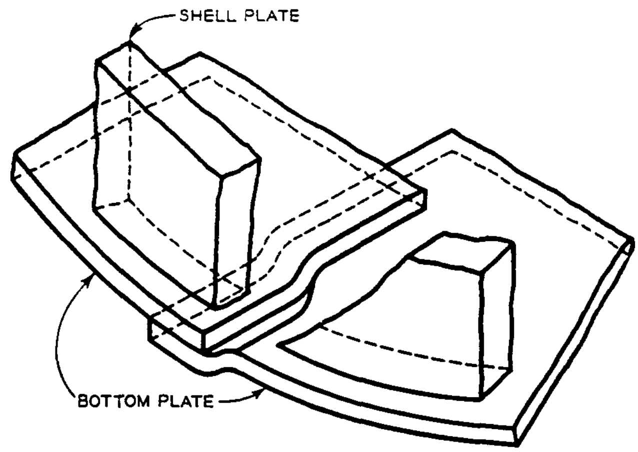


FIG. 3-4—Method for Preparing Lap-Welded Bottom Plates Under Tank Shell [See Par. 3.2.2(a)].

b. The structural design stresses shall conform to the allowable working stress given in Par. 3.5.3.

3.3.2 Loads

a. Stresses shall be computed on the assumption that the tank is filled with water at 60 F * or the liquid to be stored, if heavier than water. The tension in each ring shall be computed 12 in. above the centerline of the lower horizontal joint of the course in question. In computing these stresses, the tank diameter shall be taken as the nominal diameter † of the bottom course.

b. Isolated radial loads on tank shells, such as caused by heavy loads on platforms and elevated walkways between tanks, shall be distributed by rolled structural sections, plate ribs, or built-up members, preferably in a horizontal position.

3.3.3 Sizes and Thicknesses of Shell Plates

a. The minimum thicknesses of shell plates shall be computed from the stress on the vertical joints, using a joint efficiency factor of 0.85. The following formula may be used in calculating the minimum thickness of shell plate:

$$t=\frac{(2.6)(D)(H-1)(G)}{(0.85)(21{,}000)}$$

Where:

t = minimum thickness, in inches.‡
D = nominal diameter of tank, in feet.†
H = height, in feet, from bottom of course under consideration to top of top angle or to bottom of any overflow which limits tank filling height.
G = specific gravity of liquid to be stored, but in no case less than 1.0.

* Water at 60 F weighs 62.37 lb per cu ft.

† Nominal tank diameter shall be the centerline diameter of the shell plates, unless otherwise specified by the purchaser.

‡ Any required corrosion allowance for the shell plates should be added to the calculated thickness, unless otherwise specified by the purchaser.

b. In no case shall the nominal thickness * of shell plates (including shell extensions for floating roofs) be less than the following:

Nominal Tank Diameter † (Feet)	Nominal Plate Thickness (Inches)
Smaller than 50	3/16
50 to 120, excl.	1/4
120 to 200, incl.	5/16
Over 200	3/8

c. The width of shell plates shall be as agreed upon
R between the purchaser and the manufacturer, but preferably should not be less than 72 in. Plates which are to be butt welded shall be properly squared.

3.3.4 Arrangement of Members

a. The tank shell shall be designed to have all courses truly vertical. Unless otherwise specified, abutting shell plates at horizontal joints shall have a common vertical centerline. Vertical joints in adjacent shell courses shall not be in alignment but shall be offset from each other a minimum distance of $5t$, t being the plate thickness of the thicker course at the point of offset. However, this requirement need not apply to courses for which the plate thickness is established in accordance with Par. 3.3.3(b).

b. The wide face of unsymmetrical V- or U-butt joints may be on the outside or on the inside of the tank shell, at the option of the manufacturer.

c. Except as specified for open-top tanks in Par. 3.4.4, for self-supporting roofs in Par. 3.5.5 and 3.5.6, and for tanks having the flanged roof-to-shell detail described in Par. 3.3.4(d), tank shells shall be supplied with top angles of not less than the following sizes: tanks 35 ft and smaller in diameter—2½ in. by 2½ in. by ¼ in.; tanks of more than 35 ft to 60 ft, inclusive, in diameter—2½ in. by 2½ in. by 5/16 in.; tanks larger than 60 ft in diameter—3 in. by 3 in. by 3/8 in. The outstanding leg of the top angle may extend inside or outside the tank shell at the purchaser's option.

d. For tanks not exceeding 30 ft in diameter and having supported cone roofs (Par. 3.5.4), the top edge of the shell may be flanged in lieu of installing a top angle. The radius of bend and the width of the flanged edge shall conform to the details of Fig. 3-3.

This construction may be used for any tank having a self-supporting roof (Par. 3.5.5, 3.5.6, and 3.5.7) if the total cross-sectional area of the junction fulfills the stated area requirements for the top-angle construction. No additional member, such as an angle or bar, shall be added to the flanged roof-to-shell detail.

3.3.5 Vertical Joints

Vertical joints shall be butt joints with complete penetration and complete fusion as attained by double welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of Par. 5.2.1 and 5.2.3. The suitability of plate preparation and welding procedure shall be determined in accordance with Sect. 7.2, "Welding Procedure Qualification."

3.3.6 Horizontal Joints

Horizontal joints shall be double-welded butt joints and shall have complete fusion with the base metal over the required depth of weld. The suitability of plate preparation and welding procedure shall be determined in accordance with Sect. 7.2. Horizontal joints shall have complete penetration and complete fusion for a distance of 3 in. on each side of all vertical joint junctions. The remainder of the joints shall conform to the applicable requirements as follows:

a. Single-beveled butt joints, including the top angle-to-shell joints, shall have complete penetration and complete fusion. As an alternative, top angles may be attached to the shell by a double-welded lap joint.

b. Square-groove and double-beveled joints, if the thickness of either plate is 3/8 in. or less, shall have complete penetration and complete fusion.

c. Square-groove and double-beveled joints, if the thickness of both plates are greater than 3/8 in., shall have at least two-thirds penetration. Any lack of penetration or fusion plus any undercutting [see Par. 5.2.1(d) regarding undercutting] shall not exceed one-third of the thickness of the thinner plate, and the zone lacking penetration or fusion shall be located substantially at the center of the thinner plate.

Note: Refer to Sect. 3.1, "Joint Design," for description of, and information and certain restrictions on, the types of joints referred to in the preceding paragraphs. Refer to Sect. 5.2 for details of welding.

3.3.7 Shell Openings

Note: The following requirements on shell openings are intended to restrict the use of appurtenances to those providing for attachment to the shell by welding. The only exceptions are bolted door sheets. The design requirements for these are given in Sect. 3.6, "Tank Connections and Appurtenances."

a. Openings in tank shells larger than required to accommodate a 2-in. standard-weight coupling shall be reinforced. The minimum cross-sectional area of the reinforcement shall not be less than the product of the vertical diameter of the hole cut in the tank shell and the shell-plate thickness required by Par. 3.3.3(a). The cross-sectional area of the reinforcement shall be measured vertically, coincident with the diameter of the opening.

* The nominal thickness of shell plates refers to the tank shell as constructed. The thicknesses specified are based on erection requirements.

† Nominal tank diameter shall be the centerline diameter of the shell plates, unless otherwise specified by the purchaser.

b. All effective reinforcements shall be made within a distance, above or below the centerline of the shell opening, equal to the vertical dimension of the hole in the tank shell plate. The reinforcement may be provided by any one or by any combination of the following:

1. The attachment flange of the fitting.
2. The reinforcing plate.
3. The portion of the neck of the fitting which may be considered as reinforcement according to the following Par. (c).
4. Any excess shell-plate thickness beyond that required by Par. 3.3.3(a) within a vertical distance, both above and below the centerline of the hole in the shell, equal to the vertical dimension of the hole in the tank shell plate.

c. The following portions of the neck of a fitting may be considered a part of the area of reinforcement:

1. That portion extending outwardly from the outside surface of the tank shell plate for a distance equal to four times the neck-wall thickness or, if the neck-wall thickness is reduced within this distance, to the point of transition.
2. That portion lying within the shell-plate thickness.
3. That portion extending inwardly from the inside surface of the tank shell plate for a distance as specified in the preceding Par. (c-1).

d. The aggregate strength of the weld attaching a fitting to the shell plate or to an intervening reinforcing plate, or to both, shall equal at least the proportion of the forces, passing through the entire reinforcement, which is computed to pass through the fitting considered.

e. The aggregate strength of the welding attaching any intervening reinforcing plate to the shell plate shall at least equal the proportion of the forces, passing through the entire reinforcement, which is computed to pass through the reinforcing plate considered.

f. The attachment welding to the shell, along the outer periphery of the flanged fitting or reinforcing plate, shall be considered effective only for the parts lying outside of the area bounded by vertical lines drawn tangent to the shell opening. The outer peripheral welding, however, shall be applied completely around the reinforcement. All the inner peripheral welding shall be considered effective. The strength of the effective attachment welding shall be considered as its shear resistance at the stress values given for fillet welds in Par. 3.3.1(b). The outer peripheral weld shall be of a size equal to the thickness of the shell plate or reinforcing plate, whichever is thinner, except that when low-type nozzles are used with the reinforcing plate extending to the tank bottom (see Fig. 3-7), the size of that portion of the peripheral weld which attaches the reinforcing plate to the bottom plate shall conform to Par 3.2.3. The inner peripheral welding shall be sufficiently large to sustain the remainder of the loading.

R **g.** When two or more openings are located so close that the outer edges (toes) of their normal reinforcing plate fillet welds are closer than 8 times the size of the larger fillet weld, with a minimum of 6 in., they shall be treated and reinforced as follows:

1. All such openings shall be included in a single reinforcing plate, which shall be proportioned for the largest opening in the group.
2. If the normal reinforcing plates for the smaller openings in the group, considered separately, would fall within the area limits of the solid portion of a normal plate for the largest opening, the smaller openings may be included in a normal plate for the largest opening without increase in size of that plate; provided, however, that if any opening intersects the vertical centerline of another, the total width of the final reinforcing plate along the vertical centerline of either opening shall not be less than the sum of the widths of the normal plates for the openings involved.
3. If the normal reinforcing plates for the smaller openings, considered separately, would not fall within the area limits of the solid portion of a normal plate for the largest opening, the group reinforcing-plate size and shape shall be such as to include the outer limits of the normal reinforcing plates for all of the openings in the group. Change of size from the outer limits of the normal plate for the largest opening to the outer limits of that for the smaller opening farthest therefrom shall be by uniform straight taper unless the normal plate for any intermediate opening would extend beyond the limits so fixed, in which case uniform straight tapers shall join the outer limits of the several normal plates. Provisions of the preceding Par. (g-2), with respect to openings on the same or adjacent vertical centerlines, shall also apply in this case.

3.3.8 Flush-Type Cleanout Fittings

Note: Because of the restraint imposed by the tank bottom and the geometry of the reinforcement, cleanout fittings having the bottom member flush with the tank bottom require special consideration as provided in the following requirements. For selected sizes of fittings, dimensional details are covered in Par. 3.6.4. For restrictions on designs of cleanout fittings, see Par. 3.6.1.

a. Cleanout fittings of the flush type shall conform to the following requirements:

1. The opening shall be rectangular, except that the upper corners of the opening shall have a radius at least equal to one-third the greatest height of the clear opening. The width or height of the clear opening shall not exceed 48 in.
2. The reinforced opening shall be completely preassembled into a first-ring shell plate.
3. If any plate in the unit has a thickness greater than ⅝ in., the completed unit, including shell plate, shall be thermally stress-relieved at a temperature of 1,100 F to 1,200 F for 1 hr per in. of thickness.

b. The cross-sectional area of the shell reinforcement over the top of the opening shall not be less than

$$\frac{K_1 ht}{2}$$

Where:

K_1 = area coefficient as given in Fig. 3-5 (Detail A).
h = greatest vertical height of clear opening, in inches.
t = shell-plate thickness, in inches, required by Par. 3.3.3(a).

c. In no case shall the thickness of the shell reinforcing plate be less than the product of coefficient K_2, as given in Fig. 3-5 (Detail B) and the shell-plate thickness required by Par. 3.3.3(a).

d. The reinforcement in the plane of the shell shall be provided within a height, L, above the bottom of the opening. L shall not exceed $1.5h$ except that $L-h$ shall not be less than $h/2K_2$, nor less than 6 in. in case of small openings. Where the latter exception results in a height, L, greater than $1.5h$, only that portion of the reinforcement within a height of $1.5h$ shall be considered effective.

e. The reinforcement required may be provided by any one or by any combination of the following:

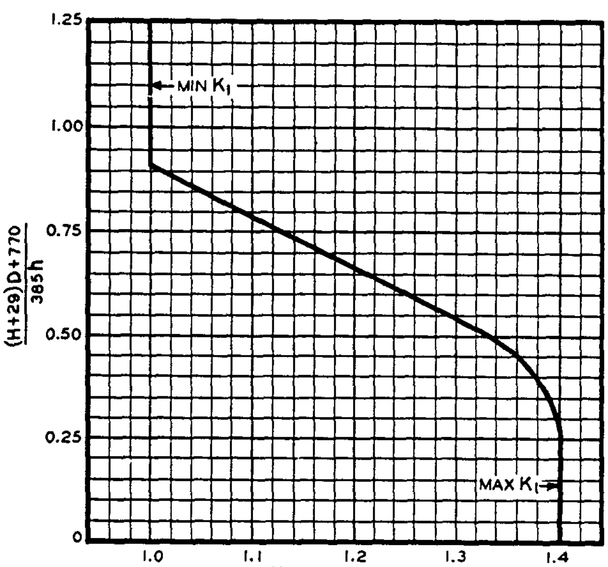
1. The shell reinforcing plate.
2. Any excess shell-plate thickness beyond that required by Par. 3.3.3(a).
3. That portion of the neck plate equal to the thickness of the reinforcing plate.

f. The minimum width of the tank-bottom reinforcing plate at the centerline of the opening shall be 10 in. plus the combined thicknesses of the shell and shell reinforcing plates. The minimum thickness of the bottom reinforcing plate, t_b, inches, shall be determined as follows: R

$$t_b = \frac{h^2}{14,000} + \frac{b}{310}\sqrt{H}$$

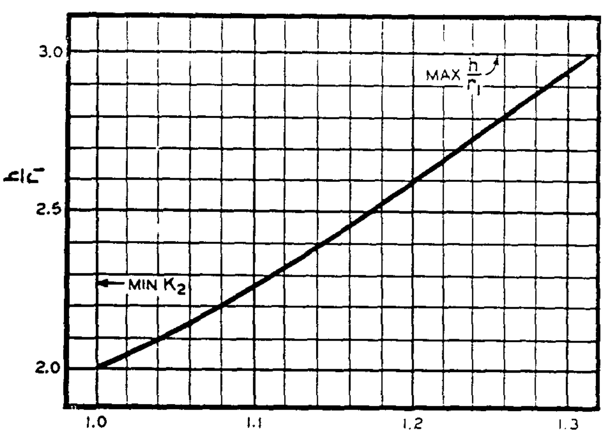
Where:

b = horizontal width of clear opening, in inches.
H = height of tank shell, in feet.
h = greatest vertical height of clear opening, in inches.



K_1 COEFFICIENT FOR DETERMINING MINIMUM SHELL REINFORCEMENT AREA AT TOP OF OPENING

DETAIL A



K_2 COEFFICIENT FOR DETERMINING MINIMUM SHELL REINFORCEMENT PLATE THICKNESS

DETAIL B

Legend:

H = height of tank, in feet.
D = inside diameter of tank, in feet.
h = greatest vertical height of clear opening, in inches.
r_1 = upper corner radius of clear opening, in inches.

FIG. 3-5—Design Factors for Flush-Type Cleanout Fittings.

3.3.9 Bolted Door Sheets

Bolted door sheets are based on specific design requirements as follows:

a. The minimum net cross-sectional area of the door plates, excluding the tapered ends, shall not be less than the product of the shell-plate thickness and the vertical height of the cutout in the shell plus twice the bolthole diameter:

$$t_D(h_D - N_1 d) = t_s(h_c + 2d)$$

b. The shear stress in the cross-section of the bolts shall not exceed 16,000 psi.

c. The bearing stress on bolts and boltholes shall not exceed 32,000 psi, and the fit of the turned bolt in the reamed hole shall conform to the standards of the American Institute of Steel Construction.

d. The strength of the bolted connection shall be at least 90 percent of the strength of the unbolted shell plate. For shear loading on the flush-type door sheet:

$$(N)(a)(16,000) = t_s(h_c + 2.5d + f)(21,000)(0.90)$$

For shear loading on the raised-type door sheet:

$$(N)(a)(16,000) = t_s(h_c - 4d)(21,000)(0.90)$$

In the equations in the preceding Par. (a) and (d):

t_s = thickness of shell plate, in inches.
t_D = thickness of door plate, in inches.
h_D = height of door plate, in inches.
h_c = height of shell cutout, in inches.
d = diameter of bolts and boltholes, in inches.
a = cross-sectional area of bolts, in square inches.
N = number of bolts required in each end section of door plate.
N_1 = number of bolts in first row of bolts next to shell cutout.
f = distance from bottom of shell cutout to centerline of bottom row of bolts.

e. The distance between centers of boltholes shall not be less than three times the bolt diameter, and the bolthole spacing at the sealing edge of the plate shall not exceed seven times the sum of the minimum door-sheet thickness plus the nominal bolt diameter plus the washer thickness (if washers are used).

f. The tensile stress in the net section of the door plate at the first row of boltholes next to the shell-plate cutout shall not exceed 21,000 psi, and at subsequent rows shall not exceed 21,000 psi after allowance is made for the total shearing value or bearing value (whichever is less) of the bolts in the preceding row or rows.

g. For flush-type bolted door sheets:

1. The girder shall be designed to withstand a bending moment which would result if the ends of the girder were on hard ground and the center unsupported.

2. The load on the girder shall be equal to the weight of a column of water with the following dimensions: *a*, 0.03 times the tank radius, in feet; *b*, width of the shell cutout plus 2 ft; and, *c*, the tank height, in feet.

3. The design length of the girder shall be equal to the width of the shell cutout plus 2 ft.

Note: When the difference in diameter of the bolts and boltholes, because of wear, approximates 0.020 in., it is recommended that the holes be rereamed and fitted with oversize milled-body bolts. However, the holes should not be reamed to the extent that the efficiency of the bolted connection becomes less than 85 percent. This point is reached when the bolthole diameters become ¼ in. larger than the bolt diameters specified in Tables 3-12 and 3-13.

3.4 WIND GIRDER DESIGN FOR OPEN-TOP TANKS

3.4.1 General

Open-top tanks shall be provided with stiffening rings to maintain roundness when the tank is subjected to wind loads. Stiffening rings shall be located at or near the top of the top course and preferably on the outside of the tank shell. This design for wind girders applies to floating-roof tanks covered in Appendix C.

3.4.2 Required Section Modulus

a. The required minimum section modulus of the stiffening ring shall be determined by the equation *:

$$Z = 0.0001\, D^2 H_2$$

Where:

Z = section modulus, in cubic inches.
D = nominal diameter of tank, in feet.
H_2 = height of tank shell, in feet, including any "freeboard" provided above the maximum filling height as a guide for a floating roof.

b. The section modulus of the stiffening ring shall be based upon the properties of the applied members and may include a portion of the tank shell for a distance of 16 plate thicknesses below and, if applicable, above the shell-ring attachment. When curb angles are attached to the top edge of the shell ring by butt welding, this distance shall be reduced by the width of the vertical leg of the angle.

Note: Section moduli values for typical ring members are given in Appendix A, see Table A-5.

3.4.3 Types of Stiffening Rings

Stiffening rings may be made of either structural sections, formed plate sections, or sections built up by welding, or of combinations of such types of sections assembled by welding. The outer periphery of stiffening rings may be circular or polygonal.

3.4.4 Restrictions on Stiffening Rings

a. The minimum size of angle for use alone, or as a component in a built-up stiffening ring, shall be 2½ in. by 2½ in. by ¼ in. The minimum nominal thickness of plate for use in formed or built-up stiffening rings shall be ¼ in.

b. When the stiffening rings are located more than 2 ft 0 in. below the top of the shell, the tank shall be provided with a 2½-in. by 2½-in. by 3/16-in. top curb angle for 3/16-in. shells and with a 3-in. by 3-in. by ¼-in. angle for shells greater than 3/16 in. or for other members of equivalent section modulus.

c. Rings of such design that liquid may be trapped thereon shall be provided with adequate drain holes.

3.4.5 Stiffening Rings as Walkways

A stiffening ring, or portions thereof, which is used regularly as a walkway shall have a width of not less than 24 in. clear of the projecting curb angle on the top of the tank shell. Preferably, it shall be located 3 ft 6 in. below the top of the curb angle, and shall be provided with a standard railing on the unprotected side and at the ends of the section so used.

* This equation is based on wind velocity of 100 mph. If specified by purchaser, other wind velocities may be used by multiplying the equation by $(V/100)^2$.

3.4.6 Stair Openings Through Stiffening Rings

When a stair opening is installed through a stiffening ring, the section modulus of that portion of the ring outside the opening, and including the transition section, shall conform to the requirements of Par. 3.4.2. The shell adjacent to such opening shall be stiffened with an angle or with a bar, the wide side of which is placed in a horizontal plane. The other sides of the opening shall be stiffened with an angle or with a bar, the wide side of which is placed in a vertical plane. The cross-sectional area of these rim stiffeners shall be at least equivalent to the cross-sectional area of that portion of shell included in the section modulus calculations of the stiffening ring (Par. 3.4.2). These stiffeners, or additional members, shall provide a suitable toeboard around the opening. The stiffening members shall extend beyond the end of the opening for a distance equal to, or greater than, the minimum depth of the regular ring sections. The end stiffening members shall frame into the side stiffening members and shall be connected to them in such manner as to develop their full strength.
R Fig. 3-5.1 shows the opening described above. Alternative details providing a load carrying capacity equal to that of the girder cross section away from the opening may be provided.

3.4.7 Supports for Stiffening Rings

Supports shall be provided for all stiffening rings when the dimension of the horizontal leg or web exceeds 16 times the leg or web thickness. Such supports shall be spaced at intervals as required for the dead load and the vertical live load which may be placed upon the ring. However, the spacing shall not exceed 24 times the width of the outside compression flange.

3.4.8 Weld Requirements

Continuous welds shall be used for all joints which, because of their location, may be subjected to corrosion from entrapped moisture or which may cause rust markings on the tank shell. Full penetration butt welds shall be used for joining ring sections.

Note: Refer to Sect. 3.1, "Joint Design," for description of, and information and certain restrictions on, types of joints referred to in the preceding paragraphs. Refer to Sect. 5.2 for details of welding.

3.5 ROOF DESIGN

3.5.1 Definitions

The following definitions shall apply to roof designs but shall not be considered as limiting the type of roof permitted by Par. 3.5.2(g):

1. Supported cone roof: A supported cone roof is a roof formed to approximately the surface of a right cone, with its principal support provided by either rafters on girders and columns or rafters on trusses with or without columns.

2. Self-supporting cone roof: A self-supporting cone roof is a roof formed to approximately the surface of a right cone, supported only at its periphery.

3. Self-supporting dome roof: A self-supporting dome roof is a roof formed to approximately a spherical surface, supported only at its periphery.

4. Self-supporting umbrella roof: A self-supporting umbrella roof is a modified dome roof so formed that any horizontal section is a regular polygon with as many sides as there are roof plates, supported only at its periphery.

3.5.2 General

a. All roofs and supporting structures shall be designed to support dead load, plus a uniform live load of not less than 25 lb per sq ft of projected area.

b. Roof plates shall have a minimum nominal thickness of $\frac{3}{16}$ in. (7.65 lb per sq ft of plate, 0.180-in. plate, or 0.1799-in. gage sheet). A greater thickness may be required for self-supporting roofs; see Par. 3.5.5 and 3.5.6. Any required corrosion allowance for the plates of self-supporting roofs should be added to the calculated thickness unless otherwise specified by the purchaser. Any corrosion allowance for plates of supported roofs should be added to the minimum nominal thickness.

c. Roof plates of supported cone roofs shall not be attached to the supporting members.

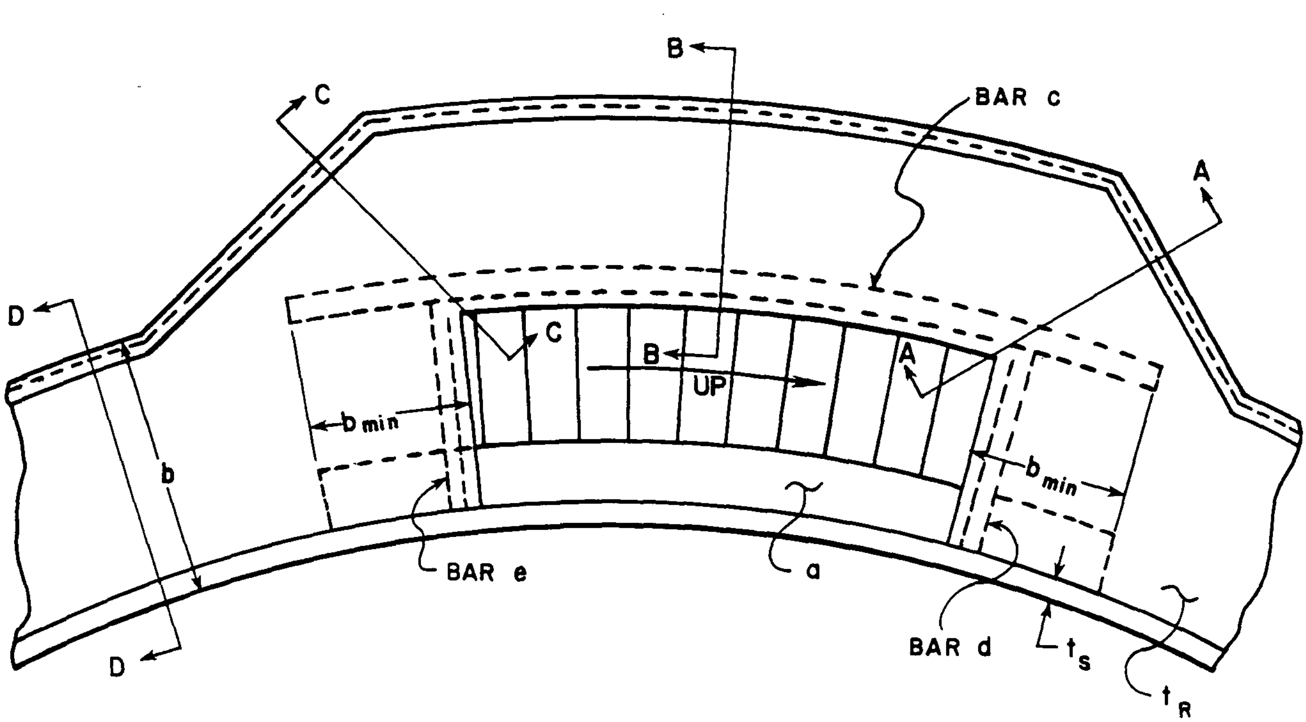
d. All internal and external structural members shall have a minimum nominal thickness, in any component, of 0.17 in. The method of providing a corrosion allowance, if any, for the structural members should be a matter of agreement between purchaser and manufacturer.

e. Roof plates shall be attached to the top angle of the tank with a continuous fillet weld on the top side only:

1. If the continuous fillet weld between the roof plates and the top angle does not exceed $\frac{3}{16}$ in. and the slope of the roof at the top-angle attachment does not exceed 2 in. in 12 in., the joint may be considered to be frangible and, in case of excessive internal pressure, will fail before failure occurs in the tank shell joints or the shell-to-bottom joint. Failure of the roof-to-shell joint may be accompanied by buckling of the top angle.
2. Where the weld size exceeds $\frac{3}{16}$ in. or where the slope of the roof at the top-angle attachment is greater than 2 in. in 12 in., emergency venting devices in accordance with API Standard 2000 shall be provided by the purchaser. The manufacturer shall provide a suitable tank connection for the device.

f. For all types of roofs, the plates may be stiffened by sections welded to the plates but not to the supporting rafters and/or girders.

g. These rules cannot cover all details of design and construction of tank roofs. With the approval of the purchaser, the roof need not comply with Par. 3.5.4, 3.5.5, 3.5.6, or 3.5.7. The manufacturer shall provide a roof that is designed and constructed to be as safe as otherwise provided under the rules of API Standard 650. Particular attention should be given to the design of these roofs against failure through instability.



Notes:

1. The cross-sectional area of a, c, d, and e must be equal to $32t_s^2$. The section of the figure designated as "a" may be a bar or an angle with its wide leg horizontal. The other sections may be bars or angles with wide legs vertical.

2. Bars c, d, and e may be placed on top of the girder web provided they do not cause a tripping hazard.

3. The section modulus at sections AA, BB, CC, and DD shall conform to the requirements of Paragraph 3.4.2.

4. The stairway may be continuous through the wind-girder or may be offset to provide a landing.

5. See Paragraph 3.4.6 for toe board requirements.

FIG. 3-5.1—Stair Opening Through Stiffening Ring.

3.5.3 Allowable Stresses

All parts of the structure shall be so proportioned that the sum of the maximum static stresses shall not exceed the following:

Tension

Rolled steel, on net section, in psi 20,000
Complete penetration groove welds on thinner plate area, in psi 18,000

Compression

Rolled steel, where lateral deflection is prevented, in psi 20,000
Complete penetration groove welds on thinner plate area, in psi 20,000
Columns, on cross-sectional area, in psi:

For L/r not over 120 ....

$$\left[1-\frac{\left(\frac{L}{r}\right)^2}{34{,}700}\right]\left[\frac{33{,}000\,Y}{FS}\right] \qquad \text{(Note 1)}$$

For L/r over 120 to 131.7, incl. ...

$$\frac{\left[1-\frac{\left(\frac{L}{r}\right)^2}{34{,}700}\right]\left[\frac{33{,}000\,Y}{FS}\right]}{1.6-\frac{L}{200r}} \qquad \text{(Note 2)}$$

For L/r over 131.7 ....

$$\frac{(149{,}000{,}000\,Y)}{\left[\left(\frac{L}{r}\right)^2\right]\left[1.6-\frac{L}{200r}\right]} \qquad \text{(Note 2)}$$

Where:

L = unbraced length of column, in inches.
r = least radius of gyration of column, in inches.

$$FS = \text{factor of safety} = \frac{5}{3}+\frac{\frac{L}{r}}{350}-\frac{\left(\frac{L}{r}\right)^3}{18{,}300{,}000}$$

$Y = 1.0$ (for structural sections or tubular sections having t/R values equal to or exceeding 0.015).

$$Y=\left[\frac{200}{3}\left(\frac{t}{R}\right)\right]\left[2-\frac{200}{3}\left(\frac{t}{R}\right)\right]$$ (for tubular sections having t/R values less than 0.015).

t = thickness of tubular section, in inches; ¼ in. minimum for main compression members, $^3/_{16}$ in. minimum for bracing and other secondary members.
R = outside radius of tubular section, in inches.

For main compression members, the ratio L/r shall not exceed 180

For bracing and other secondary members, the ratio L/r shall not exceed 200

Bending

Tension and compression on extreme fibers of rolled shapes and built-up members with an axis of symmetry in the plane of loading, where the laterally unsupported length of compression flange is no greater than 13 times its width, the compression flange width-thickness ratio does not exceed 17, and the web depth-thickness ratio does not exceed 70, in psi 22,000
Tension and compression on extreme fibers of unsymmetrical members, where the member is supported laterally at intervals no greater than 13 times its compression flange width, in psi 20,000
Tension on extreme fibers of other rolled shapes, built-up members, and plate girders, in psi .. 20,000
Compression on extreme fibers of other rolled shapes, plate girders, and built-up members having an axis of symmetry in the plane of loading, the larger value computed by the following, in psi:

$$20{,}000-0.571\left(\frac{\ell}{r}\right)^2$$

Or:

$$\frac{12{,}000{,}000}{\frac{\ell d}{A_f}}\leq 20{,}000$$

Where:

ℓ = unbraced length of compression flange.
r = radius of gyration of section about an axis in the plane of loading.
d = depth of section.
A_f = area of compression flange.

Compression on extreme fibers of other unsymmetrical sections, in psi:

$$\frac{12{,}000{,}000}{\frac{\ell d}{A_f}}\leq 20{,}000$$

Shearing

Fillet, plug, slot, and partial penetration groove welds of throat area, in psi 13,600

Notes:

1. The allowable stresses, not including the factor Y, have been tabulated in *AISC S 310-311: Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings* (1969), see Table 1-33 under column heading "Main and Secondary Members."

2. The allowable stresses, not including the factor Y, have been tabulated in AISC S 310-311, see Table 1-33 under column heading "Secondary Members."

On the gross area of the webs of beams and girders, where h (the clear distance between web flanges, in inches) is not more than 60 times t (the thickness of the web, in inches) or when the web is adequately stiffened, in psi 13,000

On the gross area of the webs of beams and girders, if the web is not stiffened so that h is more than 60 times t, the greatest average

R shear, V/A shall not exceed, in psi:

$$\frac{19{,}500}{1+\dfrac{h^2}{(7{,}200)\,t^2}}$$

Where:

V = total shear.

A = gross area of the web, in inches.

3.5.4 Supported Cone Roofs

a. Roof plates shall be welded on the top side with continuous full-fillet welds on all seams. The size of the roof-to-top angle weld shall be 3⁄16 in., or smaller if so specified on the purchase order.

b. The slope of the roof shall be ¾ in. in 12 in., or greater if specified by the purchaser. If the rafters are set directly on chord girders producing slightly varying rafter slopes, the slope of the flattest rafter shall conform to the specified or ordered roof slope.

c. Main supporting members, including those supporting the rafters, may be rolled or fabricated sections, or trusses. Although these members may be in contact with the roof plates, the compression flange of a member or the top chord of a truss shall be considered to receive no lateral support from the roof plates and shall be laterally braced, if necessary, by other acceptable methods. The allowable stresses in these members shall be governed by Par. 3.5.3.

d. Structural members, serving as rafters, may be rolled or fabricated sections but in all cases shall conform with the rules of Par. 3.5.2, 3.5.3, and 3.5.4. Rafters in direct contact with the roof plates applying the loading to the rafters may be considered to receive adequate lateral support from the friction between the roof plates and the compression flanges of the rafters, with the following exceptions:

1. Trusses and open-web joists used as rafters.
2. Rafters having a nominal depth greater than 15 in.
3. Rafters having a slope greater than 2 in. in 12 in.

e. Rafters shall be spaced so that, in the outer ring, their centers shall not be more than 2π feet apart (6.28 ft.), measured along the circumference of the tank. Spacing on inner rings shall not be greater than 5½ ft. When specified by the purchaser for tanks located in areas subject to earthquake, ¾-in.-diameter tie rods (or equivalent) shall be placed between the rafters in the outer rings. These tie rods may be omitted if I- or H-sections are used as rafters.

f. Roof columns shall be made from structural shapes or steel pipe may be used subject to the approval of the purchaser. When pipe is used it must be sealed or provisions for draining and venting must be made at purchaser's option.

g. Rafter clips for the outer row of rafters shall be welded to the tank shell. Column base clip guides shall be welded to the tank bottom to prevent lateral movement of column bases. All other structural attachments shall be either bolted, riveted, or welded.

3.5.5 Self-Supporting Cone Roofs

Self-supporting cone roofs shall conform to the following requirements*:

Maximum θ = 37 deg (tangent = 9:12).

Minimum $\sin\theta$ = 0.165 (slope 2 in. in 12 in.).

Minimum $t = \dfrac{D}{400\sin\theta}$ but not less than 3⁄16 in.

Maximum t = ½ in.

Note: Self-supporting roofs having the roof plates stiffened by sections welded to the plates need not conform to the minimum thickness requirements, but should be not less than 3⁄16 in. when so designed by the manufacturer, subject to the approval of the purchaser.

The cross-sectional area of the top angle, in square inches, plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed:

$$\frac{D^2}{3{,}000\sin\theta}$$

Where:

D = nominal diameter of tank shell in feet.

θ = angle of cone elements with the horizontal, in degrees.

t = nominal thickness of roof plates, in inches.

3.5.6 Self-Supporting Dome and Umbrella Roofs

Self-supporting dome and umbrella roofs shall conform to the following requirements*:

Minimum $R = 0.8\ D$ (unless otherwise specified by the purchaser).

Maximum $R = 1.2D$.

Minimum $t = R/200$ but not less than 3⁄16 in.

Maximum t = ½ in.

Note: Self-supporting roofs having the roof plates stiffened by sections welded to the plates need not conform to the minimum thickness requirements, but should be not less than 3⁄16 in. when so designed by the manufacturer, subject to the approval of the purchaser.

The cross-sectional area of the top angle, in square inches, plus the cross-sectional areas of the shell and

* The formulas applying to self-supporting roofs provide for a uniform live load of 25 lb per sq ft.

roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed:

$$\frac{DR}{1{,}500}$$

Where:

D = nominal diameter of tank shell, in feet.
R = radius of curvature of roof, in feet.
t = nominal thickness of roof plates, in inches.

3.5.7 Top-Angle Attachment for Self-Supporting Roofs

a. The top-angle sections for self-supporting roofs shall be joined by butt welds having complete penetration and fusion. Joint efficiency factors need not be applied in conforming to the requirements of Par. 3.5.5 and 3.5.6.

Note: Refer to Sect. 3.1, "Joint Design," for description of, and information and certain restrictions on, types of joint referred to in the preceding paragraph. Refer to Sect. 5.2 for details of welding.

b. For self-supporting roofs—whether of the cone, dome, or umbrella type—the edges of the roof plates, at the option of the manufacturer, may be flanged horizontally to rest flat against the top angle to improve welding conditions.

3.6 TANK CONNECTIONS AND APPURTENANCES

3.6.1 General

R **a.** When connections and appurtenances are installed on tanks conforming to this specification, the use of designs as specified herein is required, except that alternate designs (for other than flush-type cleanout fittings and bolted door sheets) which provide equivalent strength, tightness, and utility are permissible if agreed to by the purchaser. When intermediate sizes to those stated in Tables 3-1 to 3-17, inclusive, are specified by the purchaser, the construction details and reinforcements shall conform to the next greater opening listed in the tables. The size of opening or tank connection shall not be larger than the maximum size given in the appropriate table. Connections to the tank bottoms are permitted subject to agreement between the purchaser and the manufacturer as to details which provide equivalent strength, tightness, and utility to shell connections shown in this standard. Connections and appurtenances complying with Appendix D or with API Standard 620 are considered satisfactory alternate designs. Flush-type cleanout fittings and bolted door sheets shall conform to the designs specified in Par. 3.6.4 and 3.6.5 until existing requirements are revised to permit alternate designs as may be shown to be safe by additional field experience or further development work.

b. Manhole necks, nozzle necks, reinforcing plates, and shell-plate openings which have either sheared or oxygen-cut surfaces shall have such surfaces made uniform and smooth, with the corners rounded, except where such surfaces are fully covered by attachment welds.

c. The periphery of insert plates shall have a 1:4 tapered transition to the thickness of the adjacent shell plates.

3.6.2 Shell Manholes

a. Shell manholes shall conform to Fig. 3-6 and Tables 3-1 through 3-5. Manhole reinforcing plates, and segments thereof if not made in one piece, shall be provided with a ¼-in.-diameter telltale hole (for the purpose of detecting leakage through the interior welds). Such holes shall be located substantially on the horizontal centerline and shall be open to the atmosphere.

b. Manhole frames may be press-formed or of built-up welded construction. The dimensions listed in Tables 3-1 through 3-5 cover both types of construction. The dimensions are based on the minimum neck thickness listed for the built-up type and allow for the thinning of the neck in the pressing operation of the formed type.

c. The maximum diameter of the shell cutout shall be the sum of the inside diameter of the frame plus four times the attachment flange thickness plus 1 in. Dimensions are listed in the tables for a pressed frame, using a constant-diameter ring die, and for a built-up frame. The latter dimensions apply conservatively to a pressed frame using a constant-diameter plug die.

3.6.3 Shell Nozzles

a. Shell nozzles shall conform to Fig. 3-7 and 3-8 and Tables 3-6, 3-7, and 3-8. Nozzle reinforcing plates, and segments thereof if not made in one piece, shall be provided with a ¼-in.-diameter telltale hole located substantially on the horizontal centerline and open to the atmosphere.

b. Details and dimensions specified herein are for nozzles installed with their axes perpendicular to the shell plate. Nozzles may be installed at an angle of other than 90 deg to the shell plate in a horizontal plane, provided the width of the reinforcing plate (dimension W, Fig. 3-7 and Table 3-6) is increased by the amount that the horizontal chord of the opening cut in the shell plate (dimension D_P, Fig. 3-7 and Table 3-7) increases as the opening changes from circular to elliptical in making the angular installation. In addition, nozzles not larger than 3 in. nominal pipe size—for insertion of thermometer wells, sampling connections, or other purposes not involving the attachment of extended piping—may be installed at an angle of 15 deg or less off perpendicular in a vertical plane, without modification of the nozzle reinforcing plate.

3.6.4 Flush-Type Cleanout Fittings

a. Flush-type cleanout fittings shall conform to Par. 3.3.8, Fig. 3-9, and Tables 3-9, 3-10, and 3-11. Flush-type cleanout fittings shown in Fig. D-6 are optional by agreement between the purchaser and manufacturer.

b. When a flush-type cleanout fitting is installed on a tank resting on an earth grade without concrete or masonry walls under the tank shells, provision shall be made to support the fitting and retain the grade by either of the following methods:

Method A: Install a vertical steel bulkhead plate under the tank, along the contour of the tank shell and symmetrical with the opening as shown in Fig. 3-10, Method A.

Method B: Install a concrete or masonry retaining wall under the tank, with its outer face conforming to the contour of the tank shell as shown in Fig. 3-10, Method B.

c. When a flush-type cleanout fitting is installed on a tank resting on a ringwall, a notch having the dimensions shown in Fig. 3-10, Method C, shall be provided to accommodate the cleanout fitting.

d. When a flush-type cleanout fitting is installed on a tank resting on an earth grade inside a foundation retaining wall, a notch shall be provided in the retaining wall to accommodate the fitting and a supplementary inside retaining wall shall be provided to support the fitting and retain the grade. The dimensions shall be as shown in Fig. 3-10, Method D.

3.6.5 Flush-Type Bolted Door Sheets

a. Flush-type bolted door sheets shall conform to Fig. 3-11 and Table 3-12.

b. When a flush-type bolted door sheet is installed on a tank resting on an earth grade with or without a concrete retaining wall and without a concrete or masonry wall under the tank shell, provision shall be made to support the fitting and retain the grade as shown in Fig. 3-12, Method A.

c. When a flush-type bolted door sheet is installed on a tank resting on a ringwall, a cutout having the dimensions shown in Fig. 3-12, Method B, shall be provided.

3.6.6 Raised-Type Bolted Door Sheets

Raised-type bolted door sheets shall conform to Fig. 3-13 and Table 3-13.

3.6.7 Roof Manholes

Roof manholes shall conform to Fig. 3-14 and Table 3-14. If work is expected to be carried on through the manhole opening while the tank is in use, it is recommended that the roof structure around the manhole be suitably reinforced.

3.6.8 Roof Nozzles

Flanged roof nozzles shall conform to Fig. 3-15 and Table 3-15. Threaded nozzles shall conform to Fig. 3-16 and Table 3-16.

3.6.9 Water Drawoff Sumps

Drawoff sumps shall be as specified in Fig. 3-17 and Table 3-17 unless otherwise specified by the purchaser.

3.6.10 Scaffold Cable Support

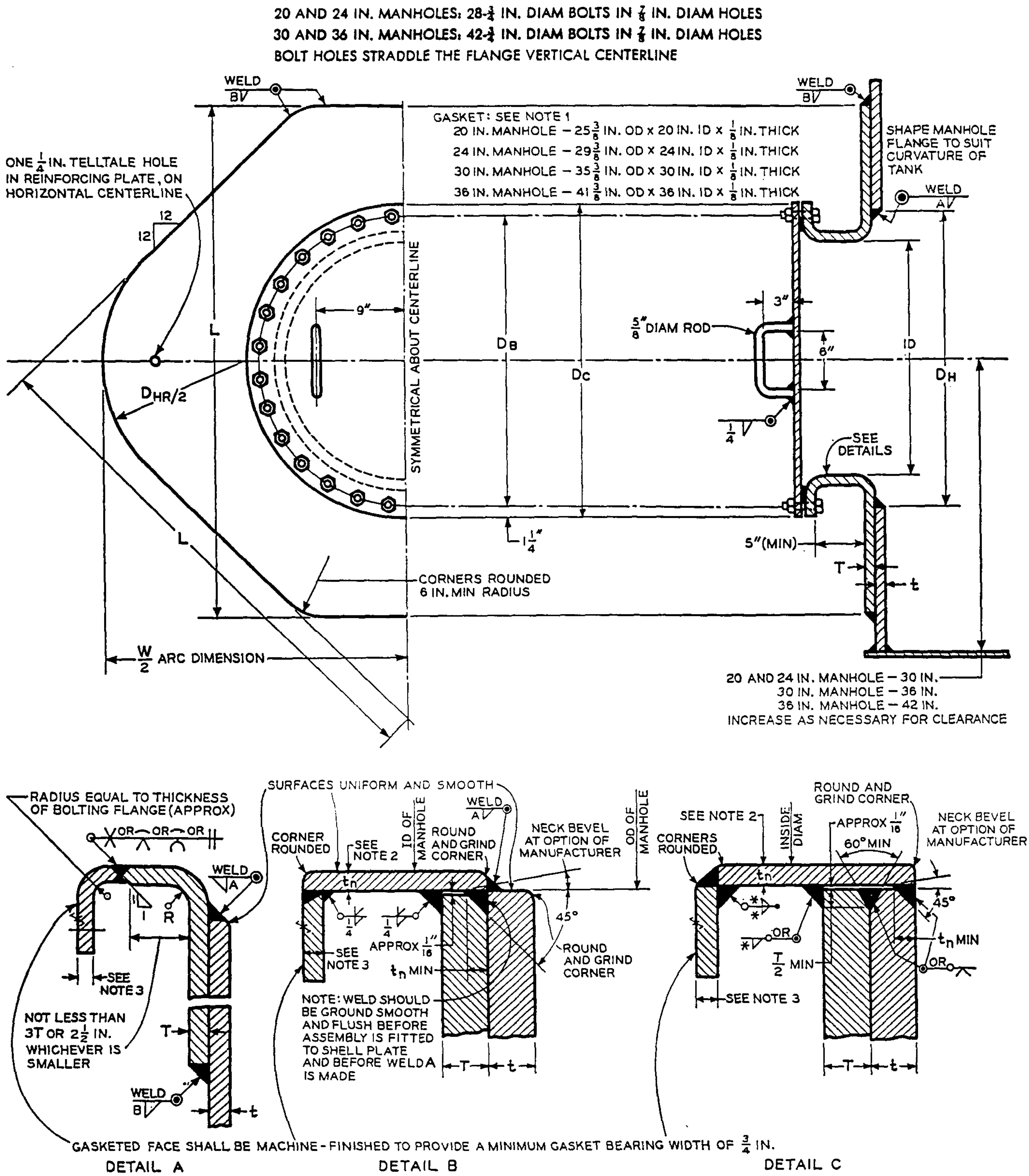
Supports for scaffold cables shall conform to Fig. 3-18.

3.6.11 Threaded Connections

Threaded piping connections shall be female and shall be tapered. The threads shall conform to the requirements for taper pipe threads included in *ANSI B2.1-1968: American Standard for Pipe Threads (Except Dryseal)*.

3.6.12 Platforms, Walkways, and Stairways

Platforms, walkways, and stairways shall be in accordance with Tables 3-18, 3-19, and 3-20.



* Size of weld shall equal the thickness of the thinner member joined.

Notes:

1. Gasket material shall be long-fiber asbestos sheet. unless otherwise specified.
2. See Tables 3-1 through 3-5.
3. See Table 3-1; types of flanges and methods for attaching bolting flanges to manhole necks are interchangeable.
4. The shell nozzles of Fig. 3-7, for manholes 20 in. in diameter and larger, may be substituted by agreement with the purchaser.
5. When the shell nozzles of Fig. 3-7 are used or when manhole Details B and C are used, the minimum centerline heights above the tank bottom, as given in Table 3-6. are also acceptable.

FIG. 3-6—Shell Manhole (See Tables 3-1 Through 3-5).

R

TABLE 3-1—Thickness of Shell Manhole Cover Plate and Bolting Flange (See Fig. 3-6)

All dimensions are in inches unless otherwise stated.

(1) Max. Tank Height (Feet)	(2) Equivalent Pressure* (Pounds per Square Inch)	(3) Min. Thickness of Cover Plate: 20-in. Manhole	(4) 24-in. Manhole	(5) 30-in. Manhole	(6) 36-in. Manhole	(7) Min. Thickness of Bolting Flange After Finishing: 20-in. Manhole	(8) 24-in. Manhole	(9) 30-in. Manhole	(10) 36-in. Manhole
21	9.1	5/16	3/8	7/16	1/2	1/4	1/4	5/16	3/8
27	11.7	3/8	7/16	1/2	9/16	1/4	5/16	3/8	7/16
32	13.9	3/8	7/16	9/16	5/8	1/4	5/16	7/16	1/2
40	17.4	7/16	1/2	5/8	11/16	5/16	3/8	1/2	9/16
45	19.5	1/2	9/16	5/8	3/4	3/8	7/16	1/2	5/8
54	23.4	1/2	9/16	11/16	13/16	3/8	7/16	9/16	11/16
65	28.2	9/16	5/8	3/4	7/8	7/16	1/2	5/8	3/4
75	32.5	5/8	11/16	13/16	15/16	1/2	9/16	11/16	13/16

* Equivalent pressure is based on water loading

TABLE 3-2—20-In. Shell Manhole (See Fig. 3-6)

All dimensions are in inches.

(1) Thickness of Shell and Manhole Attachment Flange* t and T	(2) Size of Fillet: Weld A	(3) Size of Fillet: Weld B	(4) Approx. Radius R	(5) Attachment Flange: Length of Side L	(6) Attachment Flange: Width W	(7) Frame Using Constant-Diameter Ring Die: Inside Diameter of Manhole Frame ID_R	(8) Frame Using Constant-Diameter Ring Die: Max. Diameter of Hole in Shell† D_{HR}	(9) Frame Using Constant-Diameter Plug Die: Inside Diameter of Manhole Frame ID_P	(10) Frame Using Constant-Diameter Plug Die: Max. Diameter of Hole in Shell D_{HP}	(11) Built-up Frame Min. Neck Thickness: Add Reinforcement if Neck Thickness Is Less Than ‡:
3/16	3/16	3/16	3/16	46	55	22 5/8	24 1/4	20	21 3/4	3/16
1/4	3/16	1/4	1/4	46	55	22 1/2	24 1/2	20	22	1/4
5/16	3/16	5/16	5/16	45 3/4	54 3/4	22 3/8	24 1/2	20	22 1/4	1/4
3/8	3/16	3/8	3/8	45 1/2	54 1/4	22 1/4	24 3/4	20	22 1/2	1/4
7/16	3/16	7/16	7/16	45 1/4	53 3/4	22 1/8	24 3/4	20	22 3/4	1/4
1/2	3/16	1/2	1/2	45	53 1/2	22	25	20	23	1/4
9/16	1/4	9/16	9/16	44 3/4	53	21 7/8	25	20	23 1/4	1/4
5/8	1/4	5/8	5/8	44 3/4	53	21 3/4	25 1/4	20	23 1/2	1/4
11/16	5/16	11/16	11/16	44 1/2	52 1/2	21 5/8	25 1/4	20	23 3/4	1/4
3/4	5/16	3/4	3/4	44 1/4	52 1/4	21 1/2	25 1/2	20	24	1/4
13/16	3/8	13/16	3/4	44	51 3/4	21 3/8	25 1/2	20	24 1/4	5/16
7/8	3/8	7/8	7/8	44	51 3/4	21 1/4	25 3/4	20	24 1/2	3/8
15/16	7/16	15/16	7/8	44 1/4	52	21 1/8	25 3/4	20	24 3/4	7/16
1	1/2	1	1	44 1/2	52 1/4	21	26	20	25	7/16
1 1/16	1/2	1 1/16	1	44 3/4	52 1/2	20 7/8	26	20	25 1/4	7/16
1 1/8	9/16	1 1/8	1	44 3/4	52 1/2	20 3/4	26 1/4	20	25 1/2	1/2
1 3/16	9/16	1 3/16	1	45	52 3/4	20 5/8	26 1/4	20	25 3/4	9/16
1 1/4	5/8	1 1/4	1	45	52 3/4	20 1/2	26 1/2	20	26	5/8
1 5/16	5/8	1 5/16	1	45 1/4	53	20 3/8	26 1/2	20	26 1/4	5/8
1 3/8	11/16	1 3/8	1	45 1/4	53	20 1/4	26 3/4	20	26 1/2	11/16
1 7/16	11/16	1 7/16	1	45 1/2	53 1/4	20 1/8	26 3/4	20	26 3/4	11/16
1 1/2	3/4	1 1/2	1	45 1/2	53 1/4	20	27	20	27	3/4
1 9/16§	3/4	1 9/16	1 1/8	45 3/4	53 1/2	19 7/8	27	20	27 1/4	3/4
1 5/8§	13/16	1 5/8	1 1/8	45 3/4	53 1/2	19 3/4	27 1/4	20	27 1/2	13/16
1 11/16§	13/16	1 11/16	1 1/8	46	53 3/4	19 5/8	27 1/4	20	27 3/4	13/16
1 3/4§	7/8	1 3/4	1 1/8	46	53 3/4	19 1/2	27 1/2	20	28	7/8

Diameter of bolt circle D_B = 26 1/4 in.
Diameter of cover plate D_C = 28 3/4 in.

* If a shell plate thicker than required is used for the hydrostatic loading (Sect. 3.3, "Shell Design"), the excess shell-plate thickness, within a vertical distance both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate may be considered as reinforcement; and the thickness, T, of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits for reinforcement of shell openings specified in Sect. 3.3.

† The hole in the shell may be made oval with a horizontal major diameter of 29 in., where necessary for removal of rigid scaffold brackets.

‡ The minimum neck thickness shall be the thickness of the shell plate or the allowable finished thickness of the bolting flange (see Table 3-1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Column (11). If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3.

§ t greater than 1 1/2 in. is applicable to Appendix G tanks only.

TABLE 3-3—24-In. Shell Manhole (See Fig. 3-6)

All dimensions are in inches.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
						Frame Using Constant-Diameter Ring Die		Frame Using Constant-Diameter Plug Die		Built-up Frame Min. Neck Thickness
Thickness of Shell and Manhole Attachment Flange* t and T	Size of Fillet		Approx. Radius R	Attachment Flange		Inside Diameter of Manhole Frame ID_R	Max. Diameter of Hole in Shell D_{HR}	Inside Diameter of Manhole Frame ID_P	Max. Diameter of Hole in Shell D_{HP}	Add Reinforcement if Neck Thickness Is Less Than †:
	Weld A	Weld B		Length of Side L	Width W					
3/16	3/16	3/16	3/16	54	65	26 5/8	28 1/4	24	25 3/4	3/16
1/4	3/16	1/4	1/4	54	64 3/4	26 1/4	28 1/2	24	26	1/4
5/16	3/16	5/16	5/16	53 3/4	64 1/2	26 3/8	28 1/2	24	26 1/4	1/4
3/8	3/16	3/8	3/8	53 1/2	64	26 1/4	28 3/4	24	26 1/2	1/4
7/16	3/16	7/16	7/16	53 1/2	64	26 1/8	28 3/4	24	26 3/4	1/4
1/2	3/16	1/2	1/2	53 1/4	63 1/2	26	29	24	27	1/4
9/16	3/16	9/16	9/16	53	63	25 7/8	29	24	27 1/4	1/4
5/8	1/4	5/8	5/8	52 3/4	62 3/4	25 3/4	29 1/4	24	27 1/2	1/4
11/16	1/4	11/16	11/16	52 1/2	62 1/4	25 5/8	29 1/4	24	27 3/4	1/4
3/4	5/16	3/4	3/4	52 1/2	62 1/4	25 1/2	29 1/2	24	28	1/4
13/16	5/16	13/16	3/4	52 1/4	61 3/4	25 3/8	29 1/2	24	28 1/4	1/4
7/8	3/8	7/8	7/8	52 1/4	61 3/4	25 1/4	29 3/4	24	28 1/4	5/16
15/16	3/8	15/16	7/8	52 1/4	61 3/4	25 1/8	29 3/4	24	28 3/4	7/16
1	7/16	1	1	52 3/4	62 1/4	25	30	24	29	7/16
1 1/16	7/16	1 1/16	1	52 3/4	62 1/4	24 7/8	30	24	29 1/4	7/16
1 1/8	1/2	1 1/8	1	53	62 1/2	24 3/4	30 1/4	24	29 1/2	1/2
1 3/16	1/2	1 3/16	1	53	62 1/2	24 5/8	30 1/4	24	29 3/4	9/16
1 1/4	1/2	1 1/4	1	53 1/4	62 3/4	24 1/2	30 1/2	24	30	9/16
1 5/16	9/16	1 5/16	1	53 1/4	62 3/4	24 3/8	30 1/2	24	30 1/4	5/8
1 3/8	9/16	1 3/8	1	53 1/2	63	24 1/4	30 3/4	24	30 1/2	5/8
1 7/16	5/8	1 7/16	1	53 1/2	63	24 1/8	30 3/4	24	30 3/4	11/16
1 1/2	11/16	1 1/2	1	53 3/4	63 1/4	24	31	24	31	3/4
1 9/16‡	11/16	1 9/16	1 1/8	53 3/4	63 1/4	24	31	24	31 1/4	3/4
1 5/8‡	3/4	1 5/8	1 1/8	54	63 1/2	23 7/8	31 1/4	24	31 1/2	13/16
1 11/16‡	13/16	1 11/16	1 1/8	54	63 1/2	23 3/4	31 1/4	24	31 3/4	7/8
1 3/4‡	7/8	1 3/4	1 1/8	54 1/4	63 3/4	23 5/8	31 1/2	24	32	7/8

Diameter of bolt circle D_B = 30 1/4 in.
Diameter of cover plate D_C = 32 3/4 in.

* If a shell plate thicker than required is used for the hydrostatic loading (Sect. 3.3, "Shell Design"), the excess shell-plate thickness, within a vertical distance both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate may be considered as reinforcement; and the thickness, T, of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits for reinforcement of shell openings specified in Sect. 3.3.

† The minimum neck thickness shall be the thickness of the shell plate or the allowable finished thickness of the bolting flange (see Table 3-1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Column (11). If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3.

‡ t greater than 1½ in. is applicable to Appendix G tanks only.

TABLE 3-4—30-In. Shell Manhole (See Fig. 3-6)

All dimensions are in inches.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
						Frame Using Constant-Diameter Ring Die		Frame Using Constant-Diameter Plug Die		Built-up Frame Min. Neck Thickness
Thickness of Shell and Manhole Attachment Flange* t and T	Size of Fillet: Weld A	Size of Fillet: Weld B	Approx. Radius R	Attachment Flange: Length of Side L	Attachment Flange: Width W	Inside Diameter of Manhole Frame ID_R	Max. Diameter of Hole in Shell D_{HR}	Inside Diameter of Manhole Frame ID_P	Max. Diameter of Hole in Shell D_{HP}	Add Reinforcement if Neck Thickness Is Less Than †:
3/16	3/16	3/16	3/16	66	79 1/4	32 5/8	34 1/4	30	31 3/4	3/16
1/4	3/16	1/4	1/4	66	79 1/4	32 1/2	34 1/2	30	32	1/4
5/16	3/16	5/16	5/16	65 3/4	78 3/4	32 3/8	34 1/2	30	32 1/4	5/16
3/8	3/16	3/8	3/8	65 3/4	78 3/4	32 1/4	34 3/4	30	32 1/2	5/16
7/16	3/16	7/16	7/16	65 1/4	78	32 1/8	34 3/4	30	32 3/4	5/16
1/2	3/16	1/2	1/2	65 1/4	78	32	35	30	33	5/16
9/16	3/16	9/16	9/16	65	77 1/2	31 7/8	35	30	33 1/4	5/16
5/8	1/4	5/8	5/8	64 3/4	77	31 3/4	35 1/4	30	33 1/2	5/16
11/16	1/4	11/16	11/16	64 1/2	76 3/4	31 5/8	35 1/4	30	33 3/4	5/16
3/4	1/4	3/4	3/4	64 1/2	76 3/4	31 1/2	35 1/2	30	34	5/16
13/16	5/16	13/16	3/4	64 1/4	76 1/4	31 3/8	35 1/2	30	34 1/4	5/16
7/8	5/16	7/8	7/8	64 1/4	76 1/4	31 1/4	35 3/4	30	34 1/2	5/16
15/16	5/16	15/16	7/8	64 1/4	76 1/4	31 1/8	35 3/4	30	34 3/4	7/16
1	3/8	1	1	64 3/4	76 3/4	31	36	30	35	7/16
1 1/16	3/8	1 1/16	1	64 3/4	76 3/4	30 7/8	36	30	35 1/4	7/16
1 1/8	7/16	1 1/8	1	65	77	30 3/4	36 1/4	30	35 1/2	1/2
1 3/16	7/16	1 3/16	1	65	77	30 5/8	36 1/4	30	35 3/4	9/16
1 1/4	7/16	1 1/4	1	65 1/4	77 1/4	30 1/2	36 1/2	30	36	9/16
1 5/16	1/2	1 5/16	1	65 1/4	77 1/4	30 3/8	36 1/2	30	36 1/4	5/8
1 3/8	1/2	1 3/8	1	65 1/2	77 1/2	30 1/4	36 3/4	30	36 1/2	5/8
1 7/16	9/16	1 7/16	1	65 1/2	77 1/2	30 1/8	36 3/4	30	36 3/4	11/16
1 1/2	9/16	1 1/2	1	65 3/4	77 3/4	30	37	30	37	3/4
1 9/16‡	9/16	1 9/16	1 1/8	65 3/4	77 3/4	29 7/8	37	30	37 1/4	3/4
1 5/8‡	5/8	1 5/8	1 1/8	66	78	29 3/4	37 1/4	30	37 1/2	13/16
1 11/16‡	5/8	1 11/16	1 1/8	66	78	29 5/8	37 1/4	30	37 3/4	7/8
1 3/4‡	11/16	1 3/4	1 1/8	66 1/4	78 1/4	29 1/2	38	30	38	1

Diameter of bolt circle D_B = 36 1/4 in.
Diameter of cover plate D_C = 38 3/4 in.

* If a shell plate thicker than required is used for the hydrostatic loading (Sect. 3.3, "Shell Design"), the excess shell-plate thickness, within a vertical distance both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate may be considered as reinforcement; and the thickness, T, of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits for reinforcement of shell openings specified in Sect. 3.3.

† The minimum neck thickness shall be the thickness of the shell plate or the allowable finished thickness of the bolting flange (see Table 3-1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Column (11). If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3.

‡ t greater than 1½ in. is applicable to Appendix G tanks only.

TABLE 3-5—36-In. Shell Manhole (See Fig. 3-6)

All dimensions are in inches.

(1) Thickness of Shell and Manhole Attachment Flange* t and T	(2) Size of Fillet: Weld A	(3) Size of Fillet: Weld B	(4) Approx. Radius R	(5) Attachment Flange: Length of Side L	(6) Attachment Flange: Width W	(7) Frame Using Constant-Diameter Ring Die: Inside Diameter of Manhole Frame ID_R	(8) Frame Using Constant-Diameter Ring Die: Max. Diameter of Hole in Shell D_{HR}	(9) Frame Using Constant-Diameter Plug Die: Inside Diameter of Manhole Frame ID_P	(10) Frame Using Constant-Diameter Plug Die: Max. Diameter of Hole in Shell D_{HP}	(11) Built-up Frame Min. Neck Thickness: Add Reinforcement if Neck Thickness Is Less Than †:
3/16	3/16	3/16	3/16	78	93 3/4	38 5/8	40 1/4	36	37 3/4	3/16
1/4	3/16	1/4	1/4	78	93 3/4	38 1/2	40 1/2	36	38	1/4
5/16	3/16	5/16	5/16	77 3/4	93 1/4	38 3/8	40 1/2	36	38 1/4	5/16
3/8	3/16	3/8	3/8	77 3/4	93 1/4	38 1/4	40 3/4	36	38 1/2	3/8
7/16	3/16	7/16	7/16	77 1/4	92 1/2	38 1/8	40 3/4	36	38 3/4	3/8
1/2	3/16	1/2	1/2	77 1/4	92 1/2	38	41	36	39	3/8
9/16	3/16	9/16	9/16	77	92	37 7/8	41	36	39 1/4	3/8
5/8	1/4	5/8	5/8	76 3/4	91 1/2	37 3/4	41 1/4	36	39 1/2	3/8
11/16	1/4	11/16	11/16	76 1/2	91 1/4	37 5/8	41 1/4	36	39 3/4	3/8
3/4	1/4	3/4	3/4	76 1/2	91	37 1/2	41 1/2	36	40	3/8
13/16	5/16	13/16	3/4	76 1/4	90 3/4	37 3/8	41 1/2	36	40 1/4	3/8
7/8	5/16	7/8	7/8	76 1/4	90 3/4	37 1/4	41 3/4	36	40 1/2	3/8
15/16	5/16	15/16	7/8	76 1/4	90 3/4	37 1/8	41 3/4	36	40 3/4	7/16
1	3/8	1	1	76 3/4	91 1/4	37	42	36	41	7/16
1 1/16	3/8	1 1/16	1	76 3/4	91 1/4	36 7/8	42	36	41 1/4	7/16
1 1/8	3/8	1 1/8	1	77	91 1/2	36 3/4	42 1/4	36	41 1/2	1/2
1 3/16	7/16	1 3/16	1	77	91 1/2	36 5/8	42 1/4	36	41 3/4	9/16
1 1/4	7/16	1 1/4	1	77 1/4	91 3/4	36 1/2	42 1/2	36	42	9/16
1 5/16	7/16	1 5/16	1	77 1/4	91 3/4	36 3/8	42 1/2	36	42 1/4	5/8
1 3/8	1/2	1 3/8	1	77 1/2	92	36 1/4	42 3/4	36	42 1/2	5/8
1 7/16	1/2	1 7/16	1	77 1/2	92	36 1/8	42 3/4	36	42 3/4	11/16
1 1/2	9/16	1 1/2	1	77 3/4	92 1/4	36	43	36	43	3/4
1 9/16‡	9/16	1 9/16	1 1/8	77 3/4	92 1/4	35 7/8	43	36	43 1/4	3/4
1 5/8‡	9/16	1 5/8	1 1/8	78	92 1/2	35 3/4	43 1/4	36	43 1/2	13/16
1 11/16‡	5/8	1 11/16	1 1/8	78	92 1/2	35 5/8	43 1/4	36	43 3/4	7/8
1 3/4‡	5/8	1 3/4	1 1/8	78 1/4	92 3/4	35 1/2	43 1/2	36	44	1

Diameter of bolt circle D_B = 42 1/4 in.
Diameter of cover plate D_C = 44 3/4 in.

* If a shell plate thicker than required is used for the hydrostatic loading (Sect. 3.3, "Shell Design"), the excess shell-plate thickness, within a vertical distance both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate may be considered as reinforcement; and the thickness, T, of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits for reinforcement of shell openings specified in Sect. 3.3.

† The minimum neck thickness shall be the thickness of the shell plate or the allowable finished thickness of the bolting flange (see Table 3-1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Column (11). If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3.

‡ t greater than 1 1/2 in. is applicable to Appendix G tanks only.

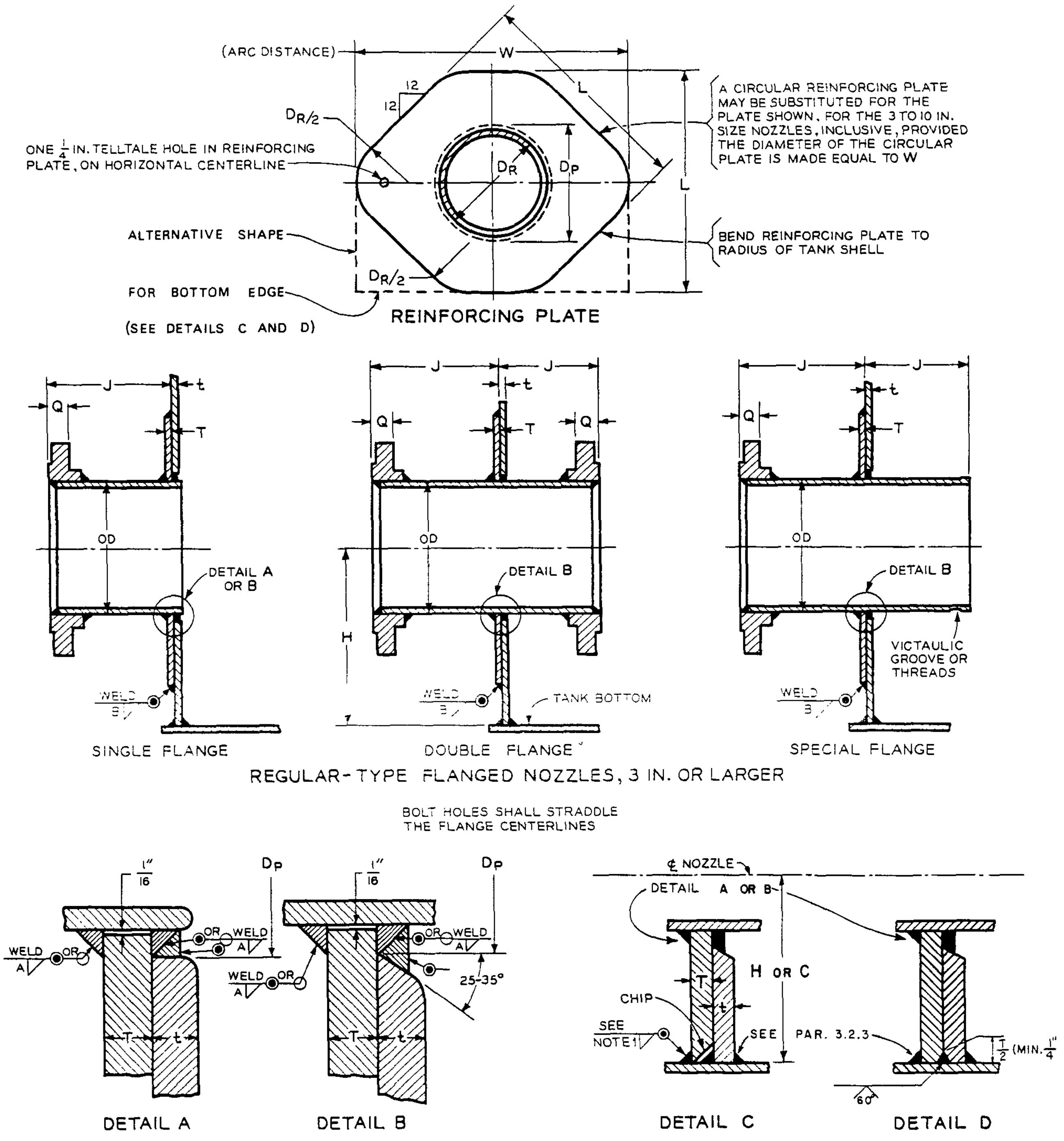
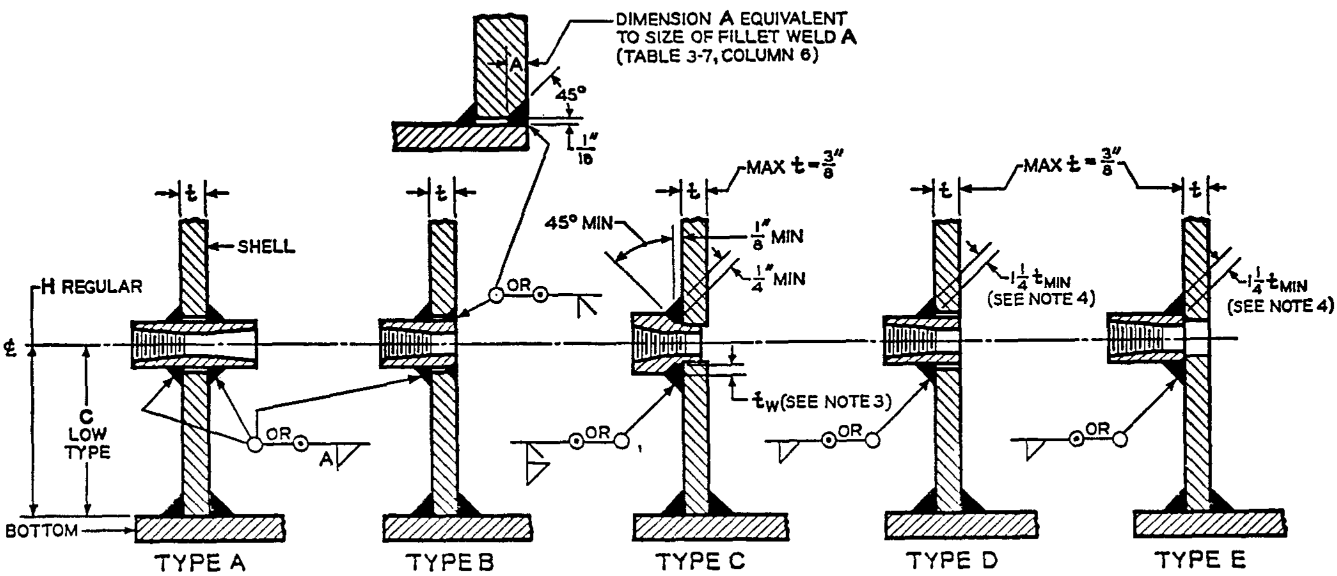


FIG. 3-7—Shell Nozzles (See Tables 3-6, 3-7, and 3-8).



SCREWED-TYPE SHELL NOZZLES, ¾ IN. TO 2 IN., INCLUSIVE

Notes:

1. See Par. 3.3.7(f) regarding size of welds.
2. See Par. 3.6.11, "Threaded Connections," regarding couplings used in shell nozzles.
3. t_w shall be not less than the thickness of Schedule 160 pipe.
4. $t_{min.}$ shall be the smaller of ¾ in. or the thickness of either part joined by the fillet weld.
5. 3-in. nozzle requires reinforcement.
6. Welding bevel details may vary from those shown if agreed to by the purchaser.

Fig. 3-7—Continued

TABLE 3-6—Shell Nozzles (See Fig. 3-7)

All dimensions are in inches.

(1)	(2)	(3)	(4)	(5)	(6)	(7)‡	(8)‡	(9)‡
							Min. Distance from Bottom of Tank to Center of Nozzle	
Size of Nozzle	OD of Pipe	Min. Thickness of Flanged Nozzle Pipe Wall* n	Diameter of Hole in Reinforcing Plate D_R	Length of Side of Reinforcing Plate L†	Width of Reinforcing Plate W	Min. Distance from Shell to Flange Face J	Regular Type H	Low Type C
				Flanged Fittings				
48	48		48⅛	96¾	117	16	52	48⅜
46	46		46⅛	92¾	112	16	50	46⅜
44	44		44⅛	88¾	107¼	15	48	44⅜
42	42		42⅛	84¾	102½	15	46	42⅜
40	40		40⅛	80¾	97¾	15	44	40⅜
38	38	See Table 3-7, Col. (2)	38⅛	76¾	92¾	14	42	38⅜
36	36		36⅛	72¾	88	14	40	36⅜
34	34		34⅛	68¾	83¼	13	38	34⅜
32	32		32⅛	64¾	78½	13	36	32⅜
30	30		30⅛	60¾	73½	12	34	30⅜
28	28		28⅛	56¾	68¾	12	32	28⅜
26	26		26⅛	52¾	64	12	30	26⅜
24	24	0.50	24⅛	49½	60	12	28	24¾
22	22	0.50	22⅛	45½	55¼	11	26	22¾
20	20	0.50	20⅛	41½	50½	11	24	20¾
18	18	0.50	18⅛	37½	45¾	10	22	18¾
16	16	0.50	16⅛	33½	40¾	10	20	16¾
14	14	0.50	14⅛	29½	36	10	18	14¾
12	12¾	0.50	12⅞	27	33	9	17	13½
10	10¾	0.50	10⅞	23	28¼	9	15	11½
8	8⅝	0.50	8¾	19	23¼	8	13	9½
6	6⅝	0.432	6¾	15¾	19½	8	11	7⅞
4	4½	0.337	4⅝	12	15¼	7	9	6
3	3½	0.300	3⅝	10½	13½	7	8	5¼
2§	2⅜	0.218	2½	...	...	6	7	3½
1½§	1.90	0.200	2	...	...	6	6	3
				Screwed Fittings				
3‖	4.00	Coupling	4⅛	11¼	14¼	...	9	5⅝
2§	2.875	Coupling	3	...	...	...	7	3
1½§	2.200	Coupling	2⅜	...	...	...	6	3
1§	1.576	Coupling	1$\frac{11}{16}$	...	...	...	5	3
¾§	1.313	Coupling	1$\frac{7}{16}$	...	...	...	4	3

* Extra-strong pipe—for sizes up to 12 in., inclusive, refer to API Standard 5L; for sizes over 12 in. to 24 in., inclusive, refer to the latest edition of ASTM A 53, A 134, A 135, or A 139. Pipe made from formed plate electrically butt welded may be substituted for any of the abovementioned pipe sections.

† Width of shell plate shall be sufficient to contain reinforcing plate and to provide clearance from girth joint of shell course.

‡ Unless specified otherwise by purchaser, nozzle shall be located at minimum distance.

§ Flanged and screwed nozzles in 2-in. pipe size or smaller do not require reinforcing plates. D_R will be the diameter of the hole in the shell plate and weld A will be as given in Column (6), Table 3-7. Reinforcing plates may be used if desired.

Screwed nozzle in the 3-in. pipe size requires reinforcement.

TABLE 3-7—Shell Nozzles: Pipe, Plate, and Welding Schedules (See Fig. 3-7)

All dimensions are in inches.

(1) Thickness of Shell and Reinforcing Plate* *t* and *T*	(2) Min. Pipe Wall Thickness of 48-in., 46-in., 44-in., 42-in., 40-in., 38-in., 36-in., 34-in., 32-in., 30-in., 28-in., and 26-in. Flanged Nozzles† *n*	(3) Max. Diameter of Hole in Shell Plate (D_p) Equals OD of Pipe Plus the Following Values	(4) Size of Fillet Weld *B*	(5) Size of Fillet Weld *A* for Nozzles Larger than 2 in.	(6) Size of Fillet Weld *A* for 2-in., 1½-in., 1-in., and ¾-in. Nozzles
3/16	1/2	5/8	3/16	1/4	1/4
1/4	1/2	5/8	1/4	1/4	1/4
5/16	1/2	5/8	5/16	1/4	1/4
3/8	1/2	5/8	3/8	1/4	1/4
7/16	1/2	5/8	7/16	1/4	1/4
1/2	1/2	5/8	1/2	1/4	5/16
9/16	1/2	5/8	9/16	1/4	5/16
5/8	1/2	3/4	5/8	5/16	5/16
11/16	1/2	3/4	11/16	5/16	5/16
3/4	1/2	3/4	3/4	5/16	5/16
13/16	1/2	15/16	13/16	3/8	5/16
7/8	1/2	15/16	7/8	3/8	5/16
15/16	1/2	15/16	15/16	3/8	5/16
1	1/2	1 1/16	1	7/16	5/16
1 1/16	9/16	1 1/16	1 1/16	7/16	5/16
1 1/8	9/16	1 1/16	1 1/8	7/16	5/16
1 3/16	5/8	1 1/4	1 3/16	1/2	5/16
1 1/4	5/8	1 1/4	1 1/4	1/2	5/16
1 5/16	11/16	1 1/4	1 5/16	1/2	5/16
1 3/8	11/16	1 3/8	1 3/8	9/16	5/16
1 7/16	3/4	1 3/8	1 7/16	9/16	5/16
1 1/2	3/4	1 3/8	1 1/2	9/16	5/16
1 9/16‡	13/16	1 1/2	1 9/16	9/16	5/16
1 5/8‡	13/16	1 1/2	1 5/8	5/8	5/16
1 11/16‡	7/8	1 1/2	1 11/16	5/8	5/16
1 3/4‡	7/8	1 1/2	1 3/4	5/8	5/16

* If a shell plate thicker than required is used for the hydrostatic loading (Sect. 3.3, "Shell Design"), the excess shell-plate thickness, within a vertical distance both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate may be considered as reinforcement; and the thickness, *T*, of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits for reinforcement of shell openings specified in Sect. 3.3.

† Refer to API Standard 5LX; or to the latest edition of ASTM A 134, A 135, or A 139. Pipe made from formed plate electrically butt welded may be submitted for any of the abovementioned pipe sections.

‡ *t* greater than 1½ in. is applicable to Appendix G tanks only.

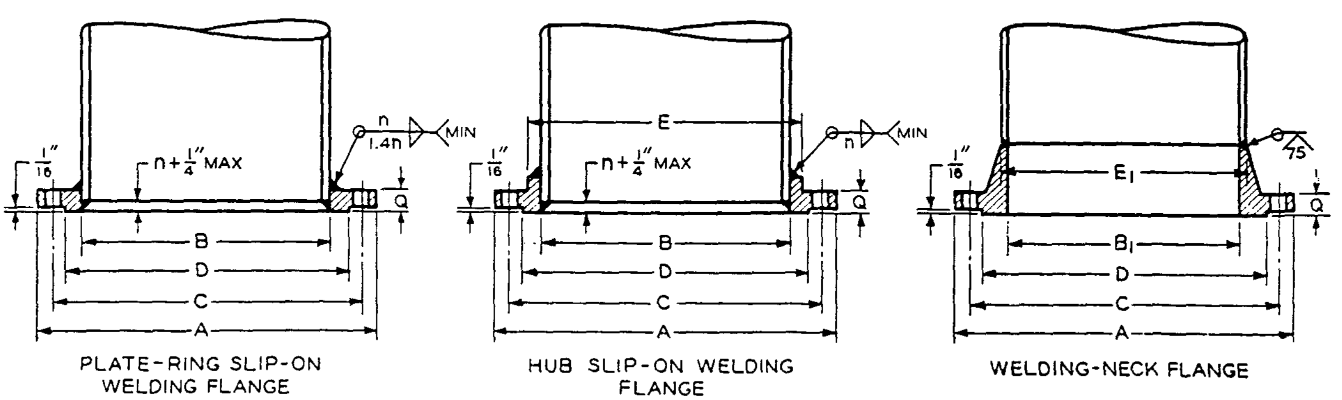
TABLE 3-8—Shell Nozzle Flanges (See Fig. 3-8)*

All dimensions are in inches.

(1) Size of Nozzle	(2) Min. Thickness of Flange Q	(3) OD of Flange A	(4) Diameter of Raised Face D	(5) Diameter of Bolt Circle C	(6) Number of Holes	(7) Diameter of Holes	(8) Diameter of Bolts	(9) Diameter of Bore: Slip-on Type, Add to OD of Pipe B	(10) Diameter of Bore: Welding-Neck Type B_1	(11) Min. Diameter of Hub at Point of Weld: Slip-on Type E	(12) Min. Diameter of Hub at Point of Weld: Welding-Neck Type E_1
48	2¾	59½	53½	56	44	1⅝	1½	0.25	Same as inside diameter of pipe	Same as outside diameter of pipe plus 2n	Same as outside diameter of pipe
46	2 11/16	57½	51	53¾	40	1⅝	1½	0.25			
44	2⅝	55¼	49	51¾	40	1⅝	1½	0.25			
42	2⅝	53	47	49½	36	1⅝	1½	0.25			
40	2½	50¾	44¼	47¼	36	1⅝	1½	0.25			
38	2⅜	48¾	42¼	45¼	32	1⅝	1½	0.25			
36	2⅜	46	40¼	42¾	32	1⅝	1½	0.25			
34	2 5/16	43¾	37¾	40½	32	1⅝	1½	0.25			
32	2¼	41¾	35¾	38½	28	1⅝	1½	0.25			
30	2⅛	38¾	33¾	36	28	1⅜	1¼	0.25			
28	2 1/16	36½	31¼	34	28	1⅜	1¼	0.25			
26	2	34¼	29¼	31¾	24	1⅜	1¼	0.25			
24	1⅞	32	27¼	29½	20	1⅜	1¼	0.19			
22	1 13/16	29½	25¼	27¼	20	1⅜	1¼	0.19			
20	1 11/16	27½	23	25	20	1¼	1⅛	0.19			
18	1 9/16	25	21	22¾	16	1¼	1⅛	0.19			
16	1 7/16	23½	18½	21¼	16	1⅛	1	0.19			
14	1⅜	21	16¼	18¾	12	1⅛	1	0.19			
12	1¼	19	15	17	12	1	⅞	0.13			
10	1 3/16	16	12¾	14¼	12	1	⅞	0.13			
8	1⅛	13½	10⅝	11¾	8	⅞	¾	0.10			
6	1	11	8½	9½	8	⅞	¾	0.10			
4	15/16	9	6 3/16	7½	8	¾	⅝	0.06			
3	15/16	7½	5	6	4	¾	⅝	0.06			
2	¾	6	3⅝	4¾	4	¾	⅝	0.07			
1½	11/16	5	2⅞	3⅞	4	⅝	½	0.07			

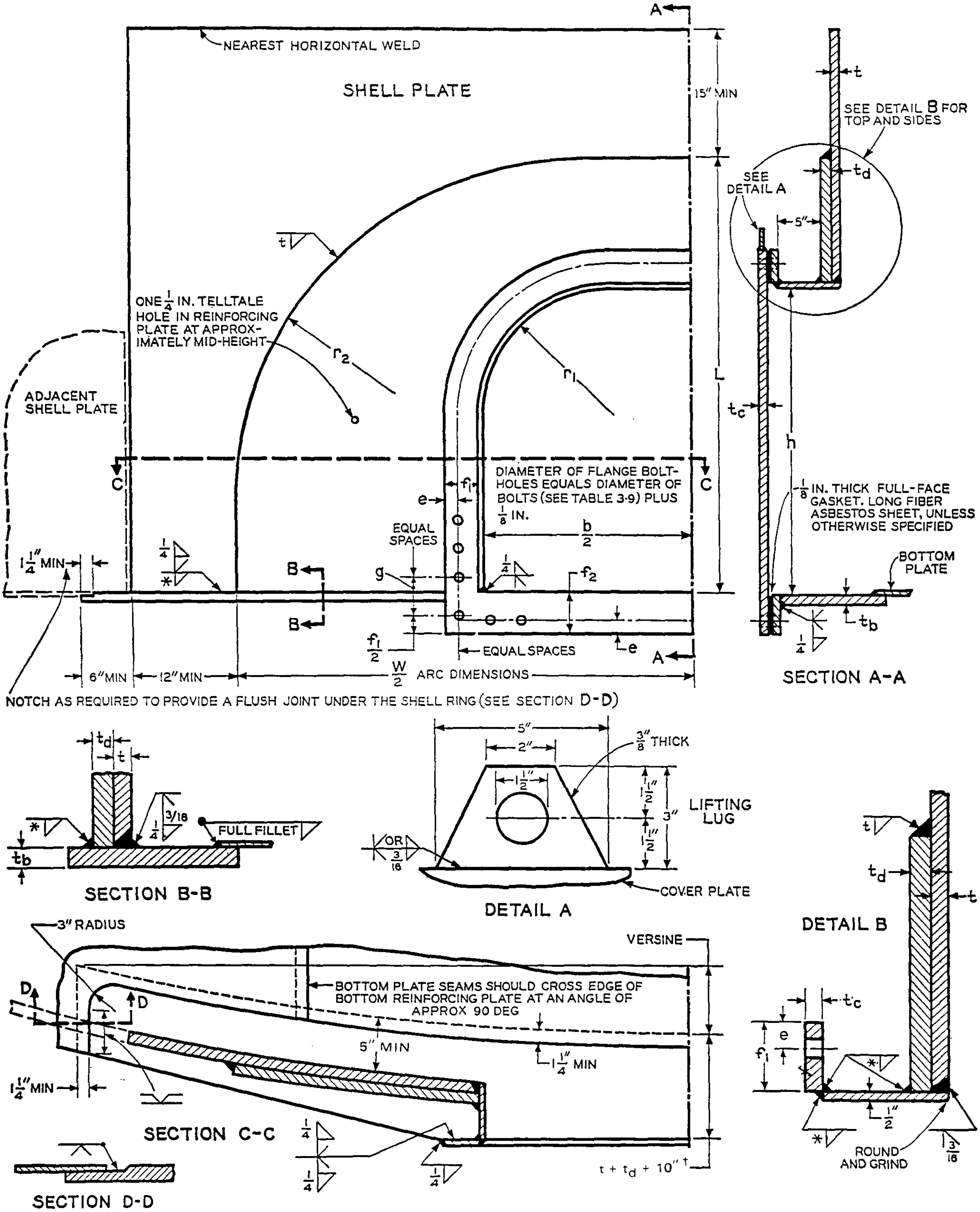
* The facing dimensions for slip-on and welding-neck flanges in sizes 1½ in. to 20 in., inclusive, and size 24 in. are identical with those specified in ANSI B16.5 for 150-lb steel flanges. The facing dimensions for flanges in sizes 30 in., 36 in., 42 in. and 48 in. are in agreement with ANSI B16.1 for 125-lb cast iron flanges. The dimensions for flanges in sizes 22 in., 26 in., 28 in., 32 in., 34 in., 38 in., 40 in., 44 in., and 46 in. (which are not included in the ANSI standards) conform to the manufacturer's standards.

Flanges conforming to API Standard 605 in sizes over 24 in. are an acceptable alternate subject to purchaser's approval. Particular attention should be given to ensure that mating flanges of appurtenances are compatible.



Note: The *n* designated for weld thickness is the minimum pipe wall thickness (see Tables 3-6 and 3-7).

FIG. 3-8—Shell Nozzle Flanges (See Table 3-8).



* Thickness of thinner plate joined, with a maximum of ½ in.

† When an annular plate is provided, the reinforcing plate shall become a segment of the annular plate and shall be the same width as the annular plate.

FIG. 3-9—Flush-Type Cleanout Fittings (See Tables 3-9, 3-10, and 3-11).

R

TABLE 3-9—Flush-Type Cleanout Fittings (See Fig. 3-9)

All dimensions are in inches.

(1) Height of Opening h	(2) Width of Opening b	(3) Arc Width of Shell Reinforcing Plate W	(4)* Upper Corner Radius of Opening r_1	(5) Upper Corner Radius of Shell Reinforcing Plate r_2	(6) Edge Distance of Bolts e	(7) Flange Width (Except at Bottom) f_1	(8) Bottom Flange Width f_2	(9) Special Bolt Spacing† g	(10) Number of Bolts	(11) Diameter of Bolts
8	16	46	3¼	14	1¼	3½	3½	3¼	22	¾
24	24	72	8	29	1¼	3½	3¾	3½	36	¾
36	48	106	15	41	1½	4	4¾	4¼	46	1
48	48	125	16	51½	1½	4	5	4½	52	1

* By agreement between purchaser and manufacturer, the upper corner radii of Table D-2 may be substituted for the radii listed in Table 3-9.

† Spacing at lower corners of cleanout fitting flange.

TABLE 3-10—Thicknesses of Cover Plate, Bolting Flange, and Bottom Reinforcing Plate for Flush-Type Cleanout Fittings (See Fig. 3-9)

All dimensions are in inches unless otherwise stated.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Size of Opening (Height, h, Times Width, b)							
		8 by 16		24 by 24		36 by 48		48 by 48	
Max. Tank Height (Feet) H	Equivalent Pressure* (Pounds per Square Inch)	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b
20	8.7	3/8	1/2	3/8	1/2	5/8	13/16	5/8	7/8
34	14.7	3/8	1/2	1/2	1/2	3/4	1	13/16	1 1/8
41	17.8	3/8	1/2	1/2	9/16	7/8	1 1/8	7/8	1 3/16
53	23	3/8	1/2	9/16	5/8	15/16	1 1/4	1	1 5/16
60	26	7/16	1/2	5/8	11/16	1	1 5/16	1 1/8	1 3/8

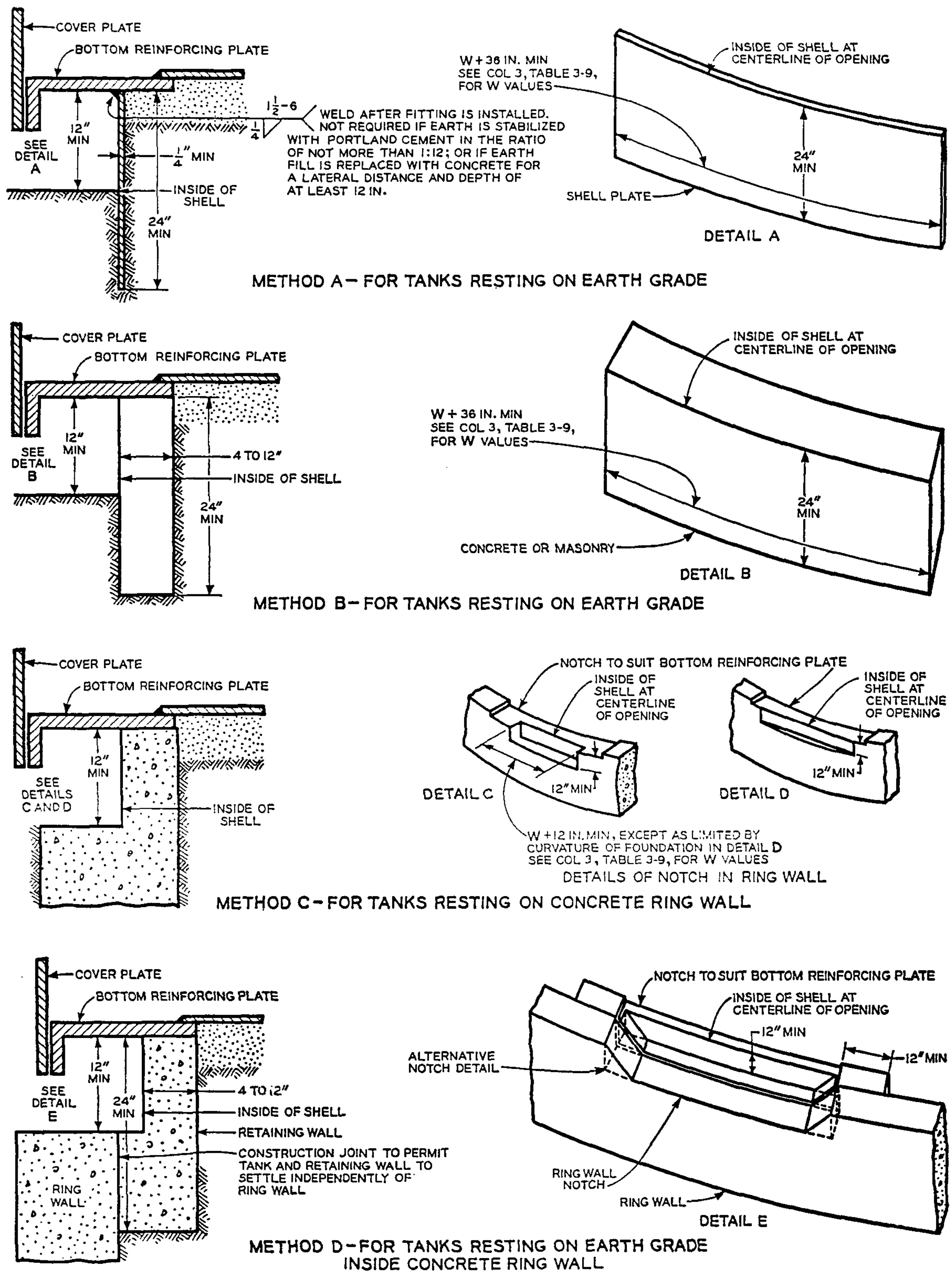
* Equivalent pressure is based on water loading.

TABLE 3-11—Thickness and Height of Shell Reinforcing Plate for Cleanout Fittings (See Fig. 3-9)

All dimensions are in inches unless otherwise stated.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Size of Opening (Height, *h*, Times Width, *b*)							
		8 by 16		24 by 24		36 by 48		48 by 48	
Thickness of Lowest Shell Course t	Max. Tank Height (Feet) H	Thickness of Shell Reinforcing Plate t_d	Height of Shell Reinforcing Plate L	Thickness of Shell Reinforcing Plate t_d	Height of Shell Reinforcing Plate L	Thickness of Shell Reinforcing Plate t_d	Height of Shell Reinforcing Plate L	Thickness of Shell Reinforcing Plate t_d	Height of Shell Reinforcing Plate L
3/16	70	1/4	14	5/16	34 1/4	5/16	51 3/4	5/16	68 1/4
1/4	70	5/16	14	3/8	35 1/4	3/8	53	3/8	70 1/2
5/16	70	3/8	14	7/16	35 3/4	7/16	54	7/16	72
3/8	31	7/16	14	1/2	35	9/16	52 1/2	9/16	70 1/2
3/8	70	7/16	14	1/2	36	9/16	53	9/16	70 1/2
7/16	33	9/16	14	5/8	33 3/4	5/8	53	5/8	71 1/2
7/16	70	9/16	14	5/8	35	5/8	53 1/2	5/8	71 1/2
1/2	33	5/8	14	11/16	33 1/2	11/16	53	11/16	72
1/2	70	5/8	14	11/16	35	11/16	54	3/4	70 1/2
9/16	29	11/16	14	3/4	33 1/4	11/16	54	3/4	72
9/16	59	11/16	14	3/4	34 1/2	3/4	54	13/16	71 1/4
5/8	32	3/4	14	7/8	33 1/4	3/4	54	7/8	70 3/4
5/8	58	3/4	14	7/8	33 1/2	13/16	54	7/8	71 3/4
5/8	70	3/4	14	7/8	33 3/4	7/8	53	7/8	72
11/16	36	13/16	14	13/16	33 1/4	13/16	54	15/16	71 1/4
11/16	60	13/16	14	15/16	33 1/4	7/8	54	15/16	72
3/4	41	7/8	14	1	33 1/4	7/8	54	1	71 1/2
3/4	65	7/8	14	1	33 1/4	15/16	54	1 1/16	71
13/16	46	1	14	1 1/8	33 1/4	15/16	54	1 1/8	70 1/2
13/16	70	1	14	1 1/8	33 1/4	1	54	1 1/8	71 1/4
7/8	48	1 1/16	14	1 3/16	33 1/4	1 1/16	52 3/4	1 3/16	70 1/2
7/8	70	1 1/16	14	1 3/16	33 1/4	1 1/16	53 3/4	1 3/16	71 1/4
15/16	48	1 1/8	14	1 1/4	33 1/4	1 1/8	52 1/4	1 1/4	70 1/2
15/16	70	1 1/8	14	1 1/4	33 1/4	1 1/8	53 1/2	1 1/4	71 1/4
1	48	1 3/16	14	1 3/8	33 1/4	1 3/16	51 3/4	1 3/8	69 1/4
1	70	1 3/16	14	1 3/8	33 1/4	1 3/16	53	1 3/8	70 1/4
1 1/16	48	1 1/4	14	1 7/16	33 1/4	1 1/4	51 3/4	1 7/16	69
1 1/16	70	1 1/4	14	1 7/16	33 1/4	1 1/4	52 1/2	1 7/16	70 1/4
1 1/8	48	1 5/16	14	1 1/2	33 1/4	1 5/16	51 3/4	1 1/2	68 3/4
1 1/8	70	1 5/16	14	1 1/2	33 1/4	1 5/16	52	1 1/2	70
1 3/16	48	1 7/16	14	1 5/8	33 1/4	1 3/8	51 3/4	1 5/8	67 3/4
1 3/16	70	1 7/16	14	1 5/8	33 1/4	1 3/8	51 3/4	1 5/8	69
1 1/4	70	1 1/2	14	1 11/16	33 1/4	1 7/16	51 3/4	1 11/16	68 3/4
1 5/16	70	1 9/16	14	1 3/4	33 1/4	1 9/16	51 3/4	1 3/4	68 1/2
1 3/8	70	1 5/8	14	1 13/16	33 1/4	1 5/8	51 3/4	1 13/16	68 1/4
1 7/16	70	1 11/16	14	1 15/16	33 1/4	1 11/16	51 3/4	1 15/16	67 1/4
1 1/2	70	1 3/4	14	2	33 1/4	1 3/4	51 3/4	2	67

Note: Dimensions t_d and L may be varied within the limits defined in Par. 3.3.8.



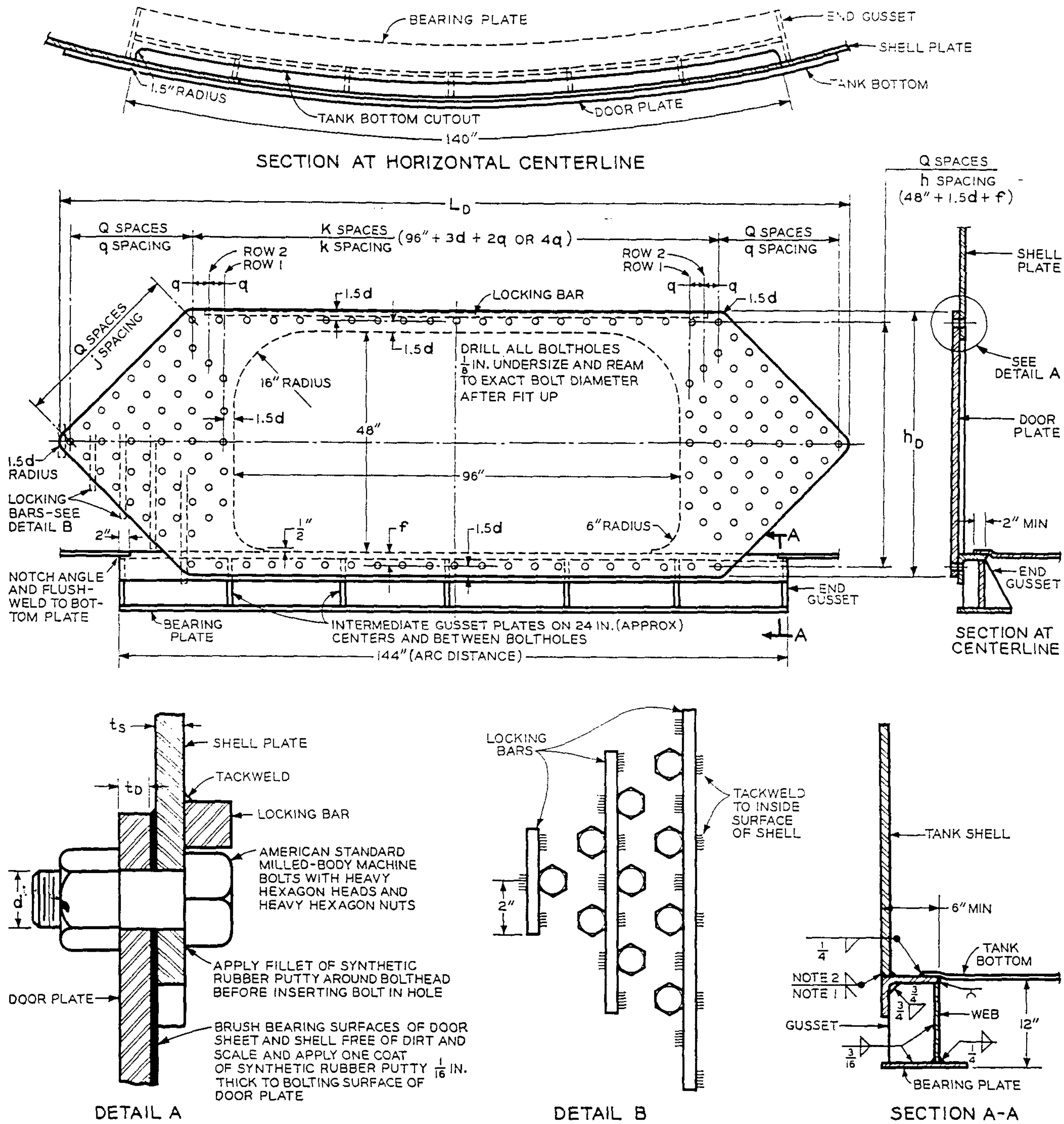
Note to Method A—Before attachment of bottom plate to bottom reinforcing plate:

1. Place sand cushion flush with top of bottom reinforcing plate.
2. Compact earth fill and sand cushion thoroughly.

Note to Methods B, C, and D—Before attachment of bottom plate to bottom reinforcing plate:

1. Place sand cushion flush with top of bottom reinforcing plate.
2. Compact earth fill and sand cushion thoroughly.
3. Grout under reinforcing plate if needed to insure firm bearing.

FIG. 3-10—Flush-Type Cleanout Fitting Supports (See Par. 3.6.4).



Notes:

1. This weld should be the same size as specified for the fillet weld attaching the shell to the tank bottom. After welding, grind smooth to clear the door plate.

2. This weld should be the same size as specified for attachment of the shell to the tank bottom.

FIG. 3-11—Flush-Type Bolted Door Sheet (See Tables 3-12 and D-5).

TABLE 3-12—Flush-Type Bolted Door Sheets (See Fig. 3-11)

All dimensions are in inches.

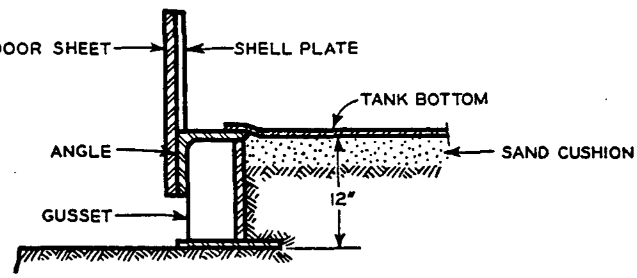
(1) Thickness of Shell t_S	(2) Q	(3) q	(4) h	(5)	(6) K	(7) k	(8) t_D	(9) h_D	(10)	(11) L_D	(12) Number of Bolts: Row 1	(13) Number of Bolts: Row 2	(14) Number of Bolts: Total
1/4	7	1 15/16	7.375	4.165	36	2.837	7/16	53 7/8	2 1/2	131 1/2	..	7	156
5/16	8	1 15/16	6.453	3.766	30	3.275	7/16	53 7/8	2 1/2	131 1/2	..	..	146
3/8	8	1 15/16	6.453	3.766	30	3.404	7/16	53 7/8	2 1/2	139 1/4	3	6	164
7/16	8	2 1/4	6.477	3.945	24	4.297	1/2	54 7/16	2 1/2	141 3/4	..	2	138
1/2	8	2 1/4	6.477	3.945	22	4.892	9/16	54 7/16	2 1/2	146 1/4	3	6	148
9/16	8	2 7/16	6.500	4.063	20	5.194	5/8	55	2 1/2	145 7/8	..	2	130
5/8	8	2 7/16	6.500	4.063	20	5.194	11/16	55	2 1/2	145 7/8	..	6	138
11/16	8	2 7/8	6.586	4.371	20	4.969	3/4	56 1/16	3	148 3/4	..	..	126
3/4	8	2 7/8	6.586	4.371	20	5.256	7/8	56 1/16	3	154 1/2	..	4	134
13/16	8	3 1/16	6.609	4.504	20	4.988	15/16	56 5/8	3	152 1/2	..	..	126
7/8	8	3 1/16	6.609	4.504	20	5.294	1	56 5/8	3	158 5/8	..	2	130
1	8	3 1/16	6.609	4.504	20	5.600	1 1/8	56 5/8	3	164 3/4	3	6	144
1 1/8	8	3 1/4	6.633	4.645	20	5.383	1 5/16	57 3/16	3	162 3/4	..	6	138
1 1/4	8	3 1/4	6.633	4.645	20	5.656	1 7/16	57 3/16	3	169 1/4	5	6	148
1 3/8	8	3 7/16	6.656	4.785	20	5.713	1 5/8	57 3/4	3	173 3/4	3	6	144
1 1/2	8	3 7/16	6.656	4.785	20	5.713	1 3/4	57 3/4	3	173 3/4	5	6	148

TABLE 3-12—Continued

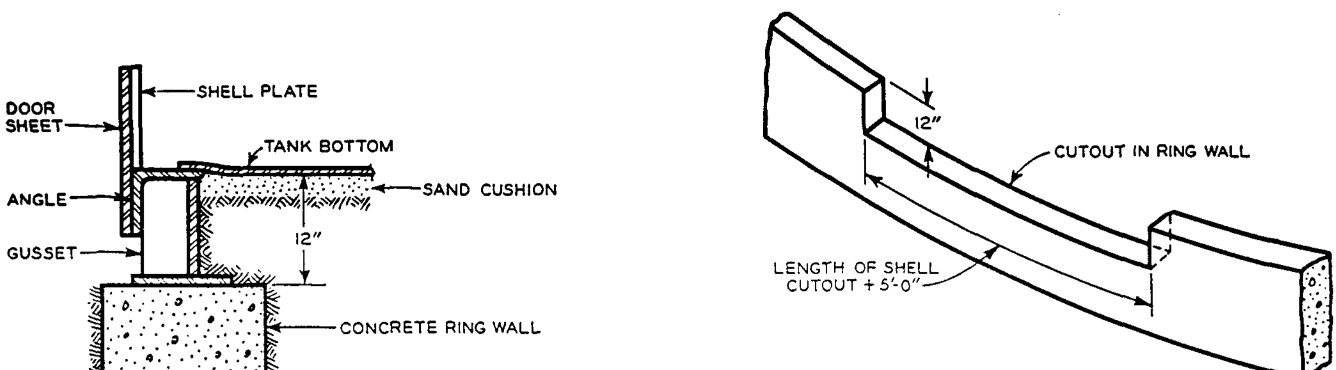
(15) Diameter of Bolt d	(16) Length of Bolt	(17) Length of Bolt Thread	(18) Square Locking Bar	(19) Angle	(20) Web	(21) Intermediate Gusset	(22) End Gusset	(23) Bearing Plate
3/4	2	1 1/8	5/8	6 by 4 by 3/8	1/4 by 11 5/8	1/4 by 5 by 11 5/8	1/4 by 8 by 11 5/8	1/4 by 9
3/4	2	1 1/16	5/8	6 by 4 by 3/8	1/4 by 11 5/8	1/4 by 5 by 11 5/8	1/4 by 8 by 11 5/8	1/4 by 9
3/4	2	1	5/8	6 by 4 by 3/8	1/4 by 11 5/8	1/4 by 5 by 11 5/8	1/4 by 8 by 11 5/8	1/4 by 9
7/8	2 1/4	1 1/8	3/4	6 by 4 by 1/2	3/8 by 11 3/8	3/8 by 5 by 11 3/8	3/8 by 8 by 11 3/8	3/8 by 9
7/8	2 1/2	1 1/4	3/4	6 by 4 by 1/2	3/8 by 11 3/8	3/8 by 5 by 11 3/8	3/8 by 8 by 11 3/8	3/8 by 9
1	2 3/4	1 3/8	3/4	6 by 4 by 5/8	3/8 by 11 1/4	3/8 by 5 by 11 1/4	3/8 by 8 by 11 1/4	3/8 by 9
1	2 1/2	1 1/4	3/4	6 by 4 by 5/8	3/8 by 11 1/4	3/8 by 5 by 11 1/4	3/8 by 8 by 11 1/4	3/8 by 9
1 1/8	2 3/4	1 3/8	1	6 by 4 by 3/4	3/8 by 11 1/8	3/8 by 5 by 11 1/8	3/8 by 8 by 11 1/8	3/8 by 9
1 1/8	3	1 1/2	1	6 by 4 by 3/4	3/8 by 11 1/8	3/8 by 5 by 11 1/8	3/8 by 8 by 11 1/8	3/8 by 9
1 1/4	3 1/4	1 5/8	1	6 by 6 by 7/8	1/2 by 10 7/8	1/2 by 4 1/2 by 10 7/8	1/2 by 8 by 10 7/8	1/2 by 9
1 1/4	3 1/4	1 1/2	1	8 by 6 by 7/8	1/2 by 10 7/8	1/2 by 4 1/2 by 10 7/8	1/2 by 8 by 10 7/8	1/2 by 12
1 1/4	3 1/2	1 3/8	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 3/8	3 3/4	1 1/2	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 3/8	4 1/4*	1 11/16	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 1/2	4 1/2*	1 11/16	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 1/2	5*	1 7/8	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12

* Special length bolts shall be furnished for bolting the bottom of the door sheet to the supporting truss.

Note: Use American National Standard washers on both sides of plate for shell thickness of 5/8 in. or less.



METHOD A – FOR TANKS RESTING ON AN EARTH GRADE, WITH OR WITHOUT A RETAINING WALL



METHOD B – FOR TANKS RESTING ON A CONCRETE RING WALL

Notes:

Before attachment of bottom plate to angle:

1. **Place sand cushion flush with top of angle.**
2. **Compact earth fill and sand cushion thoroughly.**

FIG. 3-12—Flush-Type Bolted Door Sheet Supports.

TABLE 3-13—Raised-Type Bolted Door Sheets (See Fig. 3-13)

All dimensions are in inches.

(1) Thickness of Shell t_S	(2) Q	(3) q	(4) h	(5)	(6) K	(7) k	(8) t_D	(9) h_D	(10) L_D	(11) Number of Bolts: Row 1	(12) Row 2	(13) Total	(14) Diameter of Bolt d	(15) Length of Bolt	(16) Length of Bolt Thread	(17) Square Locking Bar
1/4	7	1 15/16	7.179	4.080	36	2.837	7/16	52 1/2	131 1/2	..	5	152	3/4	2	1 1/8	5/8
5/16	7	1 15/16	7.179	4.080	30	3.404	7/16	52 1/2	131 1/2	..	7	144	3/4	2	1 1/16	5/8
3/8	8	1 15/16	6.281	3.691	30	3.404	7/16	52 1/2	135 3/8	..	8	164	3/4	2	1	5/8
7/16	8	2 1/4	6.328	3.883	24	4.109	1/2	53 1/4	137 1/4	..	..	136	7/8	2 1/4	1 1/8	3/4
1/2	8	2 1/4	6.328	3.883	22	4.688	9/16	53 1/4	141 3/4	..	6	144	7/8	2 1/2	1 1/4	3/4
9/16	8	2 7/16	6.375	4.012	20	4.950	5/8	54	141	..	..	128	1	2 3/4	1 3/8	3/4
5/8	8	2 7/16	6.375	4.012	20	5.194	3/4	54	145 7/8	..	4	136	1	2 1/2	1 1/4	3/4
11/16	8	2 7/8	6.422	4.309	20	4.969	13/16	54 3/4	148 3/4	..	..	128	1 1/8	2 3/4	1 3/8	1
3/4	8	2 7/8	6.422	4.309	20	5.256	7/8	54 3/4	154 1/2	..	2	132	1 1/8	3	1 1/2	1
13/16	8	3 1/16	6.469	4.453	20	4.988	15/16	55 1/2	152 1/2	..	..	128	1 1/4	3 1/4	1 5/8	1
7/8	8	3 1/16	6.469	4.453	20	4.988	1	55 1/2	152 1/2	..	..	128	1 1/4	3 1/4	1 1/2	1
1	8	3 1/16	6.469	4.453	20	5.294	1 3/16	55 1/2	158 5/8	..	6	140	1 1/4	3 1/2	1 7/16	1
1 1/8	8	3 1/16	6.469	4.453	20	5.600	1 3/8	55 1/2	164 3/4	5	8	154	1 1/4	3 3/4	1 3/8	1
1 1/4	8	3 1/4	6.516	4.602	20	5.656	1 1/2	56 1/4	169 1/4	3	6	146	1 3/8	4 1/4	1 5/8	1
1 3/8	8	3 1/4	6.516	4.602	20	5.656	1 11/16	56 1/4	169 1/4	7	8	158	1 3/8	4 1/2	1 9/16	1
1 1/2	8	3 7/16	6.563	4.754	20	5.712	1 13/16	57	173 3/4	5	6	150	1 1/2	5	1 13/16	1

Note: **Use American National Standard washers on both sides of plate for shell thickness of 5/8 in. or less.**

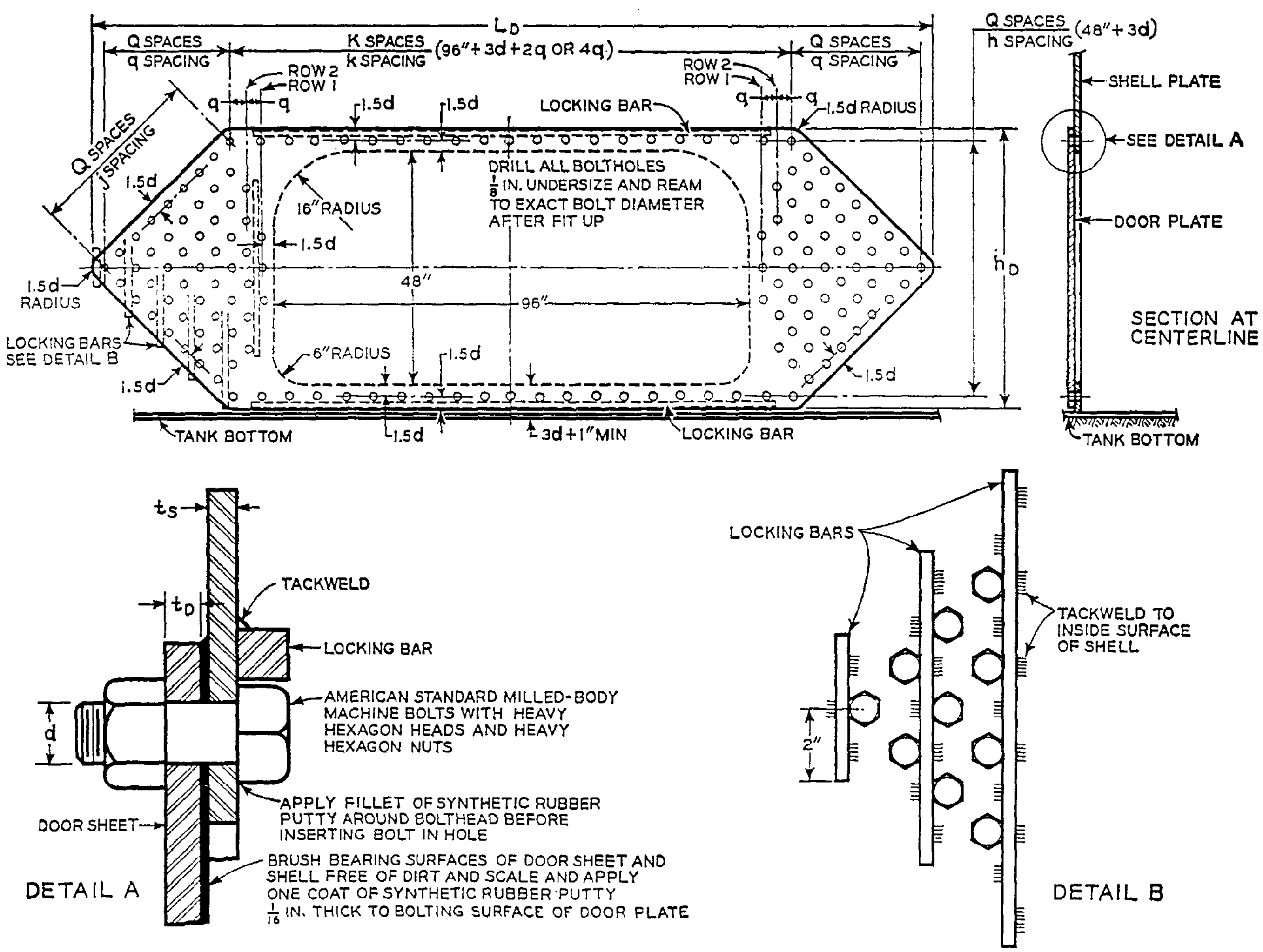


FIG. 3-13—Raised-Type Bolted Door Sheet (See Tables 3-13 and D-6).

TABLE 3-14—Roof Manholes (See Fig. 3-14)

All dimensions are in inches.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Size of Manhole	Diameter of Neck *ID*	Diameter of Cover Plate D_C	Diameter of Bolt Circle D_B	Number of Bolts	Diameter of Gasket *ID*	Diameter of Gasket *OD*	Diameter of Hole in Roof Plate or Reinforcing Plate D_P	OD of Reinforcing Plate D_R
20	20	26	23½	16	20	26	20⅝	42
24	24	30	27½	20	24	30	24⅝	46

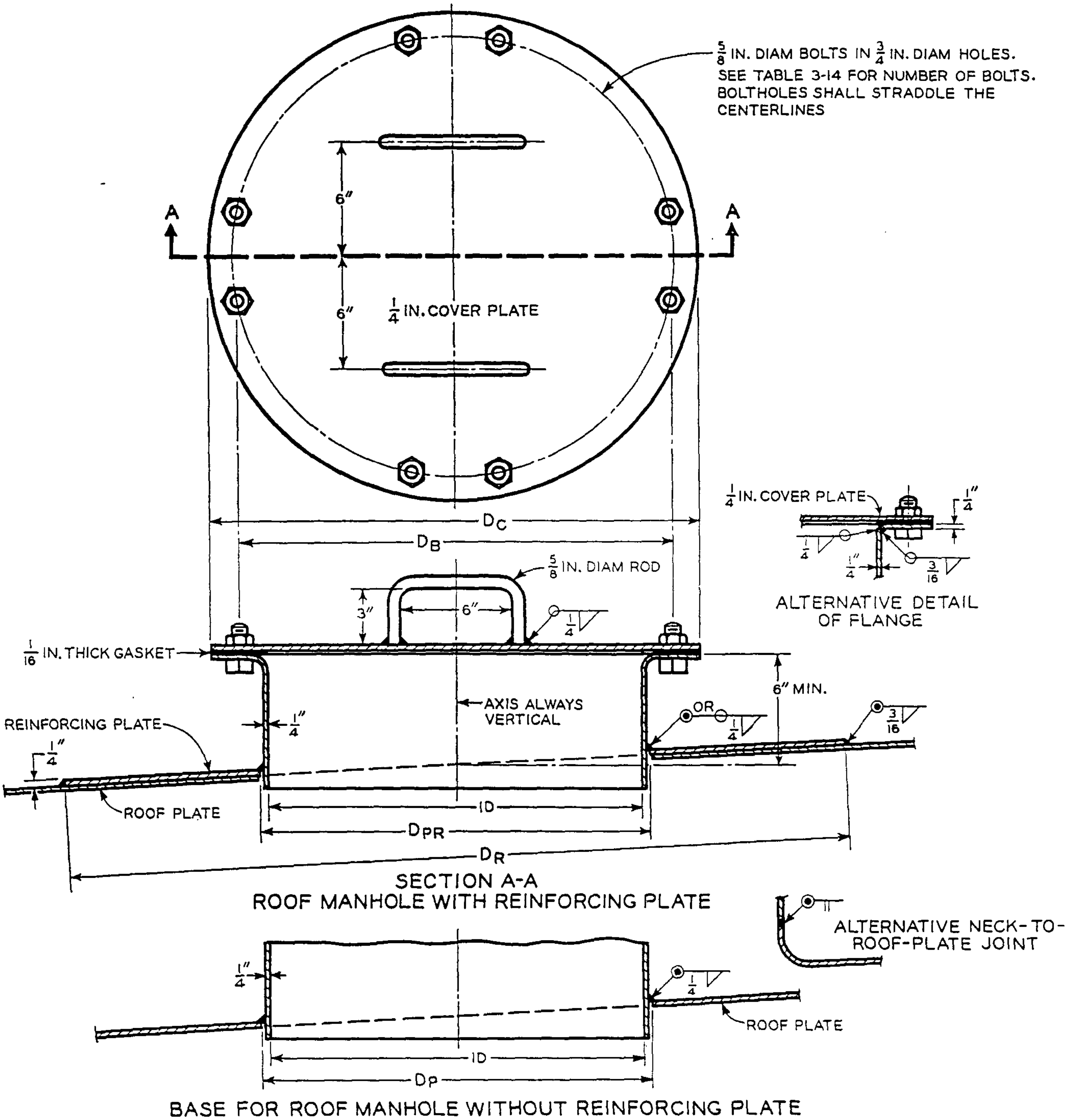


FIG. 3-14—Roof Manholes (See Table 3-14)

TABLE 3-15—Flanged Roof Nozzles (See Fig. 3-15)

All dimensions are in inches.

(1) Nominal Size of Nozzle	(2) OD of Pipe Neck	(3) Diameter of Hole in Roof Plate or Reinforcing Plate D_P	(4) Minimum Height of Nozzle H	(5) OD of Reinforcing Plate D_R
1½	1.900	2	6	5*
2	2⅜	2½	6	7*
3	3½	3⅝	6	9*
4	4½	4⅝	6	11*
6	6⅝	6¾	6	15*
8	8⅝	8⅞	6	18
10	10¾	11	8	22
12	12¾	13	8	24

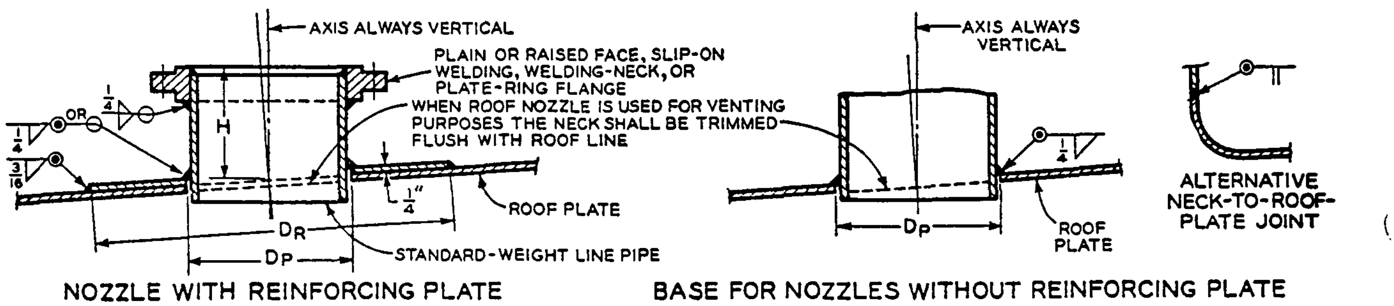
*** Reinforcing plates are not required on 6-in. or smaller nozzles, but may be used if desired.**

TABLE 3-16—Screwed Roof Nozzles (See Fig. 3-16)

All dimensions are in inches.

(1) Nominal Size of Nozzle	(2) Nominal Size of Coupling	(3) Diameter of Hole in Roof Plate or Reinforcing Plate D_P	(4) OD of Reinforcing Plate D_R
¾	¾	1 7/16	4*
1	1	1 23/32	4½*
1½	1½	2 11/32	5*
2	2	3	7*
3	3	4⅛	9*
4	4	5 11/32	11*
6	6	7 17/32	15*
8	8	9⅞	18
10	10	12	22
12	12	14¼	24

*** Reinforcing plates are not required on 6-in. or smaller nozzles, but may be used if desired.**



Requirement Notes:

1. Slip-on welding and welding-neck flanges shall conform to the requirements for 150-lb forged carbon steel raised-face flanges as given in ANSI B16.5.

2. Plate-ring flanges shall conform to all dimensional requirements for slip-on welding flanges, except that the extended hub on the back of the flange may be omitted.

FIG. 3-15—Flanged Roof Nozzles (See Table 3-15).

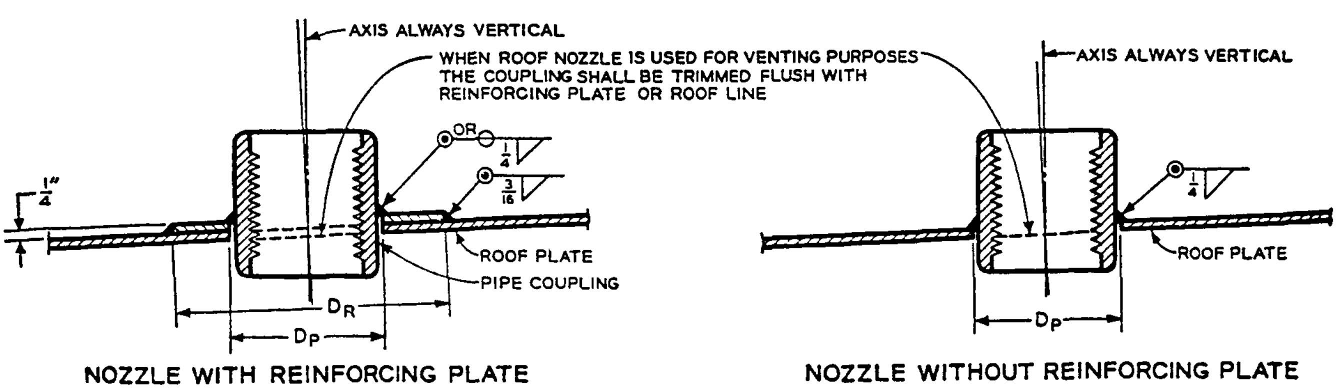
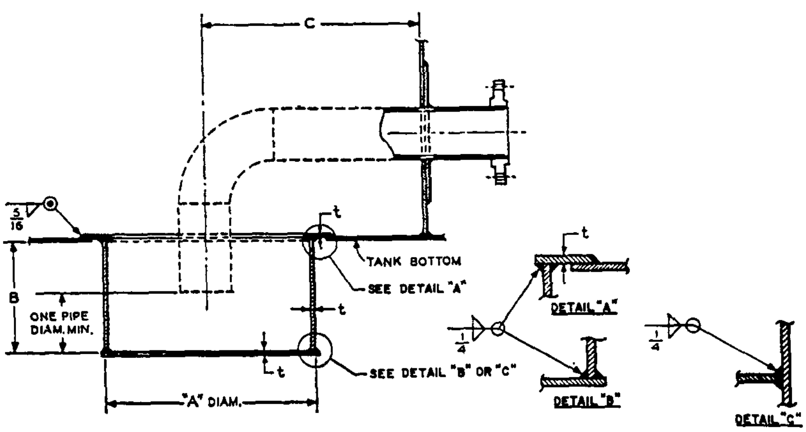


FIG. 3-16—Screwed Roof Nozzles (See Table 3-16; Also See Par. 3.6.11 for Thread Requirements).

TABLE 3-17—Diameters for Drawoff Sump

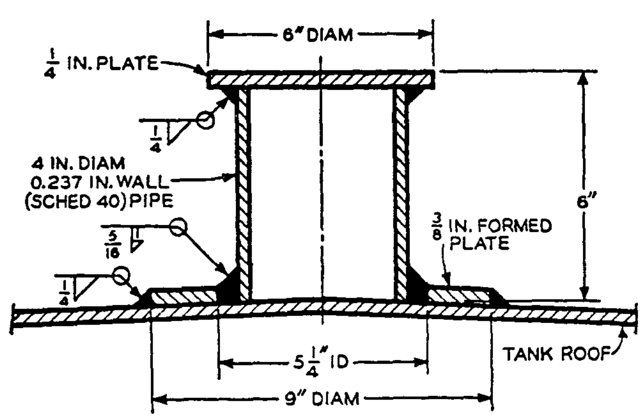
Nominal Pipe Size (Inches)	Diameter of Sump *A* (Inches)	Depth of Sump *B* (Inches)	Distance from Center of Pipe to Shell *C* (Feet)	Thickness of Plates in Sump *t* (Inches)
2	24	12	3½	5⁄16
3	36	18	5	⅜
4	48	24	6¾	⅜
6	60	36	8½	7⁄16

R



Erection Procedure Notes:
1. Cut hole in bottom plate.
2. Make neat excavation to conform to shape of drawoff sump.
3. Place and weld sump.

FIG. 3-17—Drawoff Sump.



Note: Where seams or other attachments are located at the center of the tank roof, the scaffold support shall be located as near the center as possible.

FIG. 3-18—Scaffold Cable Support.

TABLE 3-18—Platforms and Walkways

1.	All parts to be made of metal.	
2.	Width of floor level (min.), in inches	24
3.	Flooring to be made of grating or nonslip material.	
4.	Height of top railing above floor,* in inches	42
5.	Height of toeboard (min.), in inches	3
6.	Space between top of floor and bottom of toeboard (max.), in inches	¼
7.	Height of midrail—approximately one-half the distance from top of walkway to top of railing.	
8.	Distance between railing posts (max.), in inches	96
9.	The completed structure shall be capable of supporting a moving concentrated load of 1,000 lb, and the handrailing structure shall be capable of withstanding a load of 200 lb applied in any direction at any point on the top rail.	
10.	Handrails to be on both sides of platform, discontinuing where necessary for access.	
11.	At handrail openings, any space between tank and platform wider than 6 in. should be floored.	
12.	Tank runways, which extend from one part of a tank to any part of an adjacent tank or to ground or other structure, shall be so supported as to permit free relative movement of the structures joined by the runway. This may be accomplished by firm attachment of runway to one tank, but with a slip joint at point of contact between runway and other tank. This is to permit either tank to settle or be disrupted by an explosion without endangering the other.	

* Handrail height as required by ANSI specifications. This height is mandatory in some states.

TABLE 3-19—Stairways

1.	All parts to be made of metal.	
2.	Width of stairs (min.), in inches	24
3.	Angle * of stairway with a horizontal line (max.), in degrees	50
4.	Width of stair treads (min.), in inches [The run (defined as the horizontal distance between the noses of successive tread pieces) and the rise of stair treads shall be such that the sum of twice the rise, plus the run, shall be not less than 24 in. nor more than 26 in. Rises shall be uniform throughout the height of the stairway.]	8
5.	Treads to be made of grating or nonslip material.	
6.	Top railing shall join platform handrail without offset, and the height measured vertically from tread level at nose of tread shall be, in inches	30 to 34
7.	Distance between railing posts (max.) measured along slope of railing, in inches	96
8.	The completed structure shall be capable of supporting a moving concentrated load of 1,000 lb, and the handrailing structure shall be capable of withstanding a load of 200 lb applied in any direction at any point on the top rail.	
9.	Handrails shall be on both sides of straight stairs; also, handrails shall be on both sides of circular stairs when the clearance between tank shell and stair stringer exceeds 8 in.	
10.	Circumferential stairways should be completely supported on the shell of the tank, and ends of the stringers should be clear of the ground.	

* It is recommended that the same angle be employed for all stairways in a tank group or plant area.

TABLE 3-20—Stairway Rise, Run, and Angle Relationships

Height of Rise (Inches) R	$2R+r=24$ in. Width of Run (Inches) r	Angle (Degrees)	Angle (Minutes)	$2R+r=26$ in. Width of Run (Inches) r	Angle (Degrees)	Angle (Minutes)
5¼	13½	21	15	..	..	..
5½	13	22	56	15	20	9
5¾	12½	24	43	14½	21	38
6	12	26	34	14	23	12
6¼	11½	28	30	13½	24	53
6½	11	30	35	13	26	34
6¾	10½	32	45	12½	28	23
7	10	35	0	12	30	15
7¼	9½	38	20	11½	32	13
7½	9	39	50	11	34	18
7¾	8½	42	22	10½	36	26
8	8	45	0	10	38	40
8¼	7½	47	43	9½	41	0
8½	..	..	..	9	43	23
8¾	..	..	..	8½	45	49
9	..	..	..	8	48	22

4. FABRICATION

4.1 GENERAL

4.1.1 Workmanship

a. All work of fabricating API standard tanks shall be done in accordance with this specification, with the permissible alternatives specified in the inquiry or order form. The workmanship and finish shall be first class in every respect and subject to the closest inspection by the manufacturer's inspector whether or not the purchaser waives any part of the inspection.

b. When material requires straightening, the work shall be done by pressing or other noninjurious method prior to any layout or shaping. Heating or hammering is not permissible unless the material is heated to a forging temperature.

4.1.2 Finish of Plate Edges

The edges of plates may be sheared, machined, chipped, or machine oxygen cut. Shearing shall be limited to 3/8-in.* thickness of plates for butt-welded joints and to 5/8-in. thickness for lap-welded joints. When edges of plates are oxygen cut, the resulting surface shall be uniform and smooth and shall be freed of scale and slag accumulations before welding. After wire-brushing cut or sheared edges, the fine film of rust which adheres to the edges need not be removed before welding. Circumferential edges of roof and bottom plates may be manually oxygen cut.

4.1.3 Shaping of Shell Plates

Shell plates shall be shaped to suit the curvature of the tank and the erection procedure according to the following schedule:

Nominal Plate Thickness (Inches)	Nominal Tank Diameter (Feet)
3/16 to 3/8, excl.	40 or less
3/8 to 1/2, excl.	60 or less
1/2 to 5/8, excl.	120 or less
5/8 and over	All

4.1.4 Marking

All special plates, which are cut to shape before shipment, and roof-supporting structural members shall be marked as shown on the manufacturer's drawings.

4.1.5 Shipping

Plates and tank material shall be loaded on cars in such a manner as to insure delivery without damage. Bolts, nuts, railing connections, nipples, and other small parts shall be boxed or put in kegs or bags for shipment.

4.2 SHOP INSPECTION

a. The purchaser's inspector shall be permitted free entry to all parts of the manufacturer's plant concerned with the contract whenever any work under the contract is being performed. The manufacturer shall afford the purchaser's inspector, free of cost to the purchaser, all reasonable facilities to assure him that the material is being furnished in accordance with this specification. The manufacturer also shall furnish, free of cost to the purchaser, any samples or specimens of materials for the purpose of qualifying welders in accordance with Sect. 7.3. Inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. The manufacturer shall give the purchaser ample notice as to when the mill will roll the plates and when fabrication will begin so that the purchaser's inspector may be present when required. The usual mill test of plates shall be deemed sufficient to prove the quality of the steel furnished (except as noted in the following paragraph). Mill test reports shall be furnished to the purchaser when requested.

b. Mill and shop inspection shall not release the manufacturer from responsibility for replacing any defective material and for repairing any defective workmanship that may be discovered in the field.

c. Any material or workmanship which in any way fails to meet the requirements of this specification will be rejected by the purchaser's inspector, and the material involved shall not be used under the contract. Material which shows injurious defects subsequent to its acceptance at the mill, subsequent to its acceptance at the manufacturer's works, or during erection and test of the tank will be rejected. The manufacturer will be notified to this effect in writing and will be required to furnish new material promptly and make the necessary replacements or make suitable repairs.

5. ERECTION

5.1 GENERAL

a. The subgrade for receiving the tank bottom shall be provided by the purchaser, unless otherwise specified on the purchase order, and shall be uniform and level.

b. The manufacturer shall furnish all labor, tools, welding equipment and cables, falsework, scaffolding, and other equipment necessary for the erection of tanks complete and ready for use. Power for welding shall be supplied by the manufacturer, unless other arrangements are made in the purchase order.

c. No paint or foreign material shall be used between surfaces in contact in the construction of the tank proper, except as permitted by Par. 5.2.1(i).

d. Paint or other protection for structural work inside and outside of the tank shall be as specified on the order and shall be applied by competent workmen.

* This shearing limitation may be increased up to and including 5/8-in. thickness upon the approval of the purchaser.

e. For any riveted work on attachments to tank or in structural work, the requirements of API Standard 12A shall be followed.

f. Holes made for erection purposes shall be closed by any of the methods specified in Part 6, "Methods of Inspecting Shell Joints," as applicable to holes through butt welds in plates of similar thickness.

g. Lugs attached by welding to the exterior of the tank, for the purpose of erection only, shall be removed and any noticeable projections of weld metal shall be chipped from the plate. The plate must not be gouged or torn in the process of removing lugs.

5.2 DETAILS OF WELDING

5.2.1 General

R **a.** Tanks and their structural attachments shall be welded by the shielded metal-arc, the gas metal-arc, the flux-cored-arc, the submerged-arc, or the electroslag process, using suitable equipment. Use of the electroslag process or the electrogas process shall be by agreement between the manufacturer and the purchaser. Welding may be performed manually, automatically, or semiautomatically according to procedures described in, and by welders and welding operators qualified under, Part 7, "Welding Procedure and Welder Qualifications." Welding shall be performed in such a manner as to insure complete fusion with the base metal within the limits required by the applicable paragraphs and illustrations.

b. Welding shall not be performed when the surfaces of the parts to be welded are wet from rain, snow, or ice; when rain or snow is falling on such surfaces; nor during periods of high winds unless the welder and the work are properly shielded. Welding shall not be performed when the base metal temperature is less than O F. When the base metal temperature is within the range of 0 F to 32 F, inclusive, or the thickness is in excess of 1¼ in., the base metal within 3 in. of the place where welding is to be started shall be heated to a temperature warm to the hand.

c. Each layer of weld metal or multilayer welding shall be cleaned of slag and other deposits before applying the next layer.

R **d.** The edges of all welds shall merge with the surface of the plate without a sharp angle. There shall be a maximum permissible undercutting of 1/64 in. of the base metal for vertical butt joints. A horizontal butt joint's undercutting not exceeding 1/32 in. in depth is permissible, subject to the restrictions in Par. 3.3.6.

R **e.** The thickness of the reinforcement of the welds on all butt joints on each side of the plate shall not exceed the following thicknesses:

Plate Thickness (Inches)	Maximum Thickness of Reinforcement	
	Vertical Joints	Horizontal Joints
Up to 1/2, inclusive	3/32	1/8
Over 1/2 through 1, inclusive	1/8	3/16
Over 1	3/16	1/4

The reinforcement need not be removed except to the extent that it exceeds the permissible thickness or when required by Par. 6.1.2.

f. During the welding operation, plates shall be held in close contact at all lap joints.

g. The method proposed by the manufacturer to hold the plates in position for welding shall be submitted for approval to the purchaser's inspector, if such approval has not already been given in writing by the purchaser.

h. Tack welds used in the assembly of vertical joints of tank shells shall be removed and shall not remain in the finished joint when the joints are welded manually. When such joints are welded by the submerged-arc process, the tack welds shall be thoroughly cleaned of all welding slag but need not be removed provided they are sound and are thoroughly fused into the subsequently deposited weld metal. Tack welds in the bottom, roof, and circumferential joints of the tank shell need not be removed provided they are sound and the subsequently applied weld beads are thoroughly fused into the tack welds.

i. If protective coatings are to be used on surfaces to be welded, they shall be included in welding procedure qualification tests for the brand formulation and maximum thickness of coating to be applied.

5.2.2 Bottoms

a. After being laid out and tacked, the bottom plates, unless otherwise specified, shall be joined by welding the joints in a sequence that the manufacturer has found to result in the least distortion from shrinkage and to thus provide, as nearly as possible, a plane surface.

b. It is recommended that the sequence or order of welding the seams joining the bottom plates be specified by the manufacturer on approval plans so that the purchaser may object if he so desires. However, the manufacturer should follow a practice that will produce the minimum inequalities in the bottom-plate surface when the tank is completed.

c. The welding of shell to bottom shall be practically completed before starting the completion of welding of bottom joints which may have been left open to compensate for shrinkage of any welds previously made.

d. Shell plates may be aligned by metal clips attached to the bottom plates, and the shell may be tack-welded to the bottom before continuous welding is started between the bottom edge of the shell plate and the bottom plates.

5.2.3 Tank Shells

a. Plates to be joined by butt welding shall be matched accurately and retained in position during the welding operation. Misalignment in completed vertical joints shall not exceed 10 percent of the plate thickness, or 1/16 in., whichever is the larger.

b. In completed horizontal butt joints, the upper plate shall not project beyond the face of the lower plate at any point by more than 20 percent of the thickness of the upper plate, with a maximum of ⅛ in., except that a projection of $1/16$ in. is permissible for upper plates less than $5/16$ in. thick.

c. The reverse side of double-welded vertical butt joints, as well as portions of horizontal joints specified to have complete penetration and fusion, shall be thoroughly cleaned in a manner that will leave the exposed surface satisfactory for fusion of the weld metal to be added, prior to the application of the first bead to the second side. This cleaning may be done by chipping, grinding, melting out, or, where the back of the initial bead is smooth and free from crevices which might entrap slag, by other methods which may upon field inspection be acceptable to the purchaser. In the case of submerged-arc welds, the cleaning shall conform to the requirements established in *Welding Qualifications,* Sect. IX of *ASME Boiler and Pressure Vessel Code.*

5.2.4 Roofs

This standard does not include special stipulations on erection of the roof. Structural rafters, etc., must be reasonably true to line and surface.

5.3 INSPECTION, TESTING, AND REPAIRS

5.3.1 Weld Inspection

a. Butt welds: Where complete penetration and complete fusion is specified for welds joining shell plates to shell plates, inspection for quality of welds shall be made by the radiographic method specified in Sect. 6.1, except that, by agreement between the purchaser and the manufacturer, the sectioning method specified in Sect. 6.2 may be used. For horizontal shell joints for which partial penetration is specified, inspection for quality of welds shall be made by the sectioning method specified in Sect. 6.2. Where visual inspection by the purchaser's inspector indicates unsatisfactory welds between shell plates, acceptance or rejection shall be based on inspection of radiographs or segments representing the areas in question.

b. Fillet welds: Inspections of fillet welds shall be made by visual examination. Where visual inspection by the purchaser's inspector indicates unsatisfactory welds, acceptance or rejection shall be based on sectioning such areas by chipping with a mechanical round-nosed chipping tool.

c. Costs: All costs for cutting segments, for making radiographs, and for making any necessary repairs shall be borne by the manufacturer. However, if the purchaser's inspector requires segments or radiographs in excess of the number specified in Part 6, or requires chipouts of fillet welds in excess of one per 100 ft of weld and no defect is disclosed, the cost of the additional tests shall be borne by the purchaser.

5.3.2 Testing Tank Bottom

Upon completion of the welding of the tank bottom, it shall be tested by one of the following methods:

a. Air pressure or vacuum shall be applied to the joints, using soapsuds, linseed oil, or other suitable material for the detection of leaks.

b. After attachment of at least the lowest shell course, water, to be supplied by the purchaser, shall be pumped underneath the bottom. A head of 6 in. of liquid shall be maintained by holding that depth around the edge of the bottom inside a temporary dam. The line containing water for testing may be installed temporarily by running it through a manhole to a temporary flange connection at one or more points in the bottom of the tank, or it may be installed permanently in the subgrade beneath the tank. The method of installation should be governed by the nature of the subgrade. All reasonable care shall be taken to preserve the prepared subgrade under the tank.

5.3.3 Testing Reinforcement Pads R

Upon completion of the fabrication and before filling the tank with test water, the reinforcement pads shall be tested by applying up to 15-psig pneumatic pressure between the tank shell and the reinforcement plate on each opening, using the telltale hole specified in Par. 3.6.3(a). While each space is subjected to such pressure, soapsuds, linseed oil, or another suitable material for detection of leaks shall be applied to all attachment welding around the reinforcement, both inside and outside the tank.

5.3.4 Testing Tank Shell R

Upon completion of the entire tank, and before any external oil piping has been connected to the tank, the shell shall be tested by one of the following methods:

a. If water is available for testing, the tank shall be filled with water and inspected frequently during the filling operation. For tanks with tight roofs, the filling height shall be 2 in. above the top leg of the top angle. For open-top tanks, the filling height shall be the top of the top angle or the bottom of any overflow which limits the filling height.

b. If sufficient water to fill the tank is not available, the test may be made by: (1) painting all joints on the inside with a highly penetrating oil, such as automobile spring oil, and carefully examining the outside of the joints for leakage; (2) applying vacuum to either side of the joints or applying internal air pressure as specified for roof test in Par. 5.3.5 and carefully examining the joints for leakage; or (3) any combination of the methods stipulated in (1) and (2).

R **5.3.5 Testing Tank Roof**

Upon completion, the tank roof shall be tested by applying internal air pressure or external vacuum to the seams, using soapsuds, linseed oil, or other suitable material for the detection of leaks. The internal pressure shall not exceed the weight of the roof plates.

R **5.3.6 Repairs**

a. All defects found in welds shall be called to the attention of the purchaser's inspector and his approval shall be obtained before they are repaired. All completed repairs shall be subject to the approval of the purchaser's inspector.

b. Pinhole leaks or porosity in tank-bottom joints may be repaired by applying an additional weld bead over the defective area. Other defects or cracks in tank-bottom joints shall be repaired as required in Par. 6.2.7.

c. All defects, cracks, or leaks in shell joints or in the shell-to-bottom joint shall be repaired in accordance with Par. 6.2.7.

d. Isolated pinhole leaks in roof joints may be caulked mechanically; but for any indication of considerable porosity in the joints or of cracking, an additional bead of weld metal shall be laid over the affected sections. Mechanical caulking is not permitted for any other repairs.

e. Repairs of defects discovered after the tank has been filled with water for test shall be made with the water level at least 1 ft below the point being repaired or with the tank empty if repairs are on or near the tank bottom. No welding shall be done on any tank unless all lines connecting thereto have been completely blanked off. No repairs shall be attempted on a tank while filled with oil nor on a tank which has contained oil until the tank has been emptied, cleaned, and gas-freed in a safe manner. No repairs shall be attempted by the manufacturer on a tank which has contained oil, except in a manner approved in writing by the purchaser and in the presence of the purchaser's inspector.

R **5.3.7 Cleaning Up**

Upon completion of erection, the manufacturer shall remove or dispose of all rubbish and other unsightly material caused by his operations and shall leave the premises in as good condition as he found them.

R **5.3.8 Inspection**

a. The purchaser's inspector shall have at all times free entry to all parts of the job while work under the contract is being performed. The manufacturer shall afford the purchaser's inspector, free of cost, reasonable facilities to assure him that the work is being performed in accordance with this standard.

b. Any material or workmanship shall be subject to the replacement requirements of Par. 4.2(c).

c. Material damaged by defective workmanship, or otherwise defective, will be rejected. The manufacturer will be notified to this effect in writing and will be required to furnish new material promptly or correct defective workmanship.

5.3.9 Acceptance R

Before acceptance, all work shall be completed to the satisfaction of the purchaser's inspector and the entire tank, when filled with oil, must be tight and free from leaks.

5.3.10 Vacuum Testing R

a. Vacuum testing is conveniently performed by means of a metal testing box, 6 in. wide by 30 in. long, with a glass window in the top. The open bottom is sealed against the tank surface by a sponge-rubber gasket. Suitable connections, valves, and gages should be provided.

b. Approximately 30 in. of the seam under test is brushed with a soapsuds solution or linseed oil. In freezing weather, a nonfreezing solution may be necessary. The vacuum box is placed over the coated section of the seam and vacuum is applied to the box. The presence of porosity in the seam is indicated by bubbles or foam produced by air sucked through the welded seam.

c. A vacuum can be drawn on the box by any convenient method, such as connection to a gasoline or diesel motor intake manifold or to an air ejector or special vacuum pump.

d. The gage should register a partial vacuum of at least 2 psi.

5.4 DIMENSIONAL TOLERANCES R

The purpose of the following tolerances is to produce a tank of acceptable appearance and to permit proper functioning of floating roofs. These tolerances may be waived by agreement between the purchaser and the manufacturer.

a. Plumbness

1. The maximum out-of-plumbness of the top of the shell relative to the bottom of the shell shall not exceed $1/200$ of the total tank height.

2. The out-of-plumbness in one shell plate shall not exceed the values specified for mill tolerances in Table 14 or Table 15 of ASTM Specification A 6 or in Table 10 or Table 13 of ASTM Specification A 20, whichever is applicable.

b. Roundness

Radii measured at 1 ft. 0 in. above the bottom corner weld shall not exceed the following tolerances:

Diameter Range	Radius Tolerance
0 to 40 ft., exclusive	±½ in.
40 to 150 ft., exclusive	±¾ in.
150 to 250 ft., exclusive	±1 in.
250 ft. and over	±1¼ in.

c. Peaking

Using horizontal sweep board 36 in. long, peaking shall not exceed ½ in.

d. Banding

Using a vertical sweep board 36 in. long, banding shall not exceed ½ in.

e. Foundations

To achieve the above tolerances, it is essential that level foundations be provided for the tank erection. The foundation should have adequate bearing power to maintain the levelness of the foundation. (See Appendix B.)

1. Where concrete ringwalls are provided under the shell, the top of the ringwall shall be level within ±⅛ in. in any 30 ft. of circumference and within ±¼ in. in the total circumference.

2. Where concrete ringwalls are not provided, the foundation under the shell shall be level within ±⅛ in. in any 10 ft. of circumference and within ±½ in. in the total circumference.

f. Measurements

Measurements taken shall be prior to the water test.

6. METHODS OF INSPECTING SHELL JOINTS

6.1 RADIOGRAPHIC METHOD

6.1.1 Application

Radiographic inspection by X-ray or gamma-ray methods shall be confined to tank shell joints specified to have complete penetration and complete fusion, particularly the vertical joints subject to primary stress from weight or pressure of the tank contents. Inspection by radiographic methods shall not be required for roof-plate or bottom-plate welds nor for welds joining roof plates to top angle, top angle to shell plate, shell plates to bottom plates, or appurtenances to tanks. Such methods are not recommended for horizontal shell joints for which partial penetration is specified, nor for horizontal welds which are not required to have complete penetration and complete fusion; see Par. 3.3.6.

6.1.2 Preparation for Examination

All butt-welded joints to be radiographed shall be prepared as follows: The weld ripples or weld surface irregularities on both the inside and outside shall be removed by any suitable mechanical process to such a degree that the radiographic contrast resulting from any irregularities cannot mask or be confused with the image of any objectionable defect. Also, the weld surface shall merge smoothly into the plate surface. The finished surface of the reinforcement may be flush with the plate or may have a reasonably uniform crown not to exceed the following values:

Plate Thickness (Inches)	Max. Thickness of Reinforcement (Inches)
Up to ½, incl.	1/16
Over ½ to 1, incl.	3/32
Over 1	⅛

6.1.3 Number and Location of Radiographs

a. Radiographs shall be taken as specified:

1. *Vertical joints:* One spot radiograph shall be taken in the first 10 ft of completed vertical joint of each type and thickness welded by each welder or welding operator. Thereafter, without regard to the number of welders or welding operators working thereon, one additional spot radiograph shall be taken in each additional 100 ft (approximately), and any remaining major fraction thereof, of vertical joint of the same type and thickness. At least 25 percent of the selected spots shall be at junctions of vertical and horizontal joints, with a minimum of two such intersections per tank.

2. *Horizontal joints:* Where complete penetration and complete fusion are specified, one spot radiograph shall be taken in the first 10 ft of completed horizontal joint of the same type and thickness (based on the thickness of the thinner plate at the joint), without regard to the number of welders or welding operators working thereon. Thereafter, one radiograph shall be taken in each additional 200 ft (approximately), and any remaining major fraction thereof, of horizontal joint of the same type and thickness.

3. For the purpose of this section, plates shall be considered of the same thickness when the difference in the specified or design thickness does not exceed 0.03 in.

4. When two or more tanks are erected in the same location, for the same purchaser, either concurrently or continuously, the number of spot radiographs to be taken may be based on the aggregate footage of welds of the same type and thickness in each group of tanks rather than on the footage in each individual tank.

b. It is to be recognized that the same welder or welding operator may or may not weld both sides of the same butt joint. It is therefore permissible to inspect the work of two welders or welding operators with one spot radiograph if they weld opposite sides of the same butt joint. When a spot radiograph is rejected, it shall be determined by further spot radiographs whether one or both welders or welding operators were at fault.

c. Insofar as possible, an equal number of spot radiographs shall be taken from the work of each welder or welding operator, except that this requirement shall not apply where the length of joint welded by a welder or welding operator is much less than average.

d. The locations for taking spot radiographs may be determined by the purchaser's inspector.

e. As welding progresses, radiographs shall be taken as soon as practicable.

6.1.4 Film

Each radiograph shall clearly show a minimum of 3 in. of weld length. The film shall be centered on the weld and shall be of sufficient width to permit adequate space for the location of identification marks and thickness gage or penetrameter.

6.1.5 Procedure

The weld shall be radiographed with a technique of sufficient sensitivity to indicate the features of the penetrameter as described in Par. 6.1.6(c-8). The penetrameter used shall be of the specified thickness for the thickness of the weld being examined.

6.1.6 Penetrameters

a. The size and shape of the penetrameter shall be substantially as shown in Fig. 6-1. It is recommended that penetrameters be protected by being embedded in plastic.

b. The thickness of the penetrameter shall be as shown in the following tabulation. Standard penetrameters shall be limited to the following thicknesses and identified by number in symbols at least 3/32 in. high.

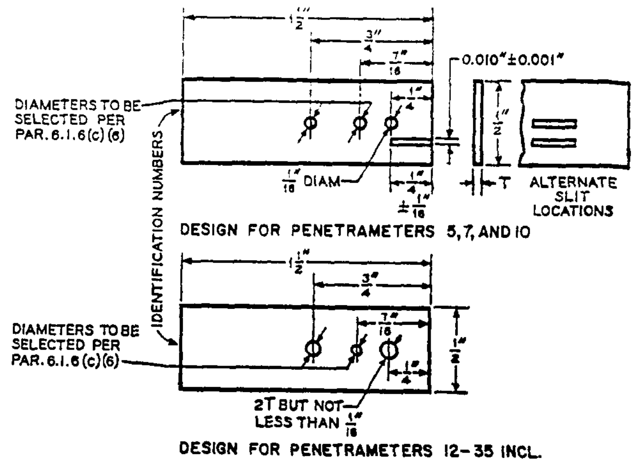
Weld Thickness (Inches)	Thickness of Penetrameter (Inches)	Designation on Penetrameter
Up to 1/4, incl.	0.005	5
Over 1/4 to 3/8, incl.	0.0075	7
Over 3/8 to 1/2, incl.	0.010	10
Over 1/2 to 5/8, incl.	0.0125	12
Over 5/8 to 3/4, incl.	0.015	15
Over 3/4 to 7/8, incl.	0.0175	17
Over 7/8 to 1, incl.	0.020	20
Over 1 to 1 1/4, incl.	0.025	25
Over 1 1/4 to 1 1/2, incl.	0.030	30
Over 1 1/2 to 1 3/4, incl.	0.035	35

c. As a check on the radiographic technique employed, penetrameters, as herein described, shall be used in the following manner to determine whether the requirements are being met:

1. The radiographic quality shall be evaluated by the image of a properly located penetrameter.

2. The penetrameter shall be placed on the side nearest the radiation source.

3. One penetrameter shall be used for each exposure, to be placed so that the plane of the penetrameter is normal to the radiation beam. Each penetrameter shall represent an area of essentially uniform radiographic density as judged by density comparison strips or a densitometer. If the film density varies more than −15 or +30 percent from the density through the penetrameter, an additional penetrameter will be required for the exceptional area or areas. The H&D* density through acceptable weld metal shall be 1.3 minimum for single film viewing and 1.8 minimum for composite viewing of double film exposures.



Dimensional Tolerances:

Length and width, in inches	± 1/64
Nominal thickness, percent	± 10
Hole nominal diameter, percent	± 10
Hole location, percent	± 10
Slit starting hole, if used, in inches	0.05 max.

FIG. 6-1—Penetrameter (Image Quality Indicator).

4. The material of the penetrameter shall be radiographically similar to that of the filler metal under examination. Any steel, preferably stainless, may be used.

5. The penetrameter shall be placed adjacent to the weld seam. If the weld reinforcement and/or backing strip is not removed, a shim of material radiographically similar to the filler metal shall be placed under the penetrameter. The shim thickness shall be selected so that the total thickness being radiographed under the penetrameter is the same as the total weld thickness (including backing strip if used and not removed). The penetrameter thickness shall be based on the total metal thickness under the penetrameter, including shim.

6. In each penetrameter there shall be three holes, one of which shall be of diameter equal to twice the penetrameter thickness ($2T$) but not less than 1/16 in. The diameters of the two remaining holes shall be selected by the manufacturer. They will ordinarily be equal to three ($3T$) and four ($4T$) times the penetrameter thickness but they need not be smaller than 1/16 in. (although smaller holes are permitted). These holes shall be true and normal to the surface and not chamfered. For weld thickness less than 1/2 in., the penetrameter shall also contain a slit 1/4 in. long by 0.010 in. wide. The long dimension of this slit is to be placed parallel to the longitudinal direction of the weld.

* Hurter-Driffield method of defining quantitative blackening of the film.

7. The holes, or the slit (in the range where the slit is required), shall be delineated on the radiograph as defined in Par. (c-8).

8. The images of the identifying numbers, of the penetrameter outline, and the $2T$ hole are all essential indexes of image quality on the radiograph and they shall appear clearly on the radiograph, except that for penetrameters 5, 7, and 10 the slit shall appear clearly and the hole need not appear. The density difference between the image of the hole, or slit, and the penetrameter image shall be the same as that between the edge of the penetrameter and the adjacent film area.

6.1.7 Film Location

The film, during exposure, shall be as close to the surface of the weld as practical.

6.1.8 Film Defects

All radiographs shall be free from excessive mechanical processing defects which would interfere with proper interpretation of the radiographs.

6.1.9 Identification and Reference Markers

Identification markers, the images of which will appear on the film, shall be placed adjacent to the weld opposite the penetrameter, and their locations shall be accurately and permanently marked near the weld on the outside surface of the structure so that a defect appearing on the radiograph may be accurately located. Also, a suitable reference marker shall be placed on each film.

6.1.10 Submission of Radiographs

Prior to any repairs of welds, the radiographs shall be submitted to the inspector with such information as he may request regarding the radiographic technique used.

6.1.11 Radiographic Standards

Sections of welds which are shown by radiography to have any of the following imperfections shall be judged unacceptable:

a. Any crack, incomplete fusion, or incomplete penetration.

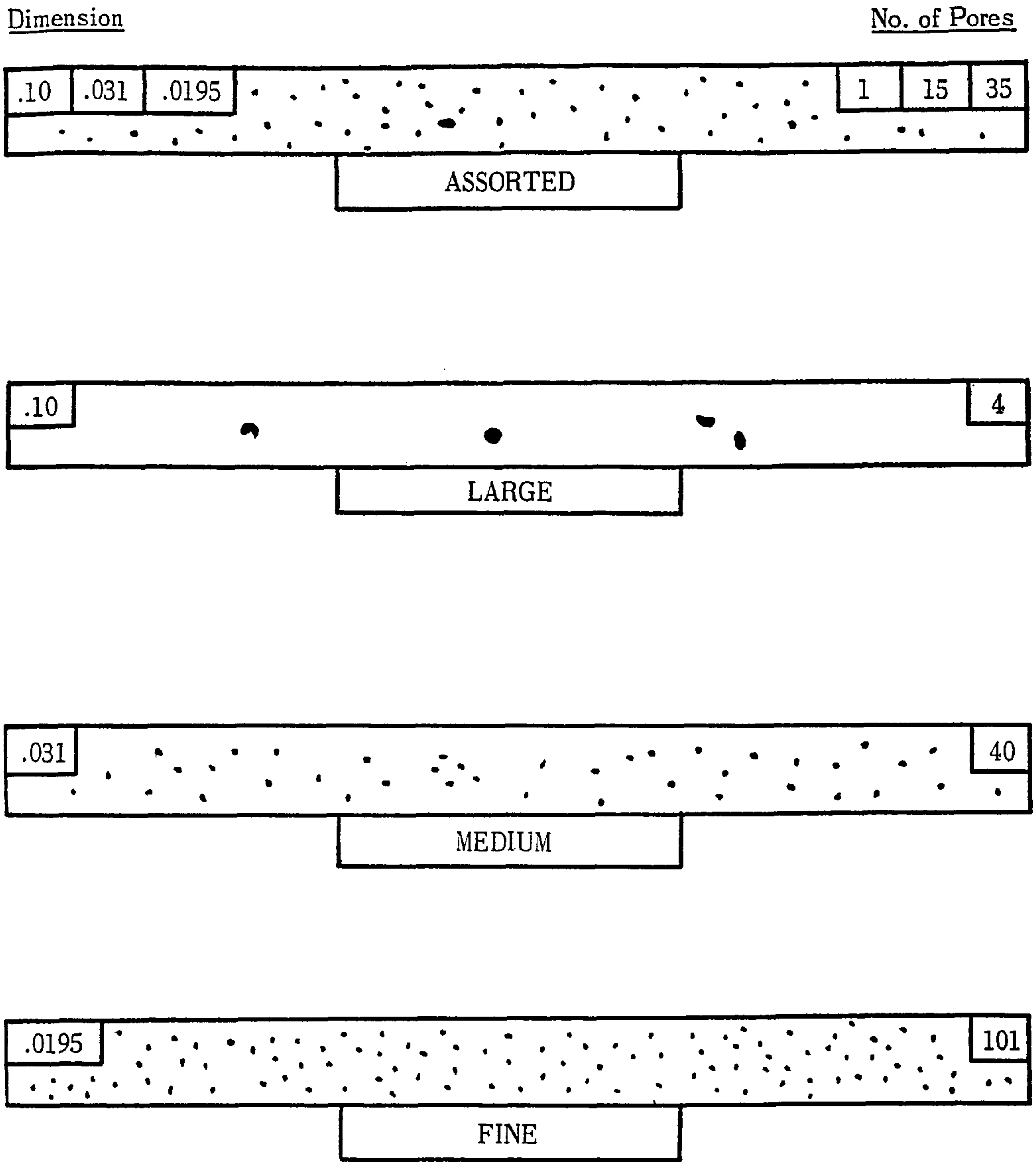
b. Any individual elongated inclusion having a length greater than two-thirds the thickness of the thinner plate of the joint. However, regardless of the plate thickness, no such inclusion shall be longer than ¾ in., and no such inclusion shorter than ¼ in. shall be cause for rejection.

c. Any group of inclusions in line, where the sum of the longest dimensions of all such imperfections is greater than T (where T is the thickness of the thinner plate joined) in a length of $6T$, except when each of the individual spaces between imperfections is greater than three times the length of the longer of the adjacent imperfections. When the length of the radiograph is less than $6T$, the permissible sum of the lengths of all inclusions shall be proportionately less than T, provided the limits of the deficient welding are clearly defined.

d. Porosity in excess of that shown as acceptable in the following specifications:

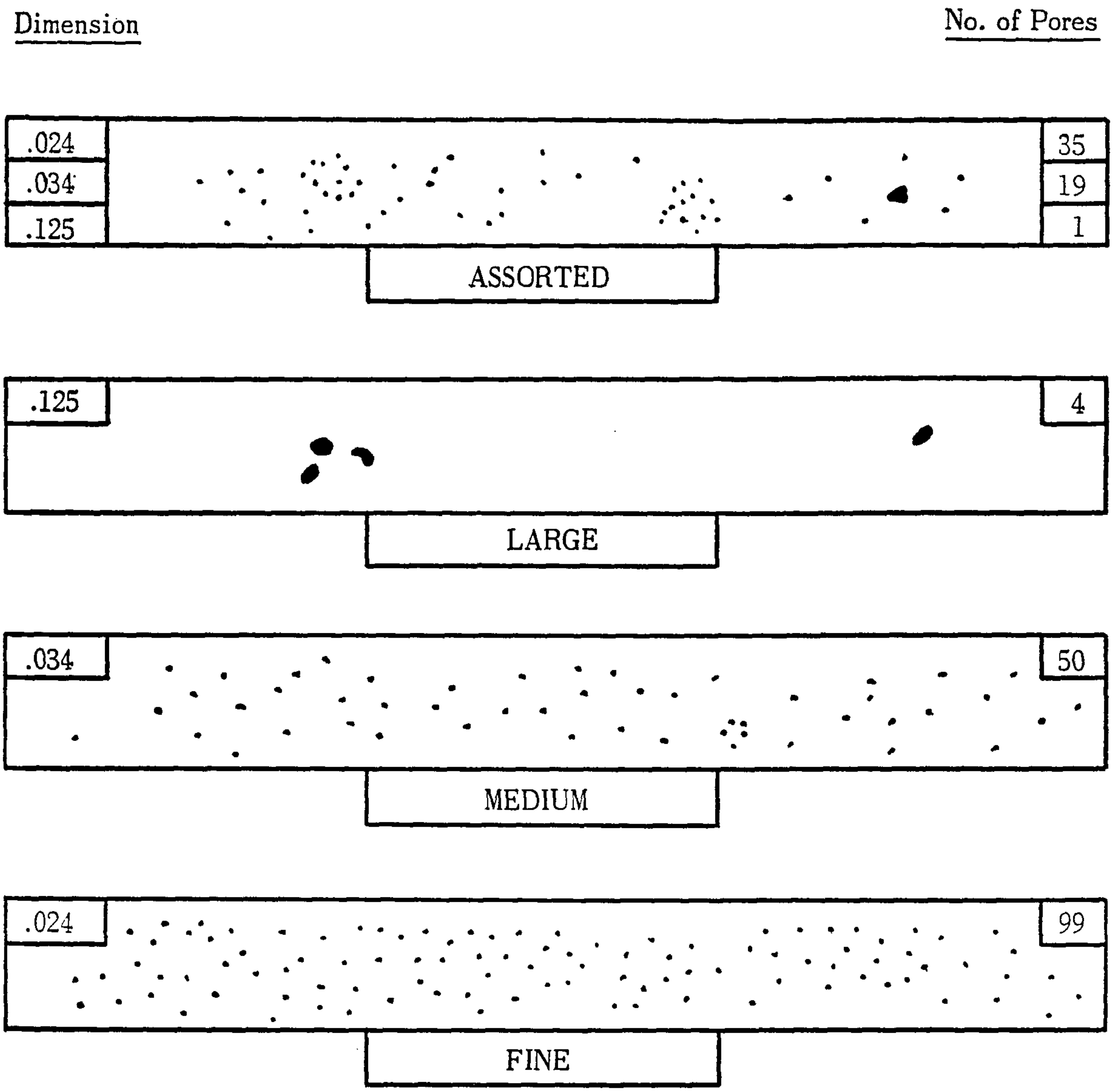
1. The total area of porosity as determined from the radiographic film shall not exceed $0.060T$ sq in. in any 6-in. length of weld, where T is the thickness of the weld. If the weld is less than 6 in. long, the total area of porosity shall be reduced in proportion. The maximum pore dimension shall be 20 percent of T or ⅛ in., whichever is smaller, except that an isolated pore separated from an adjacent pore by 1 in. or more may be 30 percent of T or ¼ in., whichever is less. Dark images of a generally circular or oval shape shall be interpreted as porosity for the purposes of this standard.

2. The porosity charts in Fig. 6-2 through 6-5 illustrate various types of assorted and uniform, randomly dispersed porosity indications. These charts represent the maximum acceptable porosity for each thickness. The charts represent full-scale 6-in. radiographs and shall



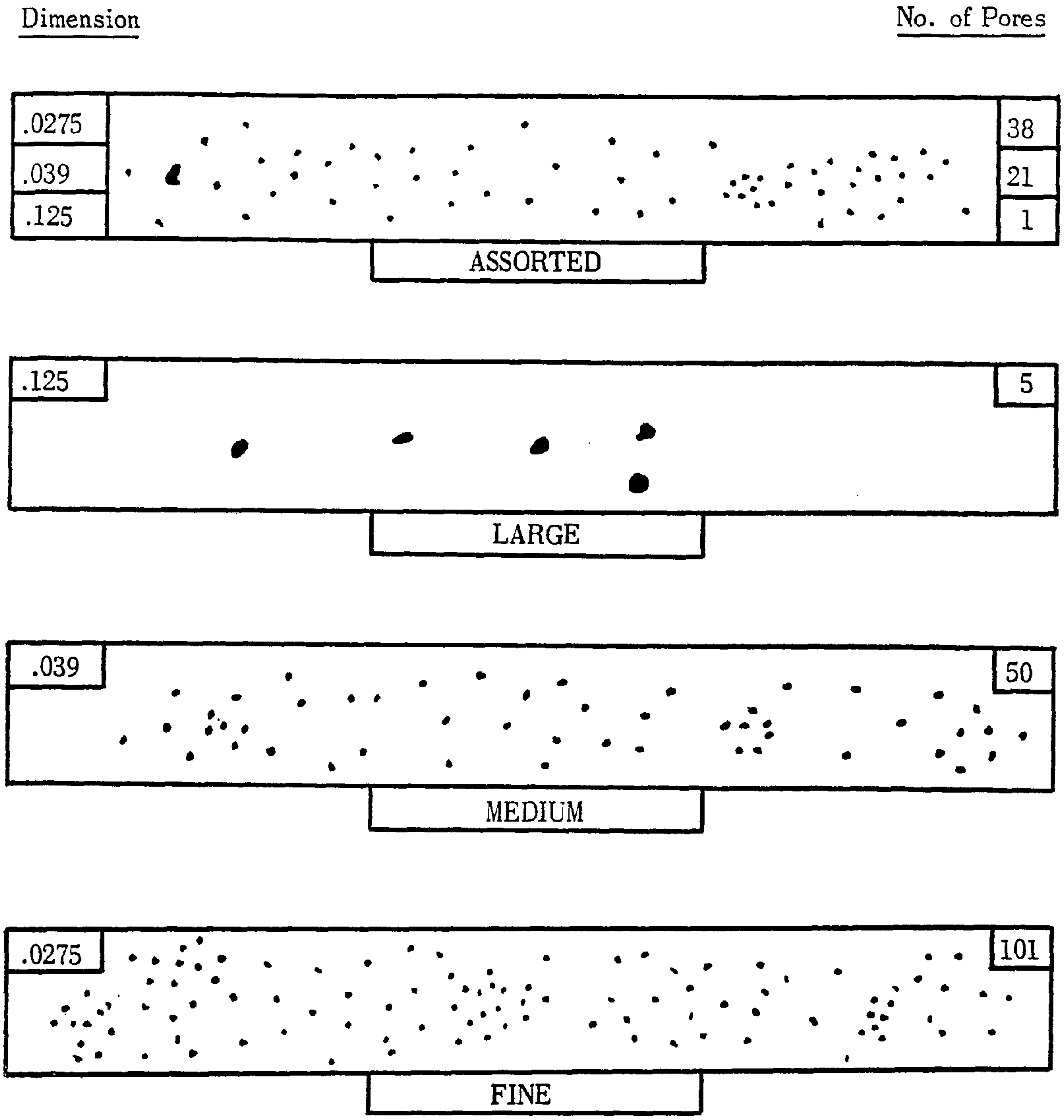
TYPICAL NUMBER AND SIZE PERMITTED
IN ANY SIX INCH LENGTH OF WELD
ONE HALF INCH WELD THICKNESS
TOTAL PORE AREA PERMITTED IS .030 SQ. IN.

FIG. 6-2—Radiographic Porosity Standards.



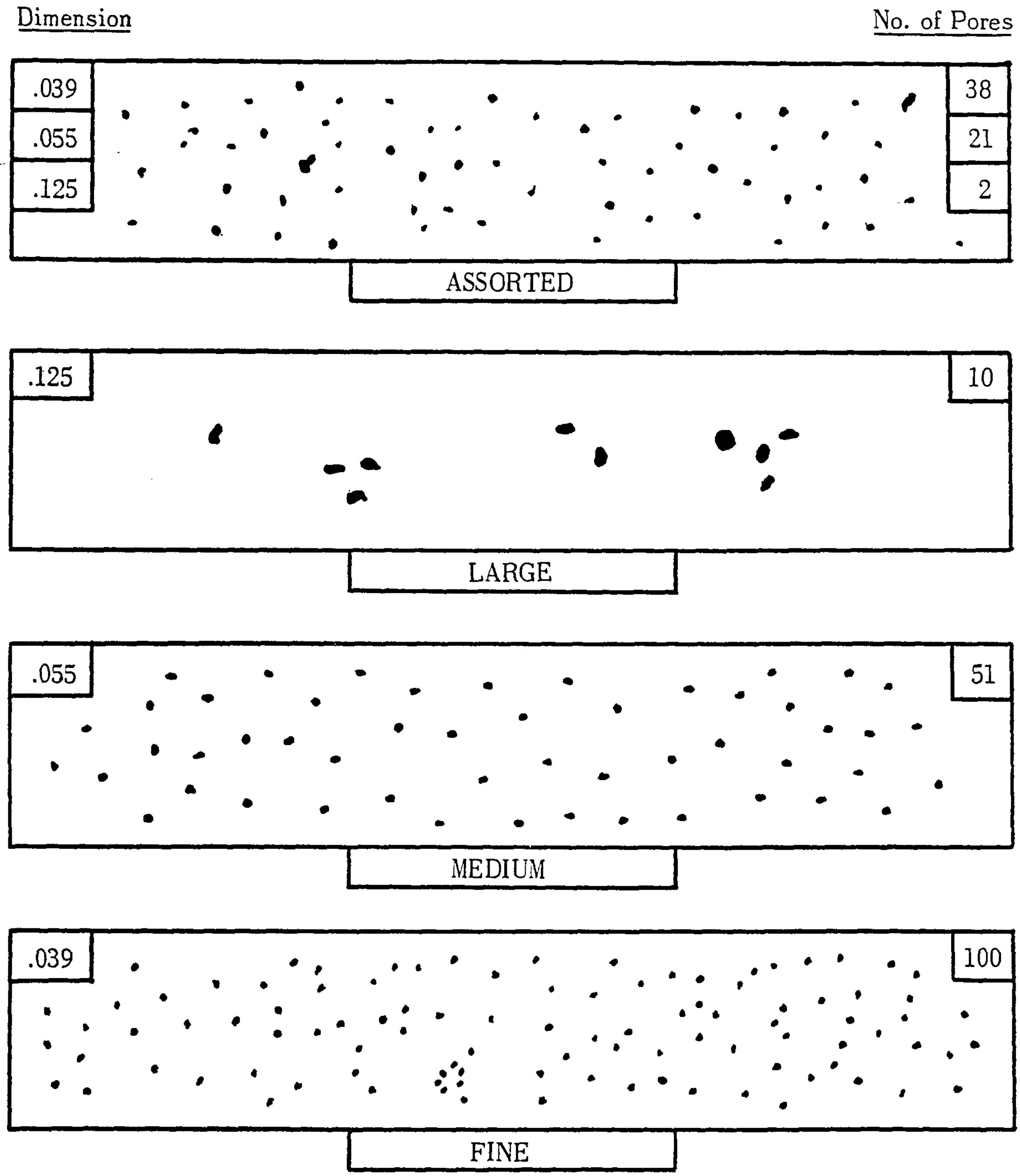
TYPICAL NUMBER AND SIZE PERMITTED
IN ANY SIX INCH LENGTH OF WELD
THREE QUARTER INCH WELD THICKNESS
TOTAL PORE AREA PERMITTED IS .045 SQ IN.

FIG. 6-3—Radiographic Porosity Standards.



TYPICAL NUMBER AND SIZE PERMITTED
IN ANY SIX INCH LENGTH OF WELD
ONE INCH WELD THICKNESS
TOTAL PORE AREA PERMITTED IS .060 SQ IN.

FIG. 6-4—Radiographic Porosity Standards.



TYPICAL NUMBER AND SIZE PERMITTED
IN ANY SIX INCH LENGTH OF WELD
TWO INCH WELD THICKNESS
TOTAL PORE AREA PERMITTED IS .120 SQ IN.

Note: This chart is provided for interpolation of plate thicknesses up to 1¾ in.

FIG. 6-5—Radiographic Porosity Standards.

not be enlarged or reduced. The porosity distributions shown are not necessarily the patterns that may appear on the radiograph but are typical of the number and size of indications permitted. When porosity indications differ significantly from the porosity charts, the actual numbers and sizes of the pores may be measured and the total area of porosity calculated.

3. In any 1-in. length of weld or 2*T*, whichever is smaller, porosity may be clustered to a concentration four times that permitted by 0.060*T*. Such clustered porosity shall be included in the porosity in any 6-in. length of weld which includes the cluster.

4. Aligned porosity shall be acceptable, provided the summation of the diameters of the pores is no more than *T* in a length 12*T*, or 6 in., whichever is less. However, each pore must be separated by a distance at least six times the diameter of the largest adjacent pore. Aligned porosity indications shall be counted in the total area of permissible indications in any 6-in. length of weld.

5. Permissible porosity indications for weld thicknesses intermediate to those illustrated may be evaluated either by comparison with the next thinner material or by calculation, as shown in Table 6-1.

6.1.12 Determination of Limits of Defective Welding

When a section of weld is shown by a radiograph to be unacceptable under the provisions of Par. 6.1.11, or the limits of the deficient welding are not defined by such radiograph, two adjacent spots shall be examined by radiography. However, if the original radiograph shows at least 3 in. of acceptable weld between the defect and any one edge of the film, an additional radiograph need not be taken of the weld on that side of the defect. If the weld at either of the two adjacent sections fails to comply with the requirements of Par. 6.1.11, additional nearby spots shall be examined until the limits of unacceptable welding are determined; or the erector may replace all the welding performed by the welder or welding operator on that joint. If the welding is replaced, the inspector shall have the option of requiring that one radiograph be taken at any selected location on any other joint on which the same welder (or operator) has welded. If any of such additional spots fails to comply with the requirements of Par. 6.1.11, the limits of unacceptable welding shall be determined as specified for the initial section.

6.1.13 Repair of Defective Welds

a. Defects in welds shall be repaired by chipping or melting out such defects from one or from both sides of the joint, as required, and rewelding. Only sufficient cutting out of defective joints is required as is necessary to correct the defects.

b. All repaired welds in joints shall be checked by R
repeating the original inspection procedure and by repeating one of the testing methods of Section 5.3 subject to the approval of the purchaser.

6.1.14 Record of Radiographic Examination

a. A record shall be made by the erector of all films, with their identification marks, on a developed shell-plate diagram.

b. After the completion of the structure, the films shall be the property of the purchaser, unless otherwise agreed upon between the purchaser and the erector.

6.2 SECTIONING METHOD

6.2.1 Application

Sectional inspection shall be confined to horizontal welded tank shell joints where complete penetration and complete fusion have not been specified, except that, by agreement between the purchaser and the manufacturer, it may be used as an alternative to spot radiographic inspection of shell-to-shell welded joints specified to have complete penetration and complete fusion. It need not be applied to: roofs, flat tank bottoms resting directly on a grade or foundation, welds between flat tank bottoms and the first ring of the tank shell, welds connecting the top curb angle to the shell or to the roof, and welds connecting manholes or other appurtenances to the tank.

6.2.2 Sectional Specimens

Sectional specimens are segments cut from the welded joints in such manner as to remove a portion of the

TABLE 6-1—Maximum Permissible Porosity Indications in Radiographs per 6-In. Length of Weld

Weld Thickness (Inches)	Total Area of Permitted Porosity (Square Inches)	Large Pore Size (Inches)			Medium Pore Size (Inches)			Fine Pore Size (Inches)		
		Approximate Fraction	Decimal Value*	No.	Approximate Fraction	Decimal Value*	No.	Approximate Fraction	Decimal Value*	No.
1/8	0.0075	...	...	..	...	...	..	1/64	0.014	49
1/4	0.015	...	...	..	3/128	0.025	31	1/64	0.0138	100
1/2	0.030	3/32	0.10	4	1/32	0.031	40	3/128	0.0195	101
3/4	0.045	1/8	0.125	4	1/32	0.034	50	3/128	0.024	99
1	0.060	1/8	0.125	5	5/128	0.039	50	1/32	0.0275	101
1 1/2	0.090	1/8	0.125	7	3/64	0.048	50	1/32	0.034	99
1 3/4	0.105	1/8	0.125	8	1/16	0.0625	50	1/32	0.037	99

* These values are used for calculating total area of permissible porosity given in second column.

plates bounding the welded joint and thereby obtain two cross-sections of the weld. The segments must expose the full cross-sections of the welded joint. Segments shall be cut with a cylindrical cutting tool.

6.2.3 Number and Location of Specimens

a. Segments shall be cut as specified:

1. *Joints specified to have complete penetration and complete fusion:* Where sectioning is applicable as an alternative to spot radiographing, the number and location of segments shall comply with the requirements for the number and location of spot radiographs as given for inspecting shell joints by the radiographic method [Par. 6.1.3(a-1) and (a-2)], except that no segments shall be taken at junctions of the vertical and horizontal joints.

2. *Horizontal joints:* Where complete penetration and complete fusion are not specified, one segment shall be cut from the first 10 ft of completed horizontal joint of each type and thickness (based on the thickness of the thicker plate at the joint) without regard to the number of welders or welding operators working thereon. Thereafter, one additional segment shall be cut from each additional 200 ft (approximately), and any remaining major fraction thereof, of horizontal joint of the same type and thickness.

3. For the purpose of this section, plates shall be considered of the same thickness when the difference in the specified or design thickness does not exceed 0.03 in.

4. When two or more tanks are erected in the same location for the same purchaser, either concurrently or continuously, the number of segments to be taken may be based on the aggregate footage of welds of the same type and thickness in each group of tanks rather than on the footage in each individual tank.

b. It is to be recognized that the same welder or welding operator may or may not weld both sides of the same butt joint. It is therefore permissible to inspect the work of two welders or welding operators with one segment if they weld opposite sides of the same butt joint. When a segment is rejected, it shall be determined by further specimens whether one or both welders or welding operators were at fault.

c. Insofar as possible, an equal number of segments shall be cut from the work of each welder or welding operator, except that this requirement shall not apply where the length of joint welded by a welder or welding operator is much less than average.

d. The locations for cutting the segments may be determined by the purchaser's inspector.

e. Segments shall be taken as the work progresses, and as soon as practicable after all the joints accessible from one scaffold position have been welded.

6.2.4 Size of Sectional Segments

a. The diameter of the segment shall be not less than the width of the finished weld plus 1/8 in., with a minimum of 1/2 in.

b. The segment shall be removed from the center of the weld in such a manner that at least 1/16 in. of parent metal will be removed with the segment on each of the two sides.

6.2.5 Preparation of Sectional Segments

a. Without further finishing or preparation, the segments shall be etched for inspection by placing in boiling 50 percent muriatic (hydrochloric) acid until a clear definition of the structure of the weld is apparent. (This will require approximately 1/2 hr.)

b. To preserve the appearance of the etched segments, they should be washed in clear water, the excess water removed, and the segments immersed in alcohol and dried. The etched surfaces may then be preserved by coating with a thin, clear lacquer.

6.2.6 Inspection of Sectional Segments

a. The etched segments shall be examined to ascertain the extent of weld defects, such as gas pockets, slag inclusions, incomplete fusion, undercutting, and cracks.

b. The etched surfaces of the segments shall show no cracks and shall show complete penetration and complete fusion between the weld metal and the base metal within the depth of penetration required for the applicable joint.

c. Slag inclusion is permissible if it occurs between layers of the weld, is substantially parallel to the plate surface, and its width is not more than one-half the width of the weld metal; or when it occurs across the thickness of the plate and is equal to not more than 10 percent of the thickness of the thinner plate.

d. Gas pockets are permissible provided the combined area of all gas pockets does not exceed 0.02 sq in. per sq in. (2 percent) of weld metal, no pocket exceeds 1/16 in. in maximum dimension, and no more than six gas pockets approach this maximum dimension per square inch of weld metal.

e. If any segment is defective, additional segments shall be cut from the work of the same welder or welding operator approximately 2 ft on each side of the defective segment. If either of these additional segments is defective, more segments shall be cut at intervals of approximately 2 ft until the limits of the defective welding have been definitely established; or the erector may replace all the welding performed by that welder or welding operator without cutting additional segments.

6.2.7 Repair of Defective Welds

a. Defects in welds shall be repaired by chipping or melting out from one or from both sides of the joint, as required, and rewelding. Only sufficient cutting out of defective joints necessary to correct the defects is required.

b. All repaired welds in joints shall be checked by repeating the original inspection procedure and by repeating one of the testing methods of Section 5.3 subject to the approval of the purchaser.

6.2.8 Closure of Openings

All openings cut in shell joints for examination by the sectioning method shall be closed by the erector. Closure of plug openings shall be in accordance with any of the following methods where such methods are applicable to the particular joint and thickness of material:

a. Plug openings in horizontal joints may be filled by inserting a disk in the hole in a mid-position between the surfaces of the thinner plate. The disk shall not be more than one-quarter of the thickness of the thinner plate, nor less than ⅛ in. thickness, and shall have a close fit in the hole. The upper side of the hole on each side of the disk shall be tapered sufficiently to permit depositing a sound weld in the opening. Both sides of the disk shall be welded over completely, fusing the circular edges of the disk with the plate and making the surfaces of the weld substantially flush with the plate surfaces.

b. Plug openings in vertical or horizontal joints, where the thickness of the plates or the thickness of the thinner plate at the joint is not greater than one-third the diameter of the hole, shall be filled completely with weld metal applied from the outside of the tank shell. Before welding, place a backing plate on the inside of the tank shell over the opening and sufficiently taper the upper side of the hole from the backing plate outward to permit depositing a sound weld in the opening.

c. Plug openings in vertical or horizontal joints, where the thickness of the plates or the thickness of the thinner plate at the joint is not less than one-third nor greater than two-thirds the diameter of the hole, shall be filled completely with weld metal applied from both sides of the tank shell. Before welding, sufficiently taper the upper side of the hole from the center outward on both sides of the plate to permit depositing a sound weld in the opening.

d. Plug openings in vertical or horizontal butt joints, where the thickness of the plates or the thickness of the thinner plate at the joint does not exceed ⅞ in., shall be filled completely with weld metal applied from the outside of the tank shell. Before welding, place a backing plate on the inside of the tank shell or a thin disk (not over ⅛ in. thick) at the bottom of the hole and chip a vertical or horizontal groove on the outside of the plate, extending from the hole in opposite directions. The length of the groove on each side of the opening shall have a slope of approximately one in one and one-half, extending from the bottom of the hole to the surface. The groove at the opening shall have sufficient width to provide a taper to the bottom of the hole to permit depositing a sound weld in the opening.

e. In plates of any thickness, plug openings in vertical or horizontal butt joints shall be filled completely with weld metal applied from both sides of the plate. Before welding, place a thin disk (not over ⅛ in. thick) in the hole at the middle of the plate and chip vertical or horizontal grooves on both sides of the plate, extending from the hole in opposite directions. The groove on each side of the opening shall have a slope along its length of approximately one in one and one-half, extending from the middle of the plate to the surface. The groove at the opening shall have sufficient width to provide a taper to the middle of the plate to permit depositing a sound weld in the opening.

6.2.9 Record of Segments

a. The segments, after removal, shall be properly stamped or tagged for identification. After the segments have been etched, they should be kept in proper containers, with a record of their place of removal as well as of the welder or welding operator who performed the welding.

b. A record shall be made by the erector of all segments, with their identification marks, on a developed shell-plate diagram.

c. The segments shall be the property of the purchaser, unless otherwise agreed upon between the purchaser and the erector.

7. WELDING PROCEDURE AND WELDER QUALIFICATIONS

7.1 GENERAL

7.1.1 Definitions

The following definitions shall apply to welders and welding procedures:

1. Welder: One who is capable of performing a manual or semiautomatic welding operation.

2. Welding operator: One who operates machine welding equipment or automatic welding equipment.

3. Manual welding: Welding wherein the entire welding operation is performed and controlled by hand.

4. Automatic welding (machine welding): Welding with equipment which performs the welding operation under the observation and control of an operator.

5. Semiautomatic arc welding: Arc welding with equipment which controls only the filler-metal feed. The advance of the welding is manually controlled.

6. Shielded Metal-Arc Welding (SMAW): An arc-welding process wherein coalescence is produced by heating with an arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

7. Gas Metal-Arc Welding (GMAW): An arc-welding process wherein coalescence is produced by heating with an arc between a continuous filler-metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas or gas mixture. Some methods of this process are called MIG or CO_2 welding.

8. Flux-Cored-Arc Welding (FCAW): An arc-welding process wherein coalescence is produced by heating with an arc between a continuous filler-metal (consumable) electrode and the work. Shielding is obtained from a flux contained within the electrode. Additional shielding may or may not be obtained from an externally supplied gas or gas mixture.

9. Electrogas Welding: A method of gas metal-arc welding or flux-cored-arc welding wherein molding shoes confine the molten weld metal for vertical position welding.

10. Submerged Arc Welding (SAW): An arc-welding process wherein coalescence is produced by heating with an arc or arcs between a bare metal electrode or electrodes and the work. The arc is shielded by a blanket of granular fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

R *11. Electroslag welding:* A welding process wherein coalescence is produced by molten slag which melts the filler metal and the surfaces of the work to be welded. The weld pool is shielded by this slag which moves along the full cross section of the joint as welding progresses. The conductive slag is maintained molten by its resistance to the electric current passing between the electrode and the wash.

7.2 WELDING PROCEDURE QUALIFICATION

a. The manufacturer shall conduct tests of his procedures to demonstrate their suitability in making welds which conform to the specified requirements.

b. The specification for each welding procedure shall be qualified in accordance with the latest practice as given in the applicable rules in *Welding Qualifications,* Sect. IX, *ASME Boiler and Pressure Vessel Code,* except as stated in the following Par. (c) for horizontal joints, and Par. (d) for material not listed in Sect. IX; see Par. 5.2.1(i) for plate surfaces having protective coatings.

c. The welding for horizontal butt joints of the tank shell which do not require complete penetration shall have the procedure qualified by the reduced-section tension test only. The reduced-section tension test shall give values not less than 63 percent of the minimum tensile strength requirement of the parent material.

d. All materials listed in Par. 2.1, 2.2, 2.4, 2.6, 2.7, D.2 of Appendix D, and G.2 of Appendix G shall be accepted in P-Number 1 material grouping even though the specific material may not be included in Table Q-11.1 of Sect. IX of the ASME Code.

7.3 WELDER QUALIFICATION

a. The manufacturer shall conduct tests for all welders assigned to manual and semiautomatic welding and all operators assigned to automatic welding to demonstrate their ability to make acceptable welds. Tests conducted by one manufacturer shall not qualify a welder or welding operator to do work for another manufacturer.

b. The tests shall be as prescribed for welder qualification in Sect. IX of the ASME Code.

c. The records of such tests shall be as follows:

1. Each welder or welding operator shall be assigned an identifying number, letter, or symbol by the manufacturer. Except for all roof seams and all flange-to-neck joints, this identifying mark shall be stamped, either by hand or machine, on all tanks adjacent to and at intervals of not more than 3 ft along the welds made by a welder or welding operator—or the manufacturer may keep, until after test, a record of welders or welding operators employed on each joint and shell opening joint and omit the stamping. If such a record is kept, it shall be available to the inspector.

2. The manufacturer shall maintain a record of the welders or welding operators employed by him, showing the date and result of tests and the identifying mark assigned to each. These records shall be certified by the manufacturer and shall be accessible to the inspector.

8. MARKING

8.1 NAMEPLATES

a. Tanks made in accordance with this standard by manufacturers authorized to use the API monogram shall be identified by a nameplate bearing the API monogram, the manufacturer's name, the number of his certificate of authority to use the API monogram, and other information as shown in Fig. 8-1.

b. The nameplate shall be attached to the tank shell adjacent to a manhole or to a manhole reinforcing plate immediately above the manhole. A nameplate which is placed directly on the shell plate or reinforcing plate shall be attached by continuous welding or brazing all around the plate. A nameplate which is riveted or otherwise permanently attached to an auxiliary plate of ferrous material shall be attached to the tank shell plate or reinforcing plate by continuous welding. The nameplate shall be rolled or cast corrosion-resistant metal.

c. When a tank is fabricated and erected by a single organization, that organization's name and certificate number shall appear on the nameplate both as fabricator and erector.

d. When a tank is fabricated by one organization and erected by another, both organizations must have applied for and received a "Certificate of Authority to Use Official API Monogram." The names and certificate numbers of both organizations shall appear on the nameplate, or separate nameplates shall be applied by each.

8.2 DIVISION OF RESPONSIBILITY

Unless otherwise agreed upon, when a tank is fabricated by one organization and erected by another, the erecting manufacturer shall be considered as having the primary responsibility. He shall take such precautions as are necessary to assure himself and the purchaser that the materials from which the tank is made and the fabrication of such materials are in accord with all applicable requirements.

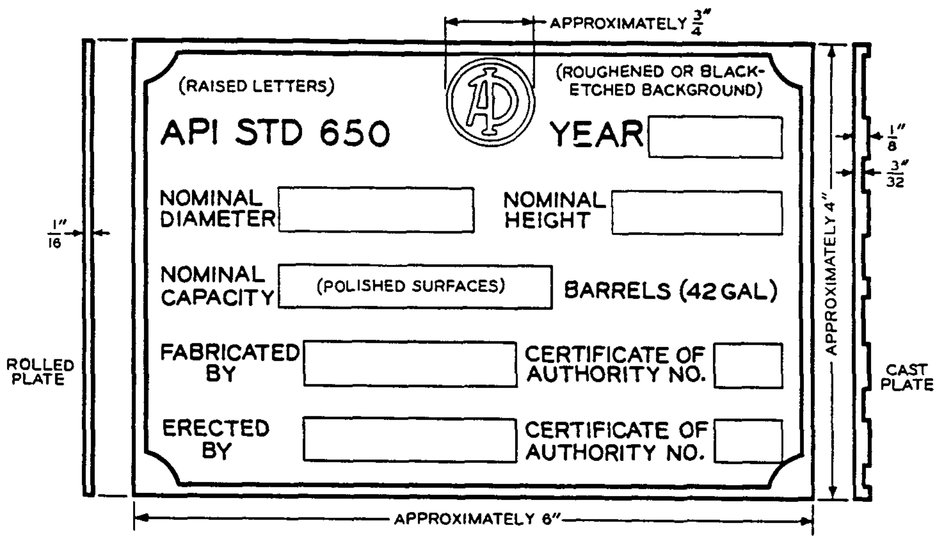
8.3 RESTRICTIONS ON USE OF API MONOGRAM

a. The API monogram shall not be used on tanks which do not meet the specifications required by this standard.

b. Authority to use the API monogram will be granted to any manufacturer under the rules and regulations given in Appendix E. The API monogram shall not be used by manufacturers who have not applied for and received the certificate of authority.

c. Each licensee shall report annually to the Institute, on forms provided, regarding his use of the monogram. Failure to so report is cause for cancellation of authority to use it. If an authorized licensee does not use the monogram in any two consecutive years, his certificate shall be cancelled. When a licensee makes material in accordance with this specification and fails to use the monogram thereon as stipulated herein, his certificate shall be cancelled. It will be necessary to make another application in order to be reinstated.

d. The use of the letters "API" or reference to API specifications to describe material which does not comply completely with the specifications in this standard is prohibited and shall be sufficient cause for cancellation of authority to use the API monogram.



Note: On request by the purchaser or at the discretion of the manufacturer, additional pertinent information may be shown on the nameplate, and the size of the nameplate may be increased proportionately.

FIG. 8-1—API Monogrammed Nameplate.

APPENDIX A

REFERENCE AND TYPICAL DESIGN DATA

The data in this appendix are not required to comply with the specifications in this standard and are presented for the convenience of tank users and manufacturers.

The following tables show typical sizes, capacities, and shell-plate thicknesses for tanks which may be built in accordance with this standard. In these tables no standardized relationship between tank sizes and course widths is implied.

Table A-1—Typical Sizes and Corresponding Nominal Capacities for Tanks with 72-In. Butt-Welded Courses.

Table A-2—Shell-Plate Thicknesses for Typical Sizes of Tanks with 72-In. Butt-Welded Courses.

Table A-3—Typical Sizes and Corresponding Nominal Capacities for Tanks with 96-In. Butt-Welded Courses.

Table A-4—Shell-Plate Thicknesses for Typical Sizes of Tanks with 96-In. Butt-Welded Courses.

Fig. A-1 shows typical designs of stiffening-ring sections for open-top tank shells, and Table A-5 gives the corresponding section moduli.

TABLE A-1—Typical Sizes and Corresponding Nominal Capacities for Tanks with 72-In. Butt-Welded Courses

(1) Tank Diameter (Feet)	(2) Approx. Capacity per Foot of Height (Barrels)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		Tank Height (Feet)								
		12	18	24	30	36	42	48	54	60
		Number of Courses in Completed Tank								
		2	3	4	5	6	7	8	9	10
10	14.0	170	250	335	420	505	...	...	...	...
15	31.5	380	565	755	945	1,130	...	...	...	...
20	56.0	670	1,010	1,340	1,680	2,010	2,350	2,690	...	...
25	87.4	1,050	1,570	2,100	2,620	3,150	3,670	4,200	4,720	5,250
30	126	1,510	2,270	3,020	3,780	4,530	5,290	6,040	6,800	7,550
35	171	2,060	3,080	4,110	5,140	6,170	7,200	8,230	9,250	10,280
40	224	2,690	4,030	5,370	6,710	8,060	9,400	10,740	12,090	13,430
45	283	3,400	5,100	6,800	8,500	10,200	11,900	13,600	15,300	17,000
50	350	4,200	6,290	8,390	10,490	12,590	14,690	16,790	18,880	20,980
60	504	6,040	9,060	12,090	15,110	18,130	21,150	24,170	27,190	30,220
70	685	8,230	12,340	16,450	20,560	24,680	28,790	32,900	37,010	41,130
80	895	10,740	16,120	21,490	26,860	32,230	37,600	42,970	48,350	53,720
90	1,133	13,600	20,390	27,190	33,990	40,790	47,590	54,390	61,180	67,980
100	1,399	16,790	25,180	33,570	41,970	50,360	58,750	67,140	75,540	83,930
120	2,014	...	36,260	48,340	60,430	72,510	84,600	96,690	108,800	120,900
140	2,742	...	49,350	65,800	82,250	98,700	115,100	131,600	148,000	164,500
160	3,581	...	...	...	107,400	128,900	150,400	171,900	193,400	214,900
180	4,532	...	...	...	136,000	163,200	190,400	217,500	244,800	**254,300**
200	5,595	...	...	...	167,900	201,400	235,000	268,600	**284,500**	**D = 174**
220	6,770	...	...	...	203,100	243,700	284,400	**322,300** **D = 219**	**D = 194**	

Notes:

1. Nominal capacities given in this table are based on the formula:

Capacity (42-gal bbl) $= 0.14\ D^2 H$

Where:
D = centerline shell diameter.
H = listed tank height.

2. Capacities and diameters shown in boldface type [Columns (9), (10) and (11)] are maximum for the tank heights shown, based on the 1½-in. maximum permissible thickness of shell plates and maximum allowable design stresses.

TABLE A-2—Shell-Plate Thicknesses for Typical Sizes of Tanks with 72-In. Butt-Welded Courses

(1) Tank Diameter (Feet)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12) Max. Allowable Height* for Diameters Listed (Feet)
	Tank Height (Feet)										
	6	12	18	24	30	36	42	48	54	60	
	Number of Courses in Completed Tank										
	1	2	3	4	5	6	7	8	9	10	
	Shell-Plate Thickness (Inches)										
10	3/16	3/16	3/16	3/16	3/16	3/16	...	...	...	...	...
15	3/16	3/16	3/16	3/16	3/16	3/16	...	...	...	...	...
20	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	...	...	...
25	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	0.20	0.22	...
30	3/16	3/16	3/16	3/16	3/16	3/16	3/16	0.21	0.24	0.26	...
35	3/16	3/16	3/16	3/16	3/16	3/16	0.21	0.24	0.27	0.30	...
40	3/16	3/16	3/16	3/16	3/16	0.21	0.24	0.28	0.31	0.35	...
45	3/16	3/16	3/16	3/16	3/16	0.23	0.27	0.31	0.35	0.39	...
50	1/4	1/4	1/4	1/4	1/4	0.26	0.30	0.35	0.39	0.43	...
60	1/4	1/4	1/4	1/4	0.26	0.31	0.36	0.41	0.47	0.52	...
70	1/4	1/4	1/4	1/4	0.30	0.36	0.42	0.48	0.54	0.61	...
80	1/4	1/4	1/4	0.27	0.34	0.41	0.48	0.55	0.62	0.69	...
90	1/4	1/4	1/4	0.31	0.38	0.46	0.54	0.62	0.70	0.78	...
100	1/4	1/4	1/4	0.34	0.43	0.51	0.60	0.69	0.78	0.86	...
120	5/16	5/16	5/16	0.41	0.51	0.62	0.72	0.83	0.93	1.03	...
140	5/16	5/16	0.35	0.47	0.60	0.72	0.84	0.96	1.08	1.21	...
160	5/16	5/16	0.40	0.54	0.68	0.82	0.96	1.10	1.24	1.38	65.3
180	5/16	5/16	0.45	0.61	0.76	0.92	1.08	1.24	1.39	...	58.2
200	5/16	0.32	0.50	0.67	0.85	1.02	1.20	1.37	...	...	52.5
220	3/8	3/8	0.55	0.74	0.94	1.13	1.32	...	...	...	47.8

* Based on the 1½-in. maximum permissible thickness of shell plates and the maximum allowable design stresses.

Note: Plate thicknesses shown in the table in fractions are thicker than required for hydrostatic loading but for practical reasons have been fixed at the values given; therefore, plates for these courses may be ordered on a weight basis. Plate thicknesses shown in the table in decimals are based on maximum allowable stresses; therefore, plates for these courses must be ordered on a thickness basis (see Sect. 2.1 and Par. 3.3.3 for thickness requirements and methods of ordering).

In deriving the plate thickness values shown, it was assumed, on the basis of average mill practice, that the edge thickness of plates 72 in. wide, ordered on the weight basis, would underrun the nominal thickness by 0.03 in. Sect 2.1 permits an actual thickness to underrun a calculated or specified thickness by 0.01 in.; consequently, fractional thickness values are shown only when the fractional value exceeds the calculated thickness of the course in question by more than 0.02 in.

TABLE A-3—Typical Sizes and Corresponding Nominal Capacities for Tanks with 96-In. Butt-Welded Courses

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Tank Height (Feet)						
		16	24	32	40	48	56	64
Tank Diameter (Feet)	Approx Capacity per Foot of Height (Barrels)	Number of Courses in Completed Tank						
		2	3	4	5	6	7	8
10	14.0	225	335	450	...	...	...	...
15	31.5	505	755	1,010	1,260	...	...	...
20	56.0	900	1,340	1,790	2,240	2,690	...	...
25	87.4	1,400	2,100	2,800	3,500	4,200	4,900	5,600
30	126	2,020	3,020	4,030	5,040	6,040	7,050	8,060
35	171	2,740	4,110	5,480	6,850	8,230	9,600	10,960
40	224	3,580	5,370	7,160	8,950	10,740	12,530	14,320
45	283	4,530	6,800	9,060	11,330	13,600	15,860	18,130
50	350	5,600	8,390	11,190	13,990	16,790	19,580	22,380
60	504	8,060	12,090	16,120	20,140	24,170	28,200	32,230
70	685	10,960	16,450	21,930	27,420	32,900	38,380	43,870
80	895	14,320	21,490	28,650	35,810	42,970	50,130	57,300
90	1,133	18,130	27,190	36,260	45,320	54,390	63,450	72,520
100	1,399	22,380	33,570	44,760	55,950	67,140	78,340	89,530
120	2,014	...	48,340	64,460	80,580	96,690	112,800	128,900
140	2,742	...	65,800	87,740	109,700	131,600	153,500	175,500
160	3,581	...	...	114,600	143,200	171,900	200,500	229,200
180	4,532	...	...	145,000	181,300	217,500	253,800	**238,100**
200	5,595	...	...	179,100	223,800	268,600	**274,200**	***D* = 163**
220	6,770	...	...	216,700	270,800	**322,300** ***D* = 219**	***D* = 187**	

Notes:
1. Nominal capacities given in this table are based on the formula:

Capacity (42-gal bbl) $= 0.14\ D^2H$

Where:
D = centerline shell diameter.
H = listed tank height.

2. Capacities and diameters shown in boldface type [Columns (7), (8), and (9)] are maximum for the tank heights shown, based on the 1½-in. maximum permissible thickness of shell plates and maximum allowable design stresses.

TABLE A-4—Shell-Plate Thicknesses for Typical Sizes of Tanks with 96-In. Butt-Welded Courses

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Tank Height (Feet)								
	8	16	24	32	40	48	56	64	
Tank Diameter (Feet)	Number of Courses in Completed Tank								Max. Allowable Height* for Diameters Listed (Feet)
	1	2	3	4	5	6	7	8	
	Shell-Plate Thickness (Inches)								
10	3/16	3/16	3/16	3/16	...	...	...	...	...
15	3/16	3/16	3/16	3/16	3/16	...	...	...	...
20	3/16	3/16	3/16	3/16	3/16	3/16	...	...	...
25	3/16	3/16	3/16	3/16	3/16	3/16	0.20	0.23	...
30	3/16	3/16	3/16	3/16	3/16	0.21	0.24	0.28	...
35	3/16	3/16	3/16	3/16	0.20	0.24	0.28	0.33	...
40	3/16	3/16	3/16	3/16	0.23	0.28	0.32	0.37	...
45	3/16	3/16	3/16	0.21	0.26	0.31	0.36	0.42	...
50	1/4	1/4	1/4	0.25	0.29	0.35	0.40	0.46	...
60	1/4	1/4	1/4	0.27	0.34	0.41	0.48	0.55	...
70	1/4	1/4	1/4	0.32	0.40	0.48	0.56	0.65	...
80	1/4	1/4	0.27	0.37	0.46	0.55	0.64	0.74	...
90	1/4	1/4	0.31	0.41	0.52	0.62	0.72	0.83	...
100	1/4	1/4	0.34	0.46	0.57	0.69	0.80	0.92	...
120	5/16	5/16	0.41	0.55	0.69	0.83	0.97	1.10	...
140	5/16	5/16	0.47	0.64	0.80	0.96	1.13	1.29	...
160	5/16	0.35	0.54	0.73	0.91	1.10	1.29	1.47	65.3
180	5/16	0.40	0.61	0.82	1.03	1.24	1.45	...	58.2
200	5/16	0.44	0.67	0.91	1.14	1.37	...	...	52.5
220	3/8	0.48	0.74	1.00	1.25	...	...	...	47.8

* Based on the 1½-in. maximum permissible thickness of shell plates and the maximum allowable design stresses.

Note: Plate thicknesses shown in the table in fractions are thicker than required for hydrostatic loading but for practical reasons have been fixed at the values given; therefore, plates for these courses may be ordered on a weight basis. Plate thicknesses shown in the table in decimals are based on maximum allowable stresses; therefore, plates for these courses must be ordered on a thickness basis (see Sect. 2.1 and Par. 3.3.3 for thickness requirements and methods of ordering).

In deriving the plate thickness values shown, it was assumed, on the basis of average mill practice, that the edge thickness of plates 96 in. wide, ordered on the weight basis, would underrun the nominal thickness by 0.05 in. Sect. 2.1 permits an actual thickness to underrun a calculated or specified thickness by 0.01 in.; consequently, fractional thickness values are shown only when the fractional value exceeds the calculated thickness of the course in question by more than 0.04 in.

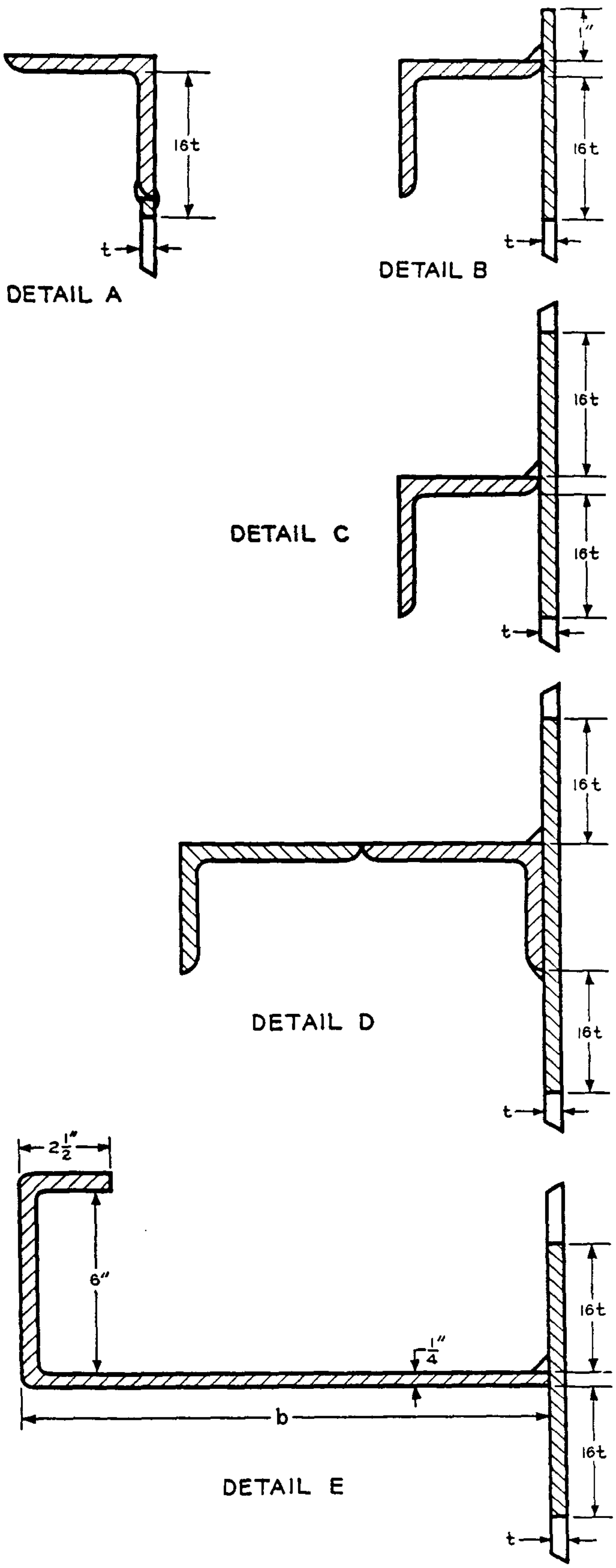


FIG. A-1—Typical Stiffening-Ring Sections on Tank Shells (See Table A-5).

TABLE A-5—Section Moduli of Various Stiffening-Ring Sections on Tank Shells

(1) Member Size (Inches)	(2) 3/16	(3) 1/4	(4) 5/16	(5) 3/8	(6) 7/16
	Shell Thickness (Inch) — Section Moduli (Cubic Inches)				
Top Angle: Detail A, Fig. A-1					
2½ by 2½ by ¼	0.41	0.42	...	...	...
2½ by 2½ by 5/16	0.51	0.52	...	...	...
3 by 3 by 3/8	0.89	0.91	...	...	...
Curb Angle: Detail B, Fig. A-1					
2½ by 2½ by ¼	1.61	1.72	...	...	...
2½ by 2½ by 5/16	1.89	2.04	...	...	...
3 by 3 by ¼	2.32	2.48	...	...	...
3 by 3 by 3/8	2.78	3.35	...	...	...
4 by 4 by ¼	3.64	4.41	...	...	...
4 by 4 by 3/8	4.17	5.82	...	...	...
One Angle: Detail C, Fig. A-1					
2½ by 2½ by ¼	1.68	1.79	1.87	1.93	2.00
2½ by 2½ by 5/16	1.98	2.13	2.23	2.32	2.40
4 by 3 by ¼	3.50	3.73	3.89	4.00	4.10
4 by 3 by 5/16	4.14	4.45	4.66	4.82	4.95
5 by 3 by 5/16	5.53	5.96	6.25	6.47	6.64
5 by 3½ by 5/16	6.13	6.60	6.92	7.16	7.35
5 by 3½ by 3/8	7.02	7.61	8.03	8.33	8.58
6 by 4 by 3/8	9.02	10.56	11.15	11.59	11.93
Two Angles: Detail D, Fig. A-1					
4 by 3 by 5/16	11.27	11.78	12.20	12.53	12.81
4 by 3 by 3/8	13.06	13.67	14.18	14.60	14.95
5 by 3 by 5/16	15.48	16.23	16.84	17.34	17.74
5 by 3 by 3/8	18.00	18.89	19.64	20.26	20.77
5 by 3½ by 5/16	16.95	17.70	18.31	18.82	19.23
5 by 3½ by 3/8	19.75	20.63	21.39	22.01	22.54
6 by 4 by 3/8	27.74	28.92	29.95	30.82	31.55
Formed Plate: Detail E, Fig. A-1					
b = 10	...	23.29	24.63	25.61	26.34
b = 12	...	29.27	31.07	32.36	33.33
b = 14	...	35.49	37.88	39.53	40.78
b = 16	...	42.06	45.07	47.10	48.67
b = 18	...	48.97	52.62	55.07	56.99
b = 20	...	56.21	60.52	63.43	65.73
b = 22	...	63.80	68.78	72.18	74.89
b = 24	...	71.72	77.39	81.30	84.45
b = 26	...	79.99	86.35	90.79	94.41
b = 28	...	88.58	95.66	100.65	104.77
b = 30	...	97.52	105.31	110.88	115.52
b = 32	...	106.78	115.30	121.47	126.66
b = 34	...	116.39	125.64	132.42	138.17
b = 36	...	126.33	136.32	143.73	150.07
b = 38	...	136.60	147.35	155.40	162.34
b = 40	...	147.21	158.71	167.42	174.99

APPENDIX B

RECOMMENDED PRACTICE FOR CONSTRUCTION OF FOUNDATIONS FOR API VERTICAL CYLINDRICAL OIL STORAGE TANKS

B.1 SCOPE

a. The following recommendations are intended to establish certain minimum basic requirements for the design and construction of foundations under vertical steel oil storage tanks with flat bottoms. They are offered as an outline of good practice and to point out some precautions which should be observed in constructing such foundations.

b. Because of the wide variety of surface, subsurface, and climatic conditions, it obviously is not practical to establish design data to cover all such situations. The allowable soil loading and the exact type of subsurface construction to use necessarily must be decided for each individual case after careful consideration. The same rules and precautions should be used in the selection of foundation sites as would be applicable in designing or building foundations for any other structure of comparable magnitude.

B.2 SUBSURFACE CONSTRUCTION

a. At any tank site, the nature of the subsurface conditions must be known in order to estimate the amount of settlement that will be experienced and the probable result. This information may be obtained by exploratory work, consisting of making deep borings and load and soil tests, and by review of experience and history of similar structures in the vicinity. The subgrade must be capable of sustaining the load of the tank and its contents. The total of final uniform settlement must not be sufficient to strain connecting piping or produce inaccuracies of gaging, nor should the settlement continue to a point where the tank bottom is below the surrounding ground surface.

b. Some of the many variations in conditions requiring special engineering consideration are:

1. Hillside sites, where part of a tank may be on undisturbed ground or rock and part on fill or other construction, or where the depth of required fill is variable.

2. Sites on swampy or filled ground, where layers of muck or compressible vegetation are at or below the surface, or where unstable or corrosive materials may have been deposited as fill.

3. Sites underlain by layers of plastic clay, which may temporarily support heavy loads but which will settle excessively over long periods of time.

4. Sites adjacent to water courses or deep excavations, where lateral stability of the ground is questionable.

5. Sites immediately adjacent to heavy structures, which distribute some of their load to the subsoil under the tank site, thereby reducing its capacity to carry the additional load without excessive settlement.

6. Sites where tanks may be exposed to flood waters, resulting in possible uplift, displacement, or scour.

c. If the subgrade is weak and inadequate to carry the load of the filled tank without excessive settlement, it should be recognized that shallow or superficial construction under the tank bottom will not much improve it. One or more of the following general methods will probably have to be used:

1. Remove the objectionable material and replace it with other suitable and compact material.

2. Compact the soft material with short piles or by preloading with an overburden of earth, suitably drained, or other material.

3. Compact the soft material by removal of the water content by drainage, if practicable.

4. Stabilize the soft material by chemical methods or injection of cement grout.

5. Support the load on a more stable material underneath the subgrade by driving bearing piles or constructing foundation piers down to it. This will involve construction of a reinforced slab on the piles to distribute the load of the tank bottom.

6. Construct a foundation of some type which will distribute the load over a sufficiently large area of the soft material so that the load intensity will be within allowable limits and excessive settlement will not occur.

d. The filling material used to replace muck or other objectionable materials or to build up the grade to suitable height should be sound and durable and at least equivalent to that used for fill in good highway practice. It should be free of vegetation and organic matter and should contain no cinders or other substances which would cause corrosion of the tank bottom. The fill should be thoroughly compacted by the best available means.

B.3 TANK GRADES

a. It is suggested that the grade or surface upon which the tank bottom will rest be constructed at least 1 ft above the surrounding ground surface. This will provide suitable drainage, will help keep the bottom dry, and will compensate for some small settlement which is likely to occur.

b. It is suggested that the top 3 in. or 4 in. of the finished grade consist of clean sand, gravel, crushed stone (not over 1 in. in maximum size) or some similar inert material which can be readily shaped to the proper contour. During construction, the movement of equipment and materials across the grade will mar the surface of the softer materials. These irregularities should be corrected before the bottom plates are placed for welding. The finished grade may be oiled or stabilized in some manner to preserve better contour during construction and to protect the tank bottom against ground moisture. Caution should be observed, however, that the quantity or kind of material used for this purpose does not create welding difficulties or risk of galvanic corrosion.

c. It is suggested that the finished tank grade be crowned from the outer periphery to the center. A slope of 1 in. in 10 ft is suggested as a minimum. This crown will partly compensate for slight settlement which is likely to be greater at the center. It will also facilitate cleaning and the removal of water and sludge through openings in the shell or from sumps situated near the shell. Because the amount of crown will affect the lengths of roof-supporting columns, it is essential that the tank manufacturer be fully informed of this feature sufficiently in advance.

d. If the tank bottom is built on a flat concrete slab, a similar type of finished grade is recommended so that it will act as a cushion and provide the proper contour for the slope of the bottom plates.

B.4 EARTH FOUNDATIONS

a. When an engineering evaluation of subsurface conditions, based on experience and/or exploratory work, indicates that it is unnecessary to construct a substructure to support the tank, suitable foundations may be constructed from earth materials. The performance requirements for an earth foundation are identical with those associated with more extensive foundations. Specifically, the foundation should:

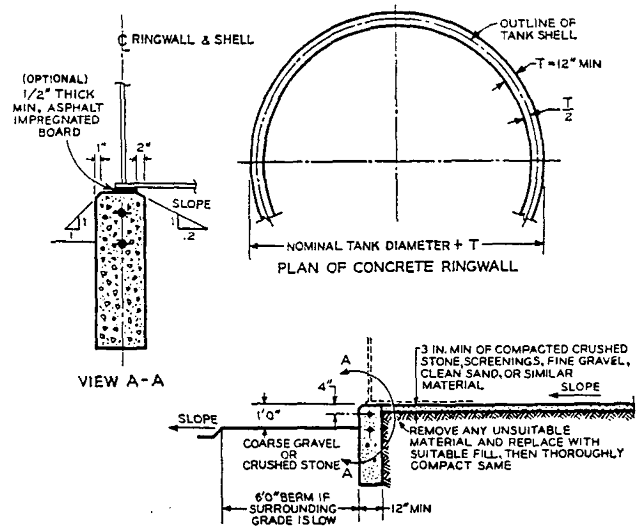
1. Provide a stable plane for the support of the tank.
2. Limit overall settlement of the tank grade to values compatible with allowances provided in the design of connecting piping.
3. Provide adequate drainage.

b. While many satisfactory designs are possible, provided sound engineering judgment is used in their development, two common types are recommended herein on the basis of satisfactory long-term performance. Details of the two recommended designs (Earth Foundations with a Ringwall, and Earth Foundations without a Ringwall) are illustrated in Fig. B-1 and B-2.

B.4.1 Earth Foundations with a Ringwall

a. Large tanks and tanks with high shells impose substantial loads on the foundation under the shell. This is particularly important with floating-roof tanks with regard to shell distortion. In these or any other cases where the ability of an earth foundation to carry the shell loads directly is doubtful, it is recommended that a ringwall foundation be used. This type of construction has the following advantages over an earth foundation without a ringwall:

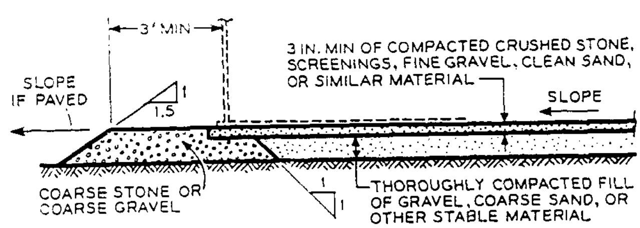
1. Will provide better distribution of the concentrated load of the shell to produce a more nearly uniform soil loading under the tank.
2. Will provide a level and solid starting plane for construction of the shell and for the application of insulation when required.
3. Will provide a better means for leveling the tank grade and preserving its contour during construction.
4. Will retain the fill under the tank bottom and prevent loss of material from erosion or adjacent tank excavation.
5. Will act as a moisture barrier.



Notes:

1. For reinforcement, see Par. B.4.1(c).
2. Top of concrete ringwall should be smooth and level. Strength of concrete shall be at least 3,000 psi after 28 days. Lap reinforcement splices to develop full strength in bond.

FIG. B-1—Example of Concrete Ringwall Foundation.



Note: Bottom of excavation should be level. Remove muck, vegetation, and unstable materials to whatever depth is necessary.

FIG. B-2—Example of Earth Foundation.

b. When designing concrete ringwalls, it is desirable that they be so proportioned that the average unit soil loading under the wall will be approximately the same as under the confined earth at the same depth. It is recommended that the thickness of ringwalls be not less than 12 in. and that the center-to-center diameter equal the nominal tank diameter. The depth of the wall will depend upon local conditions; but there appears to be no need to construct the wall to any greater depth than the soil is disturbed in constructing the fill and grade under the tank, as it adds but little to the gross area and nothing to the sustaining capacity of the subsoil. The top of the wall should be smooth and level within ±⅛ in. in any 30-ft. circumferential length. No point in the circumference of the wall should vary more than ±¼ in. from the established elevation. Recesses should be provided in the wall for flush-type cleanouts, drawoff sumps, and any other appurtenances which
R require recessing. (See Par. 5.4.e.1.)

c. The ringwall should be reinforced against temperature and shrinkage and to resist the lateral pressure of the confined fill with its surcharge. It is suggested that the minimum reinforcing in any ringwall be 0.002 times the cross-sectional area of the wall above-grade, with additional reinforcement as may be required for resisting lateral earth pressure. The latest edition of the American Concrete Institute's *Building Code Requirements for Reinforced Concrete* (ACI 318 and ANSI A89.1) is recommended for stress values and material specifications.

B.4.2 Earth Foundations Without a Ringwall

Where earth foundations without a ringwall are appropriate, careful selection of design details is necessary to assure satisfactory performance. (See Par. 5.4.e.2.) R
The general type of foundation suggested is shown in Fig. B-2. Significant details include:

1. Three-foot shoulder and berm should be protected against weathering and tank runoff by constructing it of crushed rock or covering it with a permanent paving material.

2. Care should be exercised during construction to prepare and maintain a smooth and level surface for tank bottom plates.

3. Tank grade should be constructed to provide adequate drainage away from the tank foundation.

APPENDIX C

FLOATING ROOFS

C.1 SCOPE

The requirements given herein are minimum and, unless otherwise qualified in the text, apply to pan-type, pontoon-type, and double-deck-type floating roofs. It is intended to limit only those factors that affect the safety and durability of the installation, and which are considered to be consistent with the quality and safety requirements of this specification. Numerous alternate details and proprietary appurtenances are available; however, their use requires agreement between the purchaser and the manufacturer.

C.2 MATERIAL

Material requirements as set forth in Part 2 of this specification shall apply, except as specifically covered in this appendix.

C.3 DESIGN

C.3.1 General

The roof and accessories shall be so designed and constructed as to allow the tank to overflow and then return to a liquid level which floats the roof well below the top of the tank shell without damage to any part of the roof, tank, or appurtenances. During such an occurrence, no manual attention shall be required to protect the roof, tank, or appurtenances. If a wind-skirt or top-shell extension is used for the purpose of containing the roof seals at the highest point of travel, overflow drainage openings shall be provided to indicate the rise of the liquid level in the tank above the designed capacity height, unless the tank shell has been designed for a liquid height to the top of the shell extension.

C.3.2 Joint Design

Sect. 3.1 of this specification shall apply.

C.3.3 Decks

a. In corrosive service, such as sour crude oil, it is suggested that roofs be of the contact type designed to eliminate the presence of any air-vapor mixture under the deck.

b. Unless otherwise specified by the purchaser, all deck plates shall have a minimum nominal thickness of $3/16$ in. (7.65 lb per sq ft plate, 0.180-in. plate, or 0.1799-in. sheet).

c. Deck plates shall be joined by continuous full-fillet welds on the top side. On the bottom side where flexure is anticipated adjacent to girders, support legs, or other relatively rigid members, full-fillet welds not less than 2 in. long on 10-in. centers shall be used on any plate laps which occur within 12 in. of any such rigid support or member.

d. Top decks of double-deck roofs and of pontoon sections, which are designed with a permanent slope for drainage, shall have a minimum slope of $3/16$ in. in 12 in. and preferably shall be lapped to provide the best drainage. Plate buckles shall be kept to a minimum.

C.3.4 Pontoon Volume

The minimum pontoon volume of a single-deck pontoon roof shall be sufficient to keep the roof floating on a liquid with a specific gravity of 0.7 if the single deck and any two pontoon compartments are punctured. The minimum pontoon volume of a double-deck roof shall be sufficient to keep the roof floating on a liquid with a specific gravity of 0.7 if any two pontoon compartments are punctured. The primary drainage shall be considered as inoperative for either type of roof, but no live load need be considered for the preceding design requirements. In addition, either type of roof with the primary drainage inoperative shall accommodate a 10-in. rainfall in a 24-hr period over the entire roof area without sinking (with no compartments or decks punctured). The roof may be designed to carry the entire 24-hr rainfall, or emergency drains may be installed which will limit the roof load to some lesser volume of water which the roof will carry safely. Such emergency drains shall not allow the product to flow onto the roof deck.

C.3.5 Pontoon Openings

Each compartment shall be provided with a manway with a raintight cover. The manway covers shall be provided with suitable hold-down fixtures or other means to prevent wind from removing the covers. The top edge of manway necks shall be at an elevation to prevent water entering the compartments under the conditions set forth in Par. C.3.4.

C.3.6 Bulkheads

All internal bulkhead plates or sheets shall be single-fillet welded along their bottom and vertical edges for liquid tightness. When specified by the purchaser, the top edge of the bulkhead shall also be provided with a continuous single-fillet weld for liquid tightness.

C.3.7 Ladders

The floating roof shall be supplied with a ladder which automatically adjusts to any position of the roof in such manner as always to provide access to the roof. The ladder shall be designed for full roof travel, regardless of normal setting of roof-leg supports. If a rolling ladder is furnished, it shall have full-length handrails on both sides and shall be designed for a 1,000-lb midpoint load with the ladder in any operating position.

C.3.8 Roof Drains

Primary drains shall be of the hose, jointed, or siphon type, as specified on the purchase order. A check valve shall be provided near the roof end of the hose and jointed pipe drains on single-deck and pan-type roofs to prevent backflow of stored product in case of leakage. Provisions shall be included to prevent kinking of the hose or pinching under the deck legs. Hose drains shall be designed to permit replacement without entering the tank. The swing joints of pipe drains shall be packed to prevent leakage. The installation of either type of drain shall include the installation of the proper shell fittings for its operation and, if necessary, its removal. The minimum-size primary drain shall be equivalent in capacity to one 3-in. drain for roofs up to and including 120 ft in diameter and to one 4-in. drain for roofs more than 120 ft in diameter.

C.3.9 Vents

Suitable vents shall be provided to prevent overstressing of the roof deck or seal membrane. It is advisable for the purchaser to specify liquid withdrawal rates so that the fabricator may size the vacuum vents. These vents, or bleeder valves, or other suitable means shall be adequate to evacuate air and gases from underneath the roof during initial filling.

C.3.10 Supporting Legs

a. The floating roof shall be provided with supporting legs. Legs fabricated from pipe shall be notched or perforated at the bottom to provide drainage. Length of legs shall be adjustable from the top side of the roof. The operating and cleaning position levels of the supporting legs shall be as specified on the purchase order. The manufacturer shall make certain that all tank appurtenances, such as mixers, interior piping, and fill nozzle, are cleared by the roof in its lowest position.

b. Legs and attachments shall be designed to support the roof and a uniform live load of at least 25 lb per sq ft. Where possible, roof load shall be transmitted to the legs through bulkheads or diaphragms. Leg attachments to single decks shall be given particular attention to prevent failures at the points of attachment. Steel pads or other means shall be used to distribute the leg loads on the bottom of the tank. Pads, if used, shall be continuously welded to the bottom.

C.3.11 Roof Manways

At least one roof manhole shall be provided for access to the tank interior and for ventilation when the tank is empty. The number of roof manholes shall be as specified by the purchaser. These manholes shall be at least 24 in. ID and shall have tight-gasketed and bolted covers equivalent to the roof manholes shown in Fig. 3-14 of this specification.

C.3.12 Centering and Antirotation Device

Suitable devices shall be provided to maintain the roof in a centered position and to prevent its rotation. These devices shall be capable of resisting the lateral forces imposed on them by the roof ladder, unequal snow loads, wind loads, and the like.

C.3.13 Seals

The space between the outer periphery of the roof and the tank shell shall be sealed by a flexible device which shall provide a reasonably close fit to the shell surfaces. If the sealing device employs steel shoes in contact with the shell, such shoes shall be made from galvanized sheet conforming to the latest edition of *ASTM A 93: Specification for Zinc-Coated (Galvanized) Iron or Steel Sheets, Coils, and Cut Lengths*, with a minimum nominal thickness of 16 gage and a class 1.25 (commercial) coating. If uncoated shoes are specified, they shall be made of sheet steel of a thickness and quality as specified on the purchase order. An adequate but minimum number of expansion joints shall be provided. Any fabric or nonmetallic material used as a seal or a seal component shall be durable in its environment and shall not discolor or contaminate the product stored.

Reference should be made to the latest edition of API RP 2003 regarding the possible need for bonding shunts between the roof and metallic shoes. Providing such shunts shall be a subject for agreement between the purchaser and the manufacturer.

C.3.14 Gaging Device

Each roof shall be provided with a gage hatch or gage well with a tight cap of the design specified on the purchase order.

C.4 FABRICATION, ERECTION, WELDING, INSPECTION, AND TESTING

a. Applicable fabrication, erection, welding, inspection, and testing requirements of this specification shall apply.

b. Deck seams and other joints, which are required to be liquid- or vapor-tight, shall be tested for leaks by penetrating oil or by any other method consistent with the methods described in this specification for testing cone-roof seams and tank-bottom seams.

c. The roof shall be given a flotation test while the tank is being filled with water and emptied. During this test, the upper side of the lower deck shall be examined for leaks. The appearance of a damp spot on the upper side of the lower deck shall be considered evidence of leakage.

d. The upper side of the upper decks of pontoon and double-deck roofs shall be visually inspected for pinholes or defective welding.

e. Drainpipe and hose systems of primary drains shall be pressure tested with water at 50 psi. During the flotation test, the roof drain valves shall be kept open and observed for leakage of tank contents into the drain lines.

APPENDIX D

ALTERNATE DESIGN BASIS FOR TANK SHELLS

D.1 SCOPE

a. This appendix provides an alternate design basis for shells of storage tanks. A more refined engineering design is provided for specific services or anticipated ranges of services. Steels with improved notch toughness are specified, increased weld inspection is required, and better nozzle and manhole details are incorporated. These requirements permit the use of a higher design stress and a design based on the specific gravity of the product.

b. The purchaser should give special consideration to foundations, corrosion allowance, or any other protective measures deemed necessary. A listing of minimum requirements for materials for the shells is included in this appendix.

c. This appendix is applicable only when specified by the purchaser. Shells designed on this basis must incorporate all provisions of this appendix. The purchaser shall state the design metal temperature, design specific gravity, and corrosion allowance.

R **d.** The requirements for an API Standard 650 tank are superseded by any requirements of this appendix which differ therefrom. The maximum nominal thickness of tank shell plates shall be 1½ in., except that insert plates up to a 3-in. thickness, inclusive, shall be permitted for certain materials as listed in Table D-1.

e. The specifications in this appendix are not to be used for tanks in refrigerated service.

D.2 MATERIALS

a. Plates shall conform to the latest edition of ASTM specifications and shall be in accordance with Table D-1. The top angle of the shell shall conform to the requirements for an API Standard 650 tank.

b. The design metal temperature of the steel shall be specified by the purchaser. Unless local experience or special conditions justify otherwise, the design metal temperature shall be assumed to be the lowest one-day mean ambient temperature in the locality where the tank is to be installed, plus 15 F. Isothermal lines of lowest one-day mean temperatures are shown in Fig. D-1.

R **c.** Material for nozzle and manhole necks shall be seamless open hearth complying with ASTM A 53, A 106 (Grades A and B), or A 524, or API Standard 5L, or shall be fusion welded of plate conforming to Table D-1.

d. Flanges shall conform to the requirements for an API Standard 650 tank.

R **e.** Plates used for reinforcing of shell openings shall be preferably of the same material as the shell plate, but all plates, including insert plates, shall be in accordance with the temperature/thickness requirements of Table D-1.

f. Welding procedures used shall produce weldments whose mechanical properties are adequate for the design requirements. For design metal temperatures below −50 F, the manufacturer's welding procedure qualification for vertical joints [see Par. 7.2(b)] shall include weld metal impact tests, which shall be 15 ft-lb Charpy V (average of three specimens) for the design metal temperature. If vertical welds are made by an automatic or semiautomatic process, impact tests shall be made of the weld metal and heat-affected zone with the specimen so positioned that the break will include the fusion line.

D.3 ALLOWABLE STRESS

a. The maximum allowable design stress, including the joint efficiency factor, shall be 21,000 psi.

b. The maximum allowable hydrostatic test stress, including the joint efficiency factor, shall be 23,000 psi on the gross plate thickness, including corrosion allowance.

D.4 CORROSION ALLOWANCE

The purchaser shall specify, when necessary, the corrosion allowance to be provided on the shell plates, giving consideration to the total effect of liquid stored, the vapor above the liquid, and the atmospheric environment.

D.5 SHELL THICKNESSES

a. The required shell thicknesses shall be the greater of design shell thicknesses [Par. (b)] including corrosion allowance, or hydrostatic test shell thicknesses [Par. (c)], but in no case shall the total shell thickness be less than that shown in Par. 3.3.3(b).

b. The design shell thicknesses shall be computed on the basis that the tank is filled with liquid which has a specific gravity as specified by the purchaser.

c. The hydrostatic test shell thicknesses shall be computed on the basis that the tank is filled with water.

d. Where it is practicable, the tank shall be filled with water for hydrostatic testing. Although it is recognized that the hydrostatic test may be impracticable in some instances, the computed hydrostatic test shell thicknesses shall be applicable when greater than design shell thicknesses.

e. The required minimum thickness of shell plates shall be the greater of the values computed by the following formulas:

Design shell thickness, in inches

$$= \frac{(2.6)(D)(H-1)(G)}{21{,}000} + c$$

TABLE D-1—Minimum Requirements for Steel Plates for Use with Alternate Design Basis for API Standard 650 Tank Shells

	Applicable Specifications [1] For All Courses					
				Insert Plates Only		
Plate Thickness, in Inches:	0 ≤ ½	> ½ ≤ 1	> 1 ≤ 1½	> 1½ ≤ 2 (Normalized)	> 1½ ≤ 3 (Normalized)	
Design metal temperature, deg F:						
Above +50	A 283, grade C [2] A 131, grade A A 36 Fe 42, Fe 44, grade B [5]	A 283, grade C [2] A 36 Fe 42, Fe 44, grade B [5]	A 36 Fe 42, Fe 44, grade C [6]	A 131, grade C Fe 42, Fe 44,[3] grade D [4]	A 516	R
Above +20	A 283, grade C [2] A 131, grade A A 36 A 442 Fe 42, Fe 44, grade B [5]	A 131, grade B G40.8, grade A A 36 [8] A 442 Fe 42, Fe 44, grade C [6]	A 131, grade C [7] G40.8, grade B A 662, grade B A 36 [9] A 442	A 131, grade C Fe 42, Fe 44, grade D [4]	A 516	
Above −10	A 131, grade B G40.8, grade A A 442 Fe 42, Fe 44, grade C [6]	A 131, grade C G40.8, grade B A 662, grade B A 573 A 516 Fe 42, Fe 44, grade D [4]	A 131, grade C [7] G40.8, grade B A 662, grade B A 442 A 573 A 516 Fe 42, Fe 44, grade D [4]	A 131, grade C Fe 42, Fe 44, grade D [5]	A 516	
Above −40	A 131, grade C G40.8, grade B A 662, grade B A 573 A 516 Fe 42, Fe 44, grade D [4]	A 131, grade C [10] A 131, grade CS [10] G40.8, grade B [10] A 662, grade B [10] A 573 [10] A 516 [10] Fe 42, Fe 44, grade D [4, 10]	A 131, grade C [10] A 131, grade CS [10] G40.8, grade B [10] A 662, grade B [10] A 573 [10] A 516 [10] A 442 [10] Fe 42, Fe 44, grade D [4,10]	A 537, Class 1 A 131, grade CS		R

NOTES:
1. All specification numbers refer to ASTM specifications except G40.8 which is a Canadian Standards Association specification and Fe 42 and Fe 44 which are contained in ISO Recommendation R630.
2. ASTM A 285, Grade C, may be used as an alternative for ASTM A 283, grade C.
3. For Fe 42 and Fe 44, the maximum percentage of manganese shall be 1.50 (ladle).
4. Killed and fine grain.
5. Nonrimming only.
6. Semi-killed or killed.
7. ASTM A 131, grade C, may be used to 1½ in. thickness, inclusive, without normalizing.
8. ASTM A 36 used in this thickness and temperature range shall have a manganese content of 0.80 to 1.20 percent by ladle analysis.
9. ASTM A 36 may be used at design metal temperatures of 35 F and higher.
10. Normalized.

Hydrostatic test shell thickness, in inches

$$= \frac{(2.6)(D)(H-1)}{23,000}$$

Where:

D = nominal diameter of tank, in feet.
H = height, in feet, from the bottom of the course under consideration to the top of the top angle or to the filling height limited by the tank overflow.
G = design specific gravity of liquid.
c = corrosion allowance, in inches, as specified by the purchaser.

D.6 SUPPLEMENTARY REQUIREMENTS FOR INSPECTION, FABRICATION, AND OPENING DETAILS

a. All vertical and horizontal shell joints, except shell-to-bottom sketch plate, shall have complete penetration and complete fusion, except that top angles may be atttached to the shell by a double-welded lap joint.

b. Butt-welded joints in which the thinner shell plate is ⅜ in. or less shall be spot-radiographed in accordance with Sect. 6.1. In addition to the foregoing requirement, one random spot radiograph shall be taken in each vertical joint in the lowest course (see Fig. D-2, A).

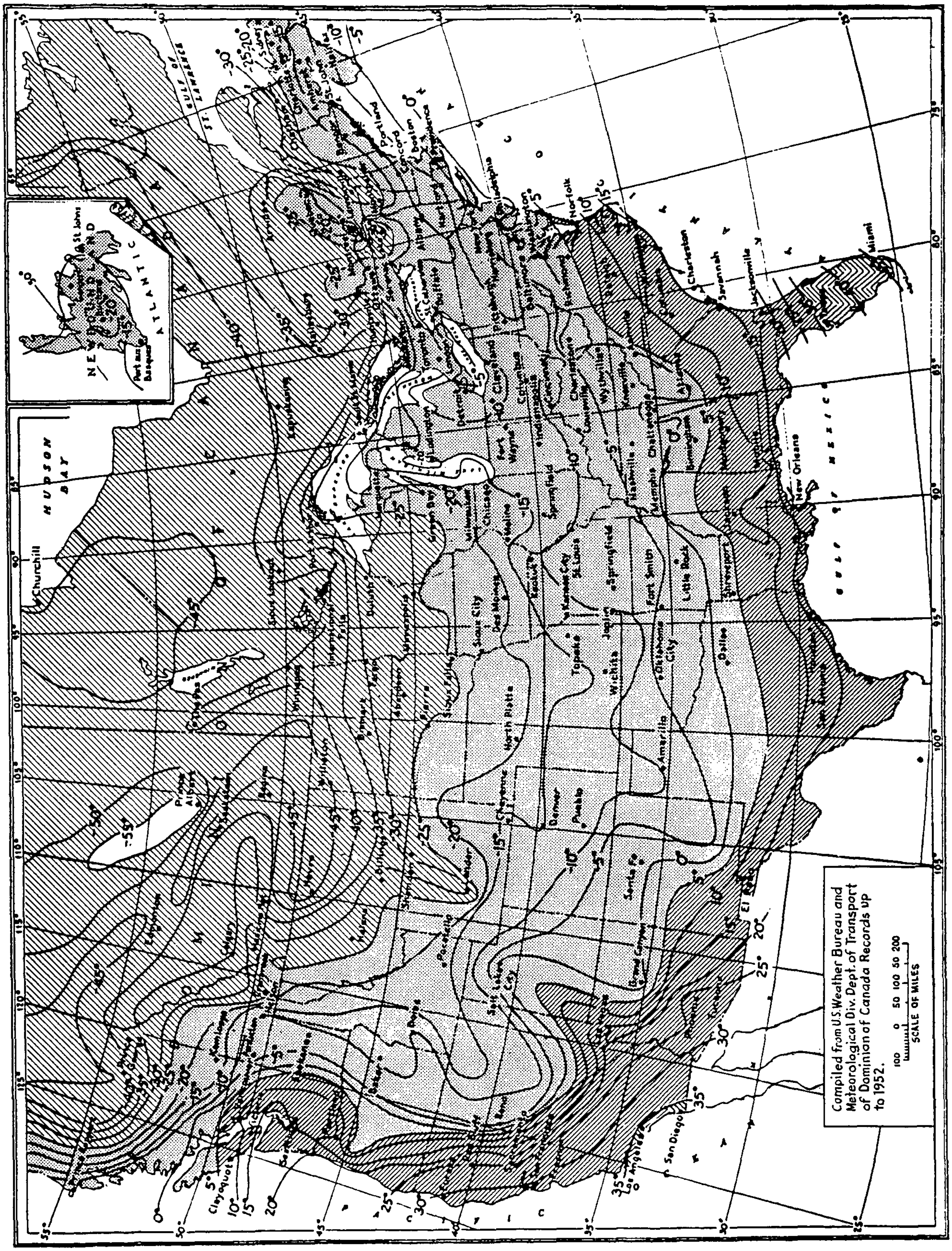
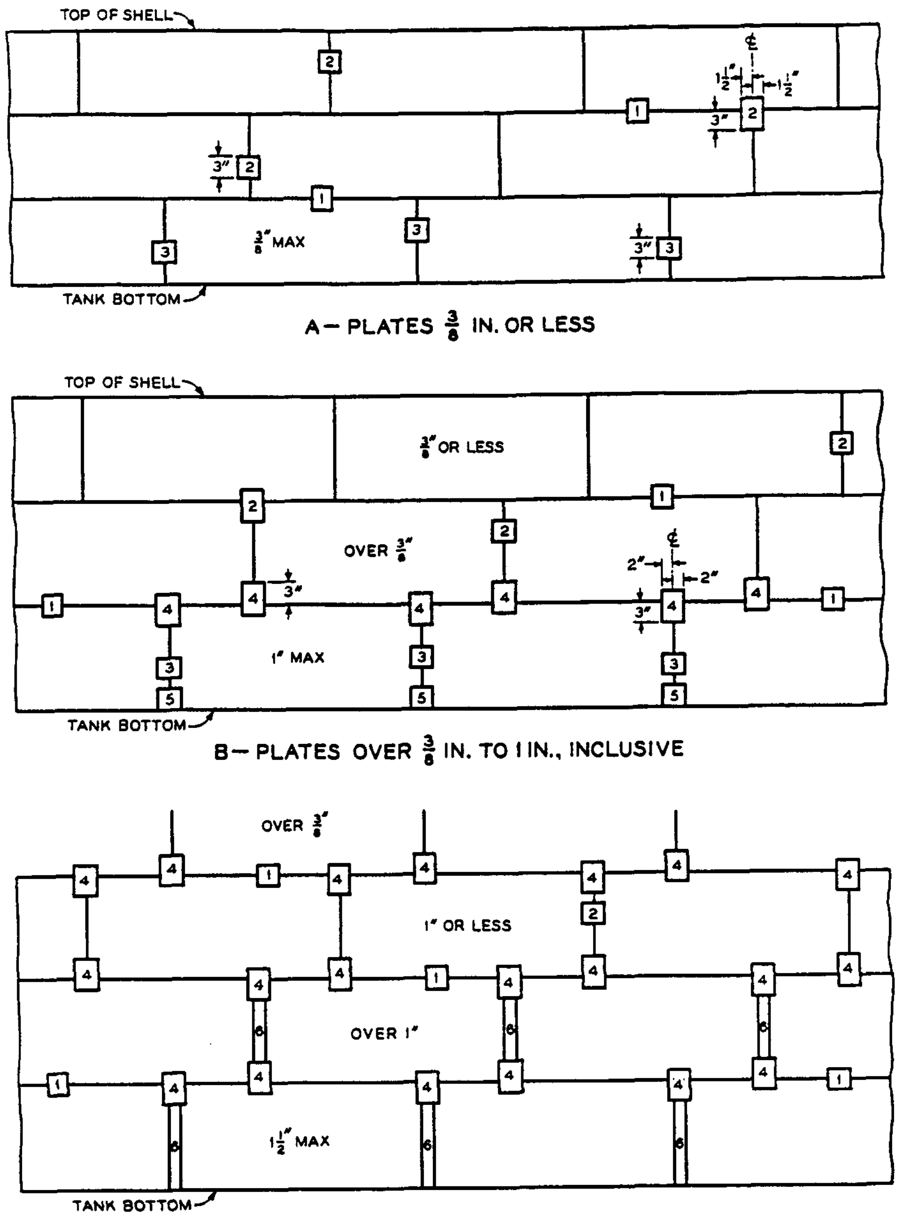


FIG. D-1—Isothermal Lines of Lowest One-Day Mean Temperatures.



A— PLATES 3/8 IN. OR LESS

B— PLATES OVER 3/8 IN. TO 1 IN., INCLUSIVE

C— PLATES OVER 1 IN.

Notes:

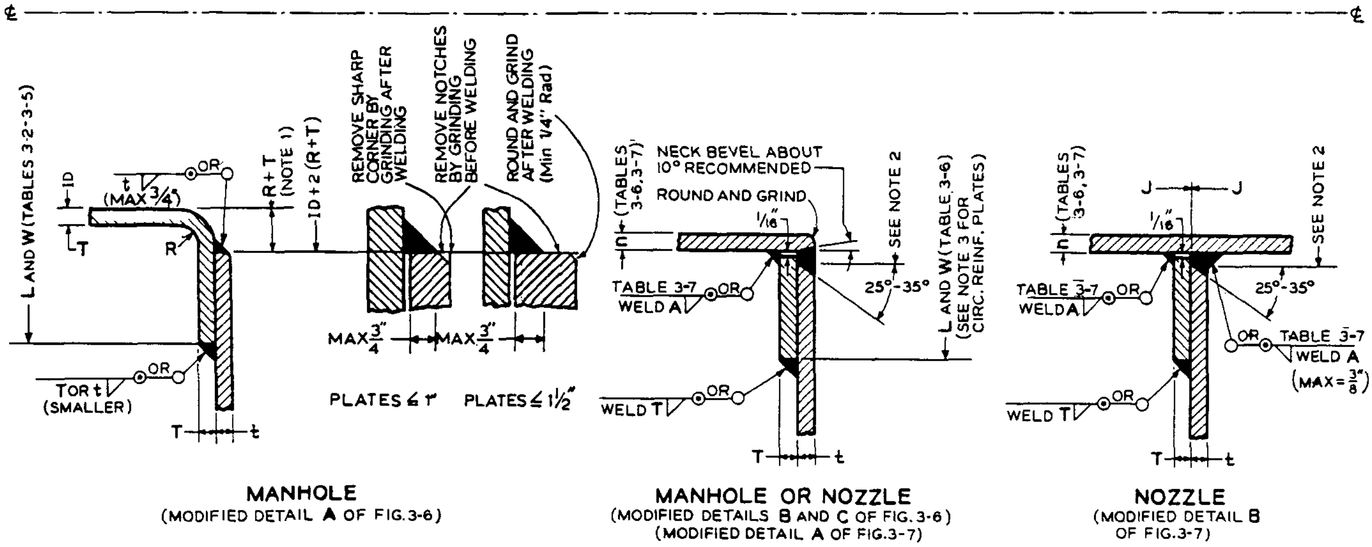
1. Horizontal spot X-ray in accordance with API Standard 650: one in first 10 ft and one in each 200 ft thereafter.
2. Vertical spot X-ray in accordance with API Standard 650: one in first 10 ft and one in each 100 ft thereafter, 25 percent of which are to be at intersections.
3. Vertical spot X-ray for alternate design basis tank shells: in each vertical seam in lowest course.
4. Spot X-ray all intersections for alternate design basis tank shells.
5. Spot X-ray bottom of each vertical seam in lowest course for alternate design basis tank shells.
6. Complete X-ray of each vertical seam for alternate design basis tank shells. The complete X-ray can include the spot X-ray of the interesections if the film has a minimum width of 4 in.

FIG. D-2—X-Ray Requirements for Alternate Design Basis Tank Shells.

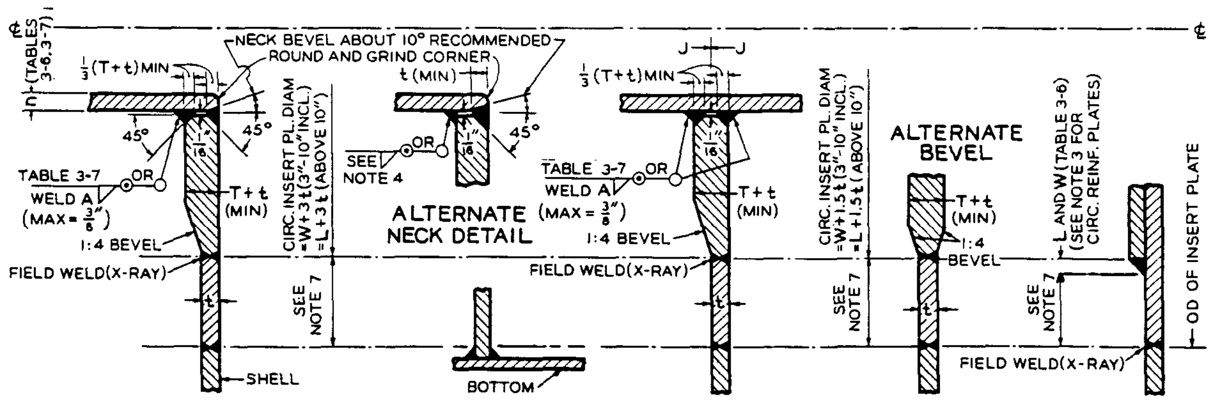
c. Butt-welded joints in which the thinner shell plate is over ⅜ in. and up to and including 1 in. in thickness shall be spot-radiographed in accordance with Sect. 6.1. In addition, all junctions of vertical and horizontal joints in plates in this thickness range shall be radiographed, with each film to show clearly not less than 2 in. of weld length on each side of the vertical intersection. In the lowest course, two spot radiographs shall be taken in each vertical joint, one of which shall be as close to the bottom as practicable, the other taken at random (see Fig. D-2, B).

d. Butt-welded horizontal joints in which the thinner shell plate is over 1 in. and up to and including 1½ in. in thickness shall be spot-radiographed in accordance with Sect. 6.1. Vertical joints in which the shell plates are over 1 in. and up to and including 1½ in. in thickness shall be fully radiographed. All junctions of vertical and horizontal joints in this thickness range shall be radiographed, with each film to show clearly not less than 2 in. of weld length on each side of the vertical intersection (see Fig. D-2, C).

e. All shell opening connections which require reinforcement, such as nozzles, manholes, and cleanout openings, shall be attached by welds fully penetrating the shell, except that the partial penetration illustrated in Fig. D-3 for insert-type reinforcement shall be per-



MODIFICATIONS IN API STANDARD 650 REINFORCEMENT DETAILS R



INSERT-TYPE REINFORCEMENT FOR MANHOLES AND NOZZLES

Notes:

1. The shell cutout shall be made accurately so that the distance $R+T$ will be held within ±⅛ in. To accomplish this accuracy, a preliminary cutout should be made to the inside diameter of the manhole and the manhole itself used to locate the final cutout. R shall be taken as the actual radius rather than the approximate inside radius of the corner.
2. Maximum diameter = OD of neck plus twice the dimension of weld A; see Table 3-7. Minimum diameter = OD of neck plus ½ in.
3. Circular reinforcing plates are permissible, where noted, for 3-in. to 10-in. size, provided diameter is made equal to W.
4. Weld size to be greater of A (from Table 3-7, based on t) or n (minimum neck thickness in Tables 3-6 and 3-7).
5. Other permissible insert details are shown in Fig. 3.16.2 of API Standard 620. Reinforcement area to conform to Par. 3.3.7 and Par. D.6(e).
6. Dimensions and weld sizes not shown are the same as those given for an API Standard 650 tank.
7. For minimum spacing of welds at opening connections, refer to Par. D.6(i). R
8. Welding bevel details may vary from those shown if agreed to by the purchaser. R

FIG. D-3—Minimum Permissible Details for Shell Manholes and Nozzles.

mitted. The minimum cross-sectional area of the reinforcement shall be not less than the product of the vertical diameter of the hole cut in the shell and the gross plate thickness used.

f. All opening connections 12 in. or larger in nominal diameter into a shell plate exceeding 1 in. in thickness shall be prefabricated into the shell plate or thickened insert plate, and the prefabricated assembly shall be thermally stress-relieved at a temperature of 1100 F to 1200 F for 1 hour per inch of thickness prior to installation. The stress-relieving requirements need not include the flange-to-neck welds or other nozzle neck and manway neck attachments provided:

1. The weld is outside the reinforcement (see Par. 3.3.7c).

2. The throat dimension of a fillet weld in a slip-on flange does not exceed ⅝ in., or the butt joint of a welding neck flange does not exceed ¾ in. If the material is preheated to a minimum temperature of 200 F during welding, these weld limits can be increased to 1¼ in. and 1½ in., respectively.

g. Welds attaching nozzles, manholes, and cleanout openings shall be inspected by the magnetic particle method or liquid penetrant method at the option of the purchaser after stress-relieving, if any, but before the hydrostatic test of the tank and any cracks or undercuts shall be removed.

h. The butt weld around the periphery of an insert manhole or nozzle shall be completely radiographed.

R **i.** The spacing of welds around connections shall conform to the following:

1. The outer edge (toe) of a non-stress-relieved weld around a penetration, around the periphery of a thickened insert plate, or around the periphery of a reinforcing plate, shall be at least the greater of 8 times the weld size or 10 in. from the centerline of any butt-welded shell seams. Where stress-relieving of the periphery weld has been performed prior to welding of the adjacent shell joint, the spacing may be reduced to 6 in. from vertical joints or 3 in. from horizontal joints provided that, in either case, the spacing is not less than 2½ times the shell thickness.

2. These rules shall also apply to the bottom-to-shell joint except that, as an alternative, the insert plate or reinforcing plate may extend to and intersect the bottom-to-shell joint at approximately 90 degrees.

D.7 FOUNDATION

The selection of the tank site and the design and construction of the foundation shall be given careful consideration as outlined in Appendix B in order to insure adequate tank support. Concrete ringwall foundations shall be considered. The adequacy of the foundation is the responsibility of the purchaser.

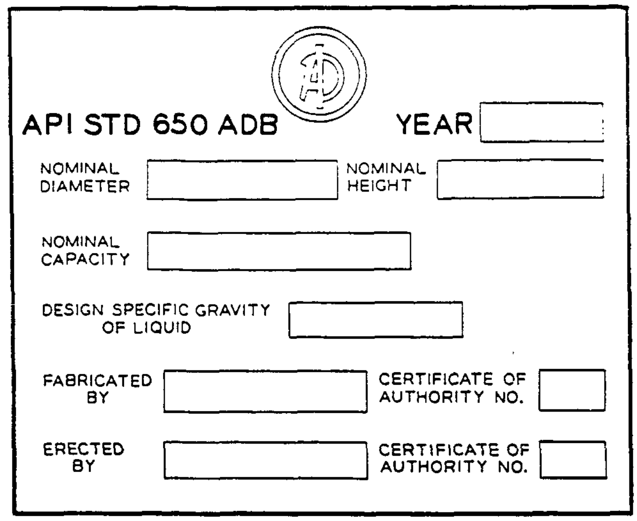


FIG. D-4—API-ADB Monogrammed Nameplate.

D.8 MARKING

a. The nameplate shall indicate that the tank has been designed in accordance with the alternate design basis. The API monogram may be applied to tanks constructed in accordance with this appendix.

b. In addition to information required by Fig. 8-1, the monogrammed nameplate shall state the design specific gravity of the liquid to be stored. A typical nameplate is illustrated in Fig. D-4.

D.9 FLUSH-TYPE CLEANOUT FITTINGS R

Flush-type cleanout fittings shall conform to the rules specified in this section and to the details and dimensions shown in Fig. D-5 and D-6 and Tables D-2, D-3,

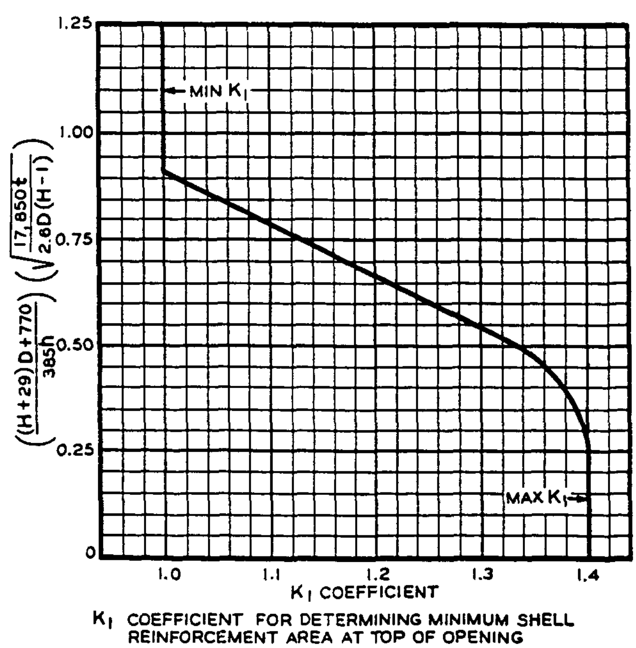


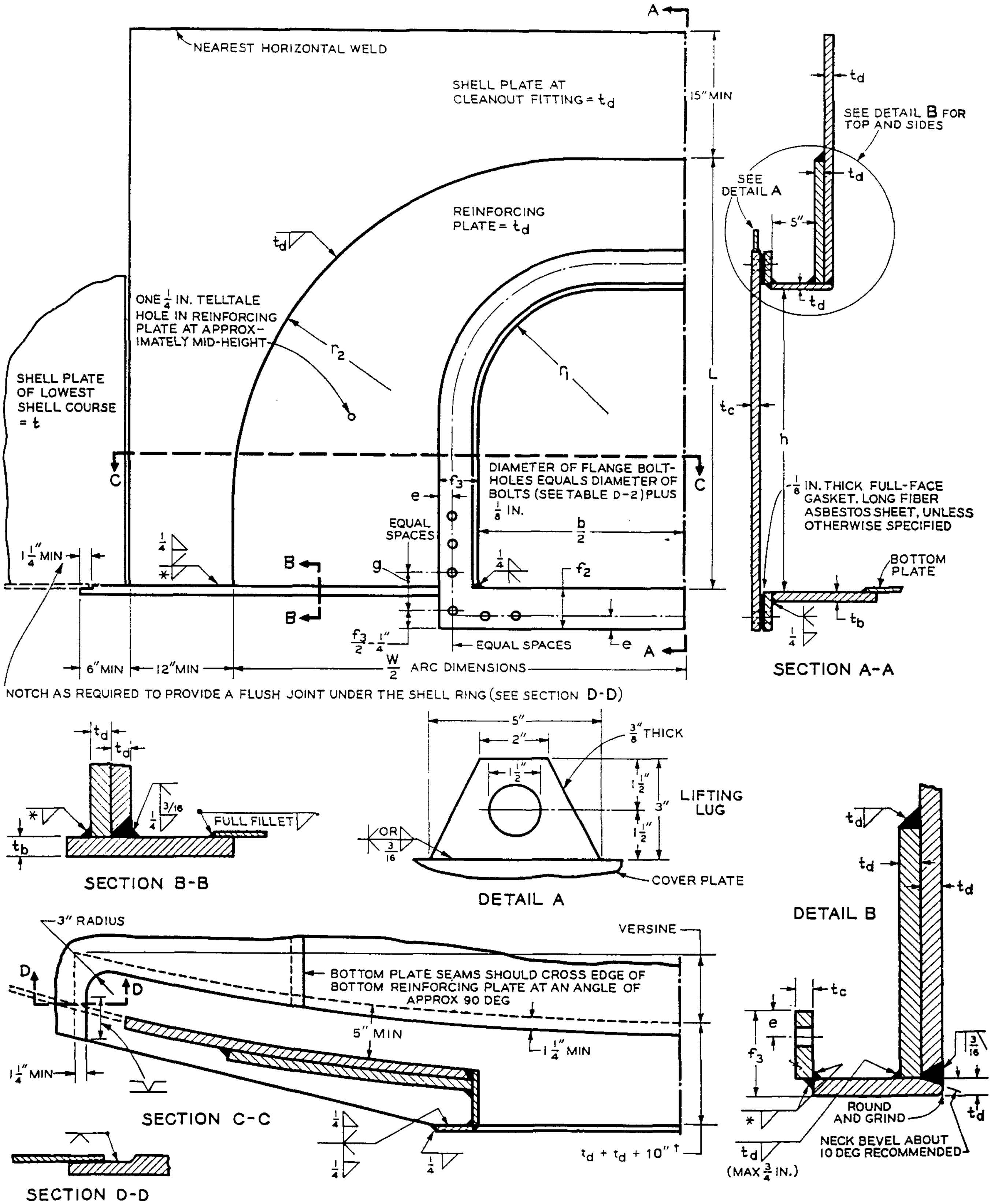
FIG. D-5—Area Coefficient for Determining Minimum Reinforcement of Flush-Type Cleanout Fitting for Alternate Design Basis Tank Shells.

and D-4, until existing requirements are revised to permit alternate designs as may be shown to be safe by additional field experience or further development work. When sizes intermediate to those stated in Tables D-2 to D-6, inclusive, are specified by the purchaser, the construction details and reinforcements shall conform to the next greater opening listed in the tables. The size of the opening or tank connection shall not be larger than the maximum size given in the appropriate table.

a. Cleanout fittings of the flush type shall conform to the following requirements:

1. The opening shall be rectangular, except that the upper corners of the opening shall have a radius equal to one-half the greatest height of the clear opening. The width or height of the clear opening shall not exceed 48 in.

2. The reinforced opening shall be completely preassembled into a shell plate, and the completed unit, including the shell plate at the cleanout fitting, shall be thermally stress-relieved at a temperature of 1,100 F to 1,200 F for 1 hr per in. of thickness.



R * Thickness of thinner plate joined, with a maximum of ½ in.

† When an annular plate is provided, the reinforcing plate shall become a segment of the annular plate and shall be the same width as the annular plate.

FIG. D-6—Flush-Type Cleanout Fittings for Alternate Design Basis Tank Shells (See Tables D-2, D-3, and D-4).

TABLE D-2—Flush-Type Cleanout Fittings for Alternate Design Basis Tank Shells (See Fig. D-6)

All dimensions are in inches.

(1) Height of Opening h	(2) Width of Opening b	(3) Arc Width of Shell Reinforcing Plate W	(4) Upper Corner Radius of Opening r_1	(5) Upper Corner Radius of Shell Reinforcing Plate r_2	(6) Edge Distance of Bolts e	(7) Flange Width (Except at Bottom) f_3	(8) Bottom Flange Width f_2	(9) Special Bolt Spacing * g	(10) Number of Bolts	(11) Diameter of Bolts
8	16	46	4	14	1¼	4	3½	3¼	22	¾
24	24	72	12	29	1¼	4	3¾	3½	36	¾
36	48	106	18	41	1½	4½	4¾	4¼	46	1
48	48	125	24	51½	1½	4½	5	4½	52	1

* Spacing at lower corners of cleanout fitting flange.

b. The cross-sectional area of the reinforcement over the top of the opening shall be not less than:

$$\frac{K_1 ht}{2}$$

Where:

K_1 = area coefficient, as given in Fig. D-5.

h = greatest vertical height of clear opening, in inches.

t = thickness of lowest shell course, in inches, required by Sect. D-5.

H = height of tank, in feet.

D = inside diameter of tank, in feet.

c. The thickness of the shell plate in the cleanout opening assembly shall be at least 1/16 in., but no more than ⅛ in., greater than the thickness of the adjacent plates in the lowest shell course (except for the 8-in. by 16-in. opening, which may be the same thickness).

d. The thickness of the shell reinforcing plate and the neck plate shall be the same thickness as the shell plate in the cleanout opening assembly.

e. The reinforcement in the plane of the shell shall be provided within a height, L, above the bottom of the opening. L shall not exceed $1.5h$, except that $L-h$ shall not be less than 6 in. in case of small openings. Where the latter exception results in a height, L, greater than $1.5h$, only that portion of the reinforcement within a height of $1.5h$ shall be considered effective.

f. The reinforcement required may be provided by any one or by any combination of the following:

1. The shell reinforcing plate.
2. Any thickness of the shell plate in the cleanout door assembly greater than the thickness of the adjacent plates in the lowest shell course.
3. That portion of the neck plate equal to the thickness of the reinforcing plate.

g. The minimum width of the tank-bottom reinforcing plate at the centerline of the opening shall be 10 in. plus the combined thickness of the shell plate in the cleanout opening assembly and the shell reinforcing plate. The minimum thickness of the bottom reinforcing plate, t_b, in inches, shall be determined by the equation: R

$$t_b = \frac{h^2}{14{,}000} + \frac{b}{310}\sqrt{H}$$

Where:

b = horizontal width of clear opening, in inches.

h. The dimensions for the cover plate, bolting flange, bolting, and bottom reinforcing plate shall conform to Tables D-2 and D-3.

TABLE D-3—Thicknesses of Cover Plate, Bolting Flange, and Bottom Reinforcing Plate for Flush-Type Cleanout Fittings for Alternate Design Basis Tank Shells (See Fig. D-6)

All dimensions are in inches unless otherwise stated.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
		Size of Opening (Height, h, Times Width, b)								
		8 by 16		24 by 24		36 by 48		48 by 48		
Max. Tank Height (Feet) H	Equivalent Pressure * (Pounds per Square Inch)	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b	Min. Thickness of Bolting Flange and Cover Plate t_c	Min. Thickness of Bottom Reinforcing Plate t_b	
20	8.7	⅜	½	⅜	½	⅝	13/16	⅝	⅞	
34	14.7	⅜	½	½	½	¾	1	13/16	1⅛	
41	17.8	⅜	½	½	9/16	⅞	1⅛	⅞	1 3/16	
53	23	⅜	½	9/16	⅝	15/16	1¼	1	1 5/16	
60	26	7/16	½	⅝	11/16	1	1 5/16	1⅛	1⅜	R
64	27.8	7/16	½	⅝	11/16	1 1/16	1⅜	1⅛	1 7/16	
72	31.2	7/16	½	11/16	¾	1⅛	1 7/16	1 3/16	1½	
			1 max.		1⅛ max.		1½ max.		1¾ max.	

* Equivalent pressure is based on water loading.

i. The material for the shell plate in the cleanout opening assembly, the shell reinforcing plate, the tank-bottom reinforcing plate, and the neck plate shall be in conformance with Table D-1 for the respective thicknesses and the stated design metal temperature for the tank. Where the thicknesses of the shell and reinforcing plates in Table D-4 are greater than 1½ in., the material indicated for 1 in. to 1½ in. in Table D-1 shall be used.

j. The material for the cover plate, the bolting flange, and the bolting shall be in conformance with Par. 2.1(a) and 2.8.

k. The dimensions and details of the cleanout door assemblies covered by this section have been based on internal hydrostatic loading with no external piping loading. The use of external piping attached to the cleanout door flange or cover plate is not recommended.

l. When a flush-type cleanout fitting is installed on a tank resting on an earth grade without concrete or masonry walls under the tank shell, provision shall be made to support the fitting and retain the grade by either of the following methods:

Method A: Install a vertical steel bulkhead plate under the tank, along the contour of the tank shell, and symmetrical with the opening as shown in Fig. 3-10, Method A.

Method B: Install a concrete or masonry retaining wall under the tank, with its outer face conforming to the contour of the tank shell as shown in Fig. 3-10, Method B.

m. When a flush-type cleanout fitting is installed on a tank resting on a ringwall, a notch having the dimensions shown in Fig. 3-10, Method C, shall be provided to accommodate the cleanout fitting.

n. When a flush-type cleanout fitting is installed on a tank resting on an earth grade inside a foundation retaining wall, a notch shall be provided in the retaining wall to accommodate the fitting, and a supplementary inside retaining wall shall be provided to support the fitting and retain the grade. The dimensions shall be as shown in Fig. 3-10, Method D.

D.10 BOLTED DOOR SHEETS

Bolted door sheets are based on specific design requirements as follows:

a. Door plates shall conform to the latest edition of ASTM specifications and shall be in accordance with Table D-1, the same as required for shell plates. For door-plate thickness greater than 1½ in., the material indicated for 1-in. to 1½-in. thickness in Table D-1 shall be used. Materials for the girder under the flush-type door shall be fabricated and fusion-welded of plate, or equivalent structural material, conforming to Table D-1.

b. The minimum net cross-sectional area of the door plates, excluding the tapered ends, shall not be less than the product of the shell-plate thickness and the vertical height of the cutout in the shell plus twice the bolthole diameter:

$$t_D(h_D - N_1 d) = t_s(h_c + 2d)$$

c. The shear stress in the cross-section of the bolts shall not exceed 16,000 psi.

d. The bearing stress on bolts and boltholes shall not exceed 32,000 psi, and the fit of the turned bolt in the reamed hole shall conform to the standards of the American Institute of Steel Construction.

e. The strength of the bolted connection shall be at least 100 percent of the strength of the unbolted plate. For shear loading on the flush-type door sheet:

$$(N)(a)(16{,}000) = t_s(h_c + 2.5d + f)(23{,}000)$$

For shear loading on the raised-type door:

$$(N)(a)(16{,}000) = t_s(h_c + 4d)(23{,}000)$$

Where:

t_s = thickness of shell plate, in inches, excluding corrosion allowance.

t_D = thickness of door plate, in inches, excluding corrosion allowance.

h_D = height of door plate, in inches.

h_c = height of shell cutout, in inches.

d = diameter of bolts and boltholes, in inches.

a = cross-sectional area of bolts, in square inches.

N = number of bolts required in each end section of door plate.

N_1 = number of bolts in first row of bolts next to shell cutout.

f = distance from bottom of shell cutout to centerline of bottom row of bolts.

f. The distance between centers of boltholes shall not be less than three times the bolt diameter, and the bolthole spacing at the sealing edge of the plate shall not exceed the nominal bolt diameter plus seven times the door sheet thickness, t_D, plus seven times the washer thickness (if washers are used).

g. The tensile stress in the net section of the door plate, during the hydrostatic test and excluding corrosion allowance, at the first row of boltholes next to the shell-plate cutout shall not exceed 23,000 psi, and at subsequent rows shall not exceed 23,000 psi after allowance is made for the total shearing value or bearing value (whichever is less) of the bolts in the preceding row or rows (see *Note* hereinafter).

h. For flush-type bolted door sheets:

1. The girder shall be designed to withstand a bending moment which would result if the ends of the girder were on hard ground and the center unsupported.

2. The load on the girder shall be equal to the weight of a column of water with the following dimensions: *a*, 0.03 times the tank radius, in feet; *b*, width of the shell cutout plus 2 ft; and, *c*, the tank height, in feet.

TABLE D24—Thicknesses and Heights of Shell Reinforcing Plates for Cleanout Fittings for Alternate Design Basis Tank Shells (See Fig. D-6)

All dimensions are in inches unless stated.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Size of Opening (Height, h, Times Width, b)							
		8 by 16		24 by 24		36 by 48		48 by 48	
Thickness of Lowest Shell Course t	Max. Tank Height (Feet) H	Thickness of Shell and Reinforcing Plate t_d	Height of Shell Reinforcing Plate L	Thickness of Shell and Reinforcing Plate t_d	Height of Shell Reinforcing Plate L	Thickness of Shell and Reinforcing Plate t_d	Height of Shell Reinforcing Plate L	Thickness of Shell and Reinforcing Plate t_d	Height of Shell Reinforcing Plate L
3/16	72	3/16	14	1/4	34 1/4	1/4	51 1/4	1/4	68 1/4
1/4	72	1/4	14	5/16	35 1/4	5/16	53	5/16	70 1/2
5/16	72	5/16	14	3/8	35 3/4	3/8	54	3/8	72
3/8	16	3/8	14	7/16	33	7/16	52 1/4	7/16	72
3/8	26	3/8	14	7/16	34 1/4	7/16	54	1/2	68
3/8	72	3/8	14	7/16	36	1/2	51	1/2	68 1/4
7/16	17	7/16	14	1/2	33 1/2	1/2	52	1/2	72
7/16	28	7/16	14	1/2	34	1/2	54	9/16	69
7/16	72	7/16	14	1/2	35 3/4	9/16	52	9/16	69 1/2
1/2	18	1/2	14	9/16	33 3/4	9/16	51 3/4	9/16	72
1/2	31	1/2	14	9/16	34	9/16	54	5/8	70
1/2	72	1/2	14	9/16	35 1/2	5/8	52 1/2	5/8	70 1/2
9/16	19	9/16	14	5/8	34	5/8	51 1/2	5/8	72
9/16	34	9/16	14	5/8	34	5/8	54	11/16	70 1/2
9/16	72	9/16	14	5/8	35 1/4	11/16	52 3/4	11/16	71
5/8	22	5/8	14	11/16	34	11/16	51 1/2	11/16	72
5/8	40	5/8	14	11/16	34	11/16	54	3/4	71
5/8	72	5/8	14	11/16	35	3/4	53	3/4	71 3/4
11/16	24	11/16	14	3/4	34 1/4	3/4	51 1/4	3/4	72
11/16	44	11/16	14	3/4	34 1/4	3/4	54	13/16	71 1/4
11/16	70	11/16	14	3/4	34 1/2	13/16	52 3/4	13/16	72
3/4	26	3/4	14	13/16	34 1/2	13/16	51 1/2	13/16	72
3/4	51	3/4	14	13/16	34 1/2	13/16	54	7/8	71 3/4
3/4	70	3/4	14	13/16	34 1/2	7/8	52 1/2	7/8	72
3/4	72	3/4	14	13/16	34 1/2	7/8	52 3/4	15/16	69 3/4
13/16	29	13/16	14	7/8	34 1/2	7/8	51 3/4	7/8	72
13/16	60	13/16	14	7/8	34 1/2	7/8	54	15/16	72
13/16	70	13/16	14	7/8	34 1/2	15/16	52 1/2	15/16	72
13/16	72	13/16	14	7/8	34 1/2	15/16	52 1/2	1	69 3/4
7/8	32	7/8	14	15/16	34 1/2	15/16	51 3/4	15/16	72
7/8	70	7/8	14	15/16	34 1/2	15/16	54	1	72
7/8	72	7/8	14	15/16	34 1/2	1	52 1/4	1 1/16	69 3/4
15/16	36	15/16	14	1	34 3/4	1	52	1	72
15/16	72	15/16	14	1	34 3/4	1	53 3/4	1 1/16	72
1	41	1	14	1 1/16	34 3/4	1 1/16	52	1 1/16	72
1	72	1	14	1 1/16	34 3/4	1 1/16	53 1/4	1 1/8	72
1 1/16	46	1 1/16	14	1 1/8	34 3/4	1 1/8	52 1/4	1 1/8	72
1 1/16	72	1 1/16	14	1 1/8	34 3/4	1 1/8	52 3/4	1 3/16	71 1/2
1 1/8	52	1 1/8	14	1 3/16	35	1 3/16	52 1/4	1 3/16	72
1 1/8	72	1 1/8	14	1 3/16	35	1 3/16	52 1/4	1 1/4	71 1/4
1 3/16	58	1 3/16	14	1 1/4	35	1 1/4	52 1/4	1 1/4	72
1 3/16	72	1 3/16	14	1 1/4	35	1 1/4	52 1/4	1 5/16	71
1 1/4	64	1 1/4	14	1 5/16	35	1 5/16	52 1/2	1 5/16	72
1 1/4	72	1 1/4	14	1 5/16	35	1 5/16	52 1/2	1 3/8	70 1/2
1 5/16	72	1 5/16	14	1 3/8	35	1 3/8	52 1/2	1 3/8	72
1 3/8	72	1 3/8	14	1 7/16	35	1 7/16	52 1/2	1 7/16	71
1 7/16	72	1 7/16	14	1 1/2	35 1/4	1 1/2	52 3/4	1 1/2	70 3/4
1 1/2	72	1 1/2	14	1 9/16	35 1/4	1 9/16	52 3/4	1 9/16	70 1/4
1 5/8*	72	1 5/8	14	1 11/16	35 1/4	1 11/16	52 3/4	. . .	. . .
1 3/4*	72	1 3/4	14	1 13/16	35 1/4	1 13/16	52 3/4	. . .	. . .

Note: Dimensions t_d and L may be varied within the limits defined in Sect. D.9.

* t greater than 1 1/2 in. is applicable to Appendix G tanks only.

3. The design length of the girder shall be equal to the width of the shell cutout plus 2 ft.

Note: When the difference in diameter of the bolts and boltholes, because of wear, approximates 0.020 in., it is recommended that the holes be reamed and fitted with oversize milled-body bolts. It is also recommended that the tensile stress for the reduced net section of the door be checked.

D.10.1 Flush-Type Bolted Door Sheets

a. Flush-type bolted door sheets shall conform to Fig. 3-11 and Tables 3-12 and D-5.

b. When a flush-type bolted door sheet is installed on a tank resting on an earth grade with or without a concrete retaining wall and without a concrete or masonry wall under the tank shell, provisions shall be made to support the fitting and retain the grade by the method shown in Fig. 3-12, Method A.

c. When a flush-type bolted door sheet is installed on a tank resting on a ringwall, a cutout having the dimensions shown in Fig. 3-12, Method B, shall be provided.

D.10.2 Raised-Type Bolted Door Sheets

Raised-type bolted door sheets shall conform to Fig. 3-13 and Tables 3-13 and D-6.

D.11 INTERMEDIATE WIND GIRDERS FOR TANK SHELLS *

Tank shells designed in accordance with Appendix D will usually be thinner than the API Standard 650 tank

* Except for the requirement for a calculation and report to purchaser of the allowable wind velocity, this section of Appendix D is nonmandatory unless specified by the purchaser.

TABLE D-5—Flush-Type Bolted Door Sheets for Alternate Design Basis Tank Shells (See Fig. 3-11)

All dimensions are in inches.

(1) Thickness of Shell t_S	(2) Q	(3) q	(4) h	(5)	(6) K	(7) k	(8) t_D	(9) h_D	(10)	(11) L_D	(12) Number of Bolts: Row 1	(13) Number of Bolts: Row 2	(14) Number of Bolts: Total
1/4	7	1 15/16	7.375	4.165	36	2.837	5/16	53 7/8	2 1/2	131 1/2	...	7	156
5/16	8	2 1/4	6.4765	3.9432	30	3.2875	3/8	54 7/16	2 1/2	137	...	...	146
3/8	8	2 1/4	6.4765	3.9432	30	3.4375	7/16	54 7/16	2 1/2	141 3/4	...	4	154
7/16	8	2 7/16	6.500	4.0625	24	4.125	1/2	55	2 1/2	141	...	...	134
1/2	8	2 7/16	6.500	4.0625	22	4.721	9/16	55	2 1/2	145 7/8	...	5	140
9/16	8	2 7/8	6.5859	4.3713	20	4.9688	5/8	56 1/16	3	148 3/4	...	...	126
5/8	8	2 7/8	6.5859	4.3713	20	5.2563	3/4	56 1/16	3	154 1/2	...	5	136
11/16	8	3 1/16	6.6093	4.5054	20	4.9875	13/16	56 5/8	3	151 1/2	...	...	126
3/4	8	3 1/16	6.6093	4.5054	20	5.2938	7/8	56 5/8	3	158 5/8	...	4	134
13/16	8	3 1/4	6.6328	4.6433	20	5.0063	15/16	57 3/16	3	156 1/4	...	...	126
7/8	8	3 1/4	6.6328	4.6433	20	5.3313	1	57 3/16	3	162 3/4	...	4	132
1	8	3 1/4	6.6328	4.6433	20	5.6563	1 3/16	57 3/16	3	169 1/4	3	6	144
1 1/8	8	3 7/16	6.6562	4.7851	20	5.3688	1 5/16	57 3/4	3	166 7/8	...	7	140
1 1/4	8	3 7/16	6.6562	4.7851	20	5.7125	1 1/2	57 3/4	3	173 3/4	5	7	150
1 3/8	8	3 11/16	6.6547	4.9668	20	5.7813	1 5/8	58 5/16	3	179 1/2	3	6	144
1 1/2	8	3 11/16	6.6547	4.9668	20	5.7813	1 13/16	58 5/16	3	179 1/2	7	7	154

R

TABLE D-5—Continued

(15) Diameter of Bolt d	(16) Length of Bolt	(17) Length of Bolt Thread	(18) Square Locking Bar	(19) Angle	(20) Web	(21) Intermediate Gusset	(22) End Gusset	(23) Bearing Plate
3/4	2	1 1/4	5/8	6 by 4 by 3/8	1/4 by 11 5/8	1/4 by 5 by 11 5/8	1/4 by 8 by 11 5/8	1/4 by 9
7/8	2 1/4	1 1/4	3/4	6 by 4 by 3/8	1/4 by 11 5/8	1/4 by 5 by 11 5/8	1/4 by 8 by 11 5/8	1/4 by 9
7/8	2 1/4	1 1/4	3/4	6 by 4 by 3/8	1/4 by 11 5/8	1/4 by 5 by 11 5/8	1/4 by 8 by 11 5/8	1/4 by 9
1	2 1/2	1 1/2	3/4	6 by 4 by 1/2	3/8 by 11 3/8	3/8 by 5 by 11 3/8	3/8 by 8 by 11 3/8	3/8 by 9
1	2 3/4	1 1/2	3/4	6 by 4 by 1/2	3/8 by 11 3/8	3/8 by 5 by 11 3/8	3/8 by 8 by 11 3/8	3/8 by 9
1 1/8	3	1 3/4	1	6 by 4 by 5/8	3/8 by 11 1/4	3/8 by 5 by 11 1/4	3/8 by 8 by 11 1/4	3/8 by 9
1 1/8	3 1/2	2	1	6 by 4 by 5/8	3/8 by 11 1/4	3/8 by 5 by 11 1/4	3/8 by 8 by 11 1/4	3/8 by 9
1 1/4	3 1/2	2 1/4	1	6 by 4 by 3/4	3/8 by 11 1/8	3/8 by 5 by 11 1/8	3/8 by 8 by 11 1/8	3/8 by 9
1 1/4	3 1/2	2	1	6 by 4 by 3/4	3/8 by 11 1/8	3/8 by 5 by 11 1/8	3/8 by 8 by 11 1/8	3/8 by 9
1 3/8	3 1/2	2	1	6 by 6 by 7/8	1/2 by 10 7/8	1/2 by 4 1/2 by 10 7/8	1/2 by 8 by 10 7/8	1/2 by 9
1 3/8	3 1/2	1 3/4	1	8 by 6 by 7/8	1/2 by 10 7/8	1/2 by 4 1/2 by 10 7/8	1/2 by 8 by 10 7/8	1/2 by 12
1 3/8	4	2	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 1/2	4 1/2*	2 1/4	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 1/2	4 1/2*	2	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 5/8	5*	2 1/4	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12
1 5/8	5 1/2*	2 1/2	1	8 by 6 by 1	1/2 by 10 3/4	1/2 by 4 1/2 by 10 3/4	1/2 by 8 by 10 3/4	1/2 by 12

* Special length bolts shall be furnished for bolting the bottom of the door sheet to the supporting truss.

Note: Use American National Standard washers on both sides of plate for shell thickness of 5/8 in. or less.

TABLE D-6—Raised-Type Bolted Door Sheets for Alternate Design Basis Tank Shells (See Fig. 3-13)

All dimensions are in inches.

(1) Thickness of Shell t_S	(2) Q	(3) q	(4) h	(5)	(6) K	(7) k	(8) D	(9) h_D	(10) L_D	(11) Number of Bolts Row 1	(12) Number of Bolts Row 2	(13) Number of Bolts Total	(14) Diameter of Bolt d	(15) Length of Bolt	(16) Length of Bolt Thread	(17) Square Locking Bar
1/4	7	1 15/16	7.179	4.080	36	2.837	5/16	52 1/2	131 1/2	...	7	156	3/4	2	1 1/8	5/8
5/16	7	2 1/4	7.232	4.259	30	3.438	3/8	53 1/4	137 1/4	...	3	136	7/8	2 1/4	1 3/8	3/4
3/8	8	2 1/4	6.328	3.882	30	3.438	7/16	53 1/4	141 3/4	...	2	152	7/8	2 1/4	1 3/8	3/4
7/16	8	2 7/16	6.375	4.013	24	4.125	1/2	54	141	...	...	136	1	2 1/2	1 1/2	3/4
1/2	8	2 7/16	6.375	4.013	22	4.722	9/16	54	145 7/8	...	4	140	1	2 3/4	1 1/2	3/4
9/16	8	2 7/8	6.422	4.310	20	4.969	5/8	54 3/4	148 3/4	...	...	128	1 1/8	3	1 5/8	1
5/8	8	2 7/8	6.422	4.310	20	5.256	11/16	54 3/4	154 1/2	...	4	136	1 1/8	3	1 5/8	1
11/16	8	3 1/16	6.469	4.454	20	4.988	3/4	55 1/2	152 1/2	...	...	128	1 1/4	3	1 3/4	1
3/4	8	3 1/16	6.469	4.454	20	5.294	13/16	55 1/2	158 5/8	...	2	132	1 1/4	3 1/4	1 3/4	1
13/16	8	3 1/4	6.516	4.602	20	5.006	15/16	56 1/4	156 1/4	...	...	128	1 3/8	3 1/2	2	1
7/8	8	3 1/4	6.516	4.602	20	5.331	1	56 1/4	162 3/4	...	2	132	1 3/8	3 1/2	1 7/8	1
1	8	3 1/4	6.516	4.602	20	5.331	1 1/8	56 1/4	162 3/4	...	8	144	1 3/8	3 3/4	1 7/8	1
1 1/8	8	3 1/4	6.516	4.602	20	5.656	1 1/4	56 1/4	169 1/4	7	8	158	1 3/8	4	1 7/8	1
1 1/4	8	3 7/16	6.563	4.752	20	5.713	1 3/8	57	173 3/4	3	8	150	1 1/2	4 1/2	2	1
1 3/8	8	3 7/16	6.563	4.752	20	5.713	1 9/16	57	173 3/4	7	8	158	1 1/2	4 3/4	2	1
1 1/2	8	3 11/16	6.609	4.952	20	5.781	1 11/16	57 3/4	179 1/2	5	8	154	1 5/8	5	2	1

Note: Use American National Standard washers on both sides of plate for shell thickness of 5/8 in. or less.

shells and, thus, will have a reduced resistance to the formation of a buckle under wind loading. The allowable wind velocity shall be calculated and the result reported to the purchaser.

a. Appendix D tanks with a closed top shall be constructed with top angles conforming to Par. 3.3.4(c). Open-top tanks, including floating-roof tanks, shall be provided with stiffening rings in conformance with Sect. 3.4. Self-supporting roofs shall fulfill the top-angle requirements of Par. 3.5.5, 3.5.6, and 3.5.7.

b. The maximum height of unstiffened shell, in feet, shall not exceed: *

$$H_1 = 6(100t)\sqrt{\left(\frac{100t}{D}\right)^3}$$

Where:

H_1 = vertical distance between the intermediate wind girder and the top angle of the shell or the top wind girder of an open-top tank, in feet.

t = average shell thickness in height H_1, in inches. [*Note:* The thicknesses as furnished for the tank shell shall be used to determine the average thickness unless the purchaser specifies that the net thickness (furnished thickness less corrosion allowance) be used for calculation of the wind girder.]

D = nominal tank diameter, in feet.

* This formula considers inward drag on open-top tanks and internal vacuum on closed-top tanks, a wind velocity of 100 mph, a gust factor, and a height factor. H_1 may be modified for other wind velocities by multiplying the formula by $(100/V)^2$, where V = wind velocity, in miles per hour, as specified by the purchaser. An acceptable source for values of V for various areas of the United States can be obtained from Paper No. 3269, "Final Report of the Task Committee on Wind Forces, Committee on Loads and Stresses, Structural Division," *Trans. ASCE* **126 (Part 2)** 1124-98 (1961).

c. In determining the maximum height of the unstiffened shell, an initial calculation shall be made using the thickness of the top shell course. Additional calculations shall be based on the weighted average thickness obtained by including part or all of the next lower course, or courses, until the calculated H_1 is equal to, or smaller than, the height of shell used in determining the average thickness. If H_1 continues to calculate greater than the height of shell used in determining the average thickness, no intermediate girder is required.

d. After establishing the location of the first intermediate girder, if required, a check of the lower shell shall be made using the first intermediate girder as the top of the tank and proceeding as outlined in Par. (b) and (c).

e. Locating the intermediate wind girder at the maximum spacing calculated by the preceding rules will usually result in the shell below the intermediate wind girder having a greater stability against wind loading than the shell above the intermediate girder. The girder may be located at a spacing less than the maximum spacing, but the lower shell must be checked for adequacy against the maximum wind pressure, as described in Par. (d) or in the following paragraphs:

1. Calculating the stability of the lower shell by averaging the thicknesses of the lower shell courses results in an incorrect higher value. A more correct solution is to change the width (W) of each shell course into a transposed width (W_{tr}) of each shell course, having a uniform thickness, by the following relationship:

$$W_{tr} = W\sqrt{\left(\frac{t\ \text{uniform}}{t\ \text{actual}}\right)^5}$$

2. The sum of the transposed widths of each course will give the height of the transformed shell. For equal

stability above and below the intermediate wind girder, the latter should be located at the mid-height of the transformed shell. The location of the girder on the transformed shell shall be transposed to the actual shell by the foregoing thickness relationship, using the actual thickness of the shell course on which the girder will finally be located and all actual thicknesses above this course.

3. If half the height of the transformed shell exceeds the maximum height of unstiffened shell (based on the uniform thickness) as calculated by Par. (b), a second intermediate girder shall be used in order to reduce the height of unstiffened shell to a height less than the maximum.

f. Intermediate wind girders shall not be attached to the shell within 6 in. of a horizontal joint of the shell. When the preliminary location of a girder is within this distance from a horizontal joint, the girder shall preferably be located 6 in. below the joint, except that the maximum unstiffened shell height shall not be exceeded.

g. The required minimum section modulus, in cubic inches, of the intermediate wind girder shall be determined by the equation:*

$$Z = 0.0001 D^2 H_1$$

* This equation is based on wind velocity of 100 mph. If specified by the purchaser, other wind velocities may be used by multiplying the equation by $(V/100)^2$.

1. Where the use of a transformed shell permits the intermediate wind girder to be located at a height less than H_1, calculated by the formula of Par. D.11(b), the spacing to the mid-height of the transformed shell, transposed to the height of the actual shell, may be substituted for H_1 in the calculation for minimum section modulus if the girder is attached at the transposed location.

2. The section modulus of the intermediate wind girder shall be based upon the properties of the attached members and may include a portion of the tank shell for a distance of $0.6\sqrt{Rt}$ above and below the attachment to the shell.

h. Intermediate stiffeners extending a maximum of 6 in. from the outside of the shell are permitted without need for an opening in the stiffener when the nominal stairway width is at least 24 in. For greater outward extensions of a stiffener, the stairway shall be increased in width to provide a minimum clearance of 18 in. between the outside of the stiffener and the handrail of the stairway, subject to the approval of the purchaser. If an opening is necessary, it may be designed with an opening in a manner similar to that provided in Par. 3.4.6 for the top wind girder, except that only an 18-in. width through the stiffener need be provided.

APPENDIX E
USE OF API MONOGRAM

The foregoing specification is for the use of all manufacturers desiring to use it.

Manufacturers desiring to warrant that articles manufactured or sold by them conform with this specification may, under certain conditions, obtain the license to use the official API monogram.

The following resolutions, adopted by the Board of Directors of the American Petroleum Institute, October 20, 1924, embody the purpose and conditions under which such official monogram may be used:

WHEREAS, There has been a movement in the petroleum industry to simplify, standardize, and improve oil-country drilling equipment and methods; and

WHEREAS, The cooperation of the American Petroleum Institute was sought in order that there might be a national forum for the discussion, consideration, and adoption or rejection of such proposed standards; and

WHEREAS, It appears desirable that the American Petroleum Institute adopt an official monogram to be used for identifying materials which comply with such standards or specifications (where such specifications or standards call for the use of such monogram) which may hereafter be adopted by the Board of Directors of the American Petroleum Institute; and

WHEREAS, It also appears desirable that the use of such monogram be encouraged wherever and whenever possible to inform the public that material so marked is manufactured in accordance with such specifications,

Now, Therefore, Be It Resolved: That the following monogram is hereby adopted as the official monogram of the American Petroleum Institute; and

Be It Further Resolved: That the words "Official Publication" shall be incorporated with said monogram on all such standards and specifications which may hereafter be adopted and published by the American Petroleum Institute, as follows:

OFFICIAL PUBLICATION

REG. U.S. PATENT OFFICE

Be It Further Resolved: That the general secretary or assistant general secretary be and he is hereby directed to authorize anyone desiring to do so to use such monogram under the following conditions:

Anyone desiring to use the monogram of the American Petroleum Institute shall apply to the American Petroleum Institute, using the form shown hereinafter entitled: "Application to Use Official Monogram of the American Petroleum Institute." Upon receipt of this application, properly acknowledged, and accompanied by a statement satisfactory to the Institute of the applicant's qualifications (when applicant is a manufacturer) to comply with the specification stated in the application, the secretary shall issue a certificate of authority to use the said monogram in the form shown hereinafter entitled: "Certificate of Authority to Use Official Monogram of the American Petroleum Institute";

Be It Further Resolved: That the Board of Directors of the American Petroleum Institute reserves the right to modify or change the said monogram and to revoke the right or license to use it on the part of any manufacturer for any reason satisfactory to the Board of Directors.

CANCELLATION OF MONOGRAM RIGHTS

The right to use the monogram is subject to cancellation for the following causes:

1. Using the monogram on material which does not meet the specification.

2. Failure to report on use of monogram. Each authorized manufacturer is required to report annually regarding his use of the monogram on the products covered by his authorizing certificates. Report forms will be provided by the Institute.

3. Failure to use the monogram on material furnished to the specification.

4 Failure to follow marking stipulations.

5. Improper use of the letters "API."

6. Failure to test master gages or to report on condition of master gages.

7. Using the monogram on material controlled by gages which are beyond approved tolerances.

8. Failure to repair gages known to be beyond approved tolerances.

FORM OF CERTIFICATE OF AUTHORITY TO USE OFFICIAL MONOGRAM OF THE AMERICAN PETROLEUM INSTITUTE

No. ________

AMERICAN PETROLEUM INSTITUTE
CERTIFICATE OF AUTHORITY TO USE
OFFICIAL MONOGRAM

The AMERICAN PETROLEUM INSTITUTE hereby grants to ....

....

the right to use the official monogram on

....

....

under the conditions specified in the official publication of the American Petroleum Institute entitled

....

....

with the understanding that the use of this monogram shall constitute a representation that the material so marked complies with the latest edition of said specification, and with the further understanding that material which fails to comply will not be so marked.

The American Petroleum Institute reserves the right to revoke this authorization to use the official monogram, for any reason satisfactory to the Board of Directors of the American Petroleum Institute.

Issued at Washington D.C., __________, 19 ____

American Petroleum Institute,

(Seal) ____________________

Secretary

AMERICAN PETROLEUM INSTITUTE
Division of Refining
1801 K Street, N.W.
Washington, D.C. 20006

STATEMENT OF MANUFACTURER'S QUALIFICATIONS TO USE API MONOGRAM

The information indicated below, when requested by the Institute, must accompany all applications to use the API monogram. All such information is subject to investigation, and applications must be rejected if the information supplied so warrants.

Material: ____
(List here the equipment on which applicant desires to apply the monogram.)

API specification designation ______________________________

1. Name of applicant ______________________________

2. Location of principal office ______________________________

3. Where will equipment be manufactured? ______________________________

4. Class of ownership ______________________________
(Corporation, partnership, or individual)

5. Capital invested ______________________________

6. Year organized ______________________________

7. Is the applicant thoroughly familiar with all stipulations given in the API specification covering this material? ______________________________

8. Is the applicant actually manufacturing this material now? ______________________________

   a. State the length of time applicant has made the material and supplied it to the oil industry ________
   ____
   (Years and months)

   b. State the approximate percentage of production of this material in relation to applicant's total production ______________________________

9. Give names and addresses of five representative users in the oil industry to whom applicant has sold this material (give name of company, complete mailing address including zip code, and name of company representative to whom inquiries should be addressed).

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10. If applicant has not supplied this material to the oil industry and cannot furnish the five references under item 9, give the names and addresses of five representative users in other industries to whom applicant has sold similar equipment (give name of company, complete mailing address including zip code, and name of company representative to whom inquiries should be addressed).

11. If the applicant is not now manufacturing this material, when does he expect to begin production?

12. If the applicant has not previously made this material, state fully the experience of any members of applicant's present organization in the manufacture of this material, giving names of organizations where such experience was obtained.

13. Give names of five responsible businessmen as references regarding applicant's general character, integrity, and reputation (give complete mailing address, including zip code, and name of organization with which each is affiliated).

14. Name and address of applicant's representative to whom API correspondence should be directed.

(Signature and title of authorized officer)

Date ______________

(Name of organization, company, or individual)

(The above statement to be signed in the name of the applicant by an authorized officer)

[*Copies of this form may be obtained from the director of the API Division of Refining.*]

APPLICATION TO USE OFFICIAL MONOGRAM OF THE AMERICAN PETROLEUM INSTITUTE

AMERICAN PETROLEUM INSTITUTE
1801 K Street, N.W.
Washington, D.C. 20006

Gentlemen:

In consideration of the American Petroleum Institute granting ______________ (us—me) the right to use the official monogram of the American Petroleum Institute in the manufacturing of ______________________

____

__________ (we—I) agree that the use of this monogram is a representation that material so marked complies with all of the conditions and specifications contained in the official publication of the Institute entitled

____

____

including any amendments or modifications that may hereafter be adopted.

______________ (We—I) further agree that no material which fails to comply with such specifications shall be so marked.

____
(Name of Company)

____
(Authorized Agent or Officer)

COUNTY OF ______________________ }
STATE OF ________________________ } ss.:

Acknowledged and sworn to before me

this ______________ day of ______ ______________, 19____
Notary Public

[Copies of this form may be obtained from the American Petroleum Institute.]

APPENDIX F

DESIGN OF TANKS FOR SMALL INTERNAL PRESSURES

F.1 SCOPE

a. The scope of API Standard 650 covers vertical cylindrical welded steel storage tanks, in various sizes and capacities, for a maximum internal pressure approximating atmospheric pressure. This maximum pressure may be increased for closed-top tanks to that permitted when the additional requirements of this appendix are met.

b. The internal pressure permitted in tanks built in accordance with this appendix, when multiplied by the cross-sectional area of the nominal tank diameter, shall not exceed the nominal weight of the metal in the shell, roof, and any framing supported by the shell or roof.

c. When design pressures higher than permitted by Par. (b) are desired, the shell may be anchored to a counterbalancing weight, such as a concrete ringwall, or may be attached to a bottom designed to resist the uplifting tendency of the shell. In either of these cases, the design of the roof, compression rings, shell, and bottom shall conform to the rules of API Standard 620.

d. Tanks designed in accordance with this appendix shall also comply with all applicable rules of API Standard 650.

F.2 VENTING

a. Operating conditions: Vents shall be sized and set so that, at their rated capacity, the internal pressure under any normal operating condition shall neither exceed the internal design pressure, P, nor the maximum design pressure, $P_{max.}$ (see Sect. F.4 and *Note* following Sect. F.6).

b. Emergency conditions:

1. When the compression ring construction conforms to but does not exceed the minimum requirements of Par. 3.3.4(c), 3.5.2, and 3.5.4, the frangible characteristic of the ring is retained and additional emergency venting devices are not required.

2. Where the weld size exceeds 3/16 in. or where the slope of the roof at the top-angle attachment is greater than 2 in. in 12 in., emergency venting devices conforming to the specifications noted in API Standard 2000 shall be provided by the purchaser. The manufacturer shall provide a suitable tank connection for the device.

F.3 DETAILS OF ROOF-SHELL JUNCTION

The details of the roof-shell junction and the limits of the area resisting the compressive force at the junction shall be in conformance with Fig. F-1.

F.4 MAXIMUM DESIGN PRESSURE

a. The design pressure, P, for a tank which has been constructed, or which has had the design details established, may be determined by the following expression (subject to the limitations of $P_{max.}$ in Par. (b):

$$P=\frac{(30{,}800)(A)(\tan\theta)}{D^2}+8t$$

Where:

P = internal design pressure, in inches of water.
A = area of top angle (or girder) plus the participating roof and shell, as illustrated in Fig. F-1, in square inches.
θ = angle between the roof and a horizontal plane at the roof-shell junction, in degrees. [*Note:* Tan θ is the slope of the roof.]
D = diameter of tank, in feet.
t = nominal thickness of roof, in inches.

b. The maximum design pressure, $P_{max.}$, limited by uplift at the base of the shell, shall not exceed the following in inches of water (subject to *Note* following Sect. F.6):

$$P_{max.}=\frac{0.245W}{D^2}+8t$$

Where:

W = total weight of shell plus any framing supported by shell and roof, in pounds.

Note: For large tanks, having the minimum top angle and a roof of small slope, the vent setting should be lower than $P_{max.}$ (see *Note* following Sect. F.6).

F.5 REQUIRED COMPRESSION AREA AT ROOF-SHELL JUNCTION

Where the maximum design pressure has already been established [not higher than permitted by Par. F.4(b)], the total required area at the roof-shell junction may be determined by the following expression:

$$A=\frac{D^2(P-8t)}{30{,}800\tan\theta}$$

F.6 CALCULATED FAILURE PRESSURE

Failure can be expected to occur when the stress in the compression ring area reaches the yield point. On this basis, an approximate formula for the pressure, P_F, at which failure of the top compression ring might occur can be expressed in terms of the maximum design pressure permitted by Par. F.4(a), as follows:

$$P_F=1.6P-4.8t$$

Where:

P_F = calculated failure pressure, in inches of water.

Note: This formula is based upon failure occurring at a yield stress of 32,000 psi. Experience with actual failures indicates that buckling of the roof-shell junction is localized and probably occurs when the yield point of the material is exceeded in the compression ring area. Overpressure in low-pitched roofs usually results in a failure of the frangible joint at the roof-shell junction.

The application of this formula to large tanks having the minimum top angle and a roof of small slope will result in the calculation of a failure pressure exceeding by only a small amount the maximum design pressure. In such unusual cases, a vent setting should be specified which will provide a safe margin, depending on the characteristics of the vent, between the maximum operating pressure and the calculated failure pressure. A suggested limitation is that $P_{max.}$ should not exceed $0.8\ P_F$.

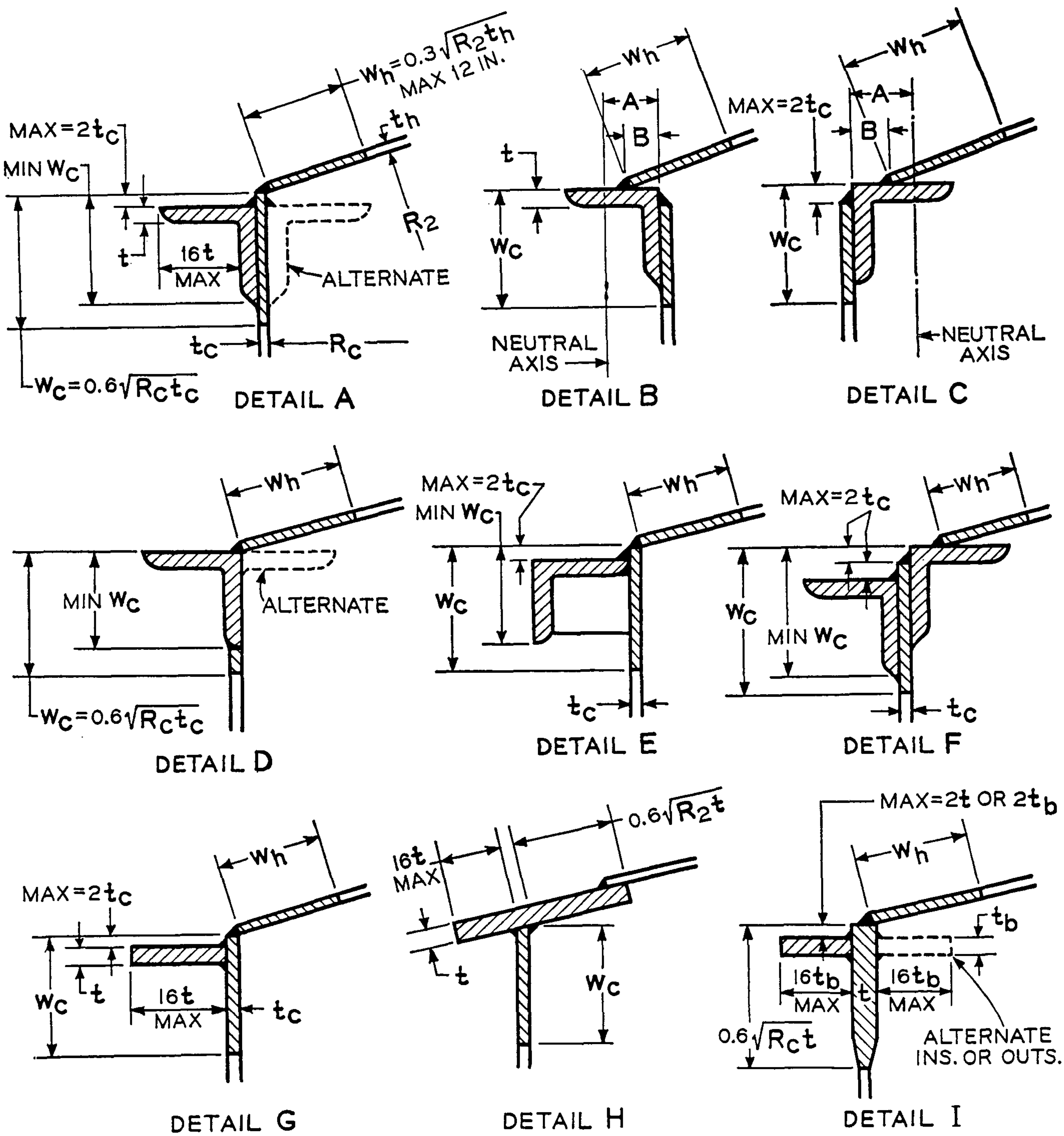


FIG. F-1—Some Permissible Details of Compression Rings.

APPENDIX G

HIGH-STRESS DESIGN FOR TANK SHELLS

G.1 SCOPE

a. This appendix provides a special design basis for shells of storage tanks. High-strength steels with improved notch toughness are used with a high-stress design based on the specific gravity of the product. Additional weld inspection is required. To minimize stress concentrations, openings in the shell are limited to specific details. The thinness of the shell plates necessitates a check of the tank shell for stability against lateral loading, such as wind. Intermediate wind girders may be required.

b. The purchaser should give special consideration to foundations, corrosion allowance, or any other protective measures deemed necessary.

c. This appendix is applicable only when specified by the purchaser. The purchaser shall state the design metal temperature (based on ambient temperatures), the design specific gravity, and the corrosion allowance, if any. The purchaser shall state the magnitude and direction of external loads or restraint, if any, for which the shell or shell connections must be designed. The design for such loadings shall be a matter of agreement between the purchaser and manufacturer.

d. The manufacturer may substitute upper shell courses that conform to all the requirements of Appendix D for the plate thicknesses and the design metal temperature, subject to the approval of the purchaser.

e. The requirements for an API Standard 650 tank, including Appendix D, shall apply, except that the maximum nominal thickness of 1½ in. for tank shell plates, as stated in Par. 3.3.3(c), may be increased to 1¾ in.

f. The specifications in this appendix are not intended for tanks in refrigerated service.

TABLE G-2—Maximum Permissible Alloy Content

	Heat Analysis (Percent)	Notes
Columbium	0.05	1,2,3
Vanadium	0.10	1,2,4
Columbium (0.05 percent max.) with vanadium	0.10	1,2,3
Nitrogen with vanadium	0.015	1,2,4
Copper	0.35	1,2,5
Nickel	0.50	1,2
Chromium	0.25	1,2,5
Molybdenum	0.08	1,2,5

NOTES:
1. Unless otherwise specified, the use of these alloys, or combinations thereof, shall be at the option of the plate producer, subject to approval of the purchaser. These elements shall be reported when requested by the purchaser.
2. The material shall conform on product analysis to these requirements subject to the product analyses tolerances of Table C of ASTM A6.
3. Columbium, when added either singly or in combination with vanadium, shall be restricted to plates of ½ in. max. thickness, unless combined with 0.15 percent min. silicon.
4. Nitrogen (0.015 percent max.), when added as a supplement to vanadium, shall be reported and the minimum ratio of vanadium to nitrogen shall be 4:1.
5. The total content of copper, chromium, and molybdenum shall not exceed 0.70 percent.

G.2 MATERIALS

a. Shell plates shall be in accordance with Tables G-1 and G-2 except that plates over 1½ in. shall be

TABLE G-1—Permissible Plate Materials and Allowable Stresses
(In Pounds per Square Inch)

				Product Design Stress, S_d		Hydrostatic Test Stress, S_t	
Steel Specification	Notes	Minimum Yield Strength	Minimum Tensile Strength	1st Course	Upper Courses	1st Course	Upper Courses
API Standard 650, Sect. G.10	1	50,000	70,000	26,300	28,000	28,000	30,000
ASTM A 573, grade 70	1,3	42,000	70,000	26,300	28,000	28,000	30,000
ASTM A 537, Class 1	1,3,4	50,000	70,000	26,300	28,000	28,000	30,000
ASTM A 537, Class 2	1,3,5	60,000	80,000	30,000	32,000	32,000	34,300
ASTM A 633, grades C and D	1	50,000	70,000	26,300	28,000	28,000	30,000
ASTM A 678, grade A	1,2	50,000	70,000	26,300	28,000	28,000	30,000
ASTM A 678, grade B	1,2	60,000	80,000	30,000	32,000	32,000	34,200
ABS hull structural steels: Grade EH	1,4	47,000	71,000	26,600	28,400	28,400	30,400
ISO R630: Fe 52, grades C and D	1	48,500	71,000	26,600	28,400	28,400	30,400

NOTES:
1. By agreement between purchaser and manufacturer, the tensile strength of the materials in this table may be increased up to 75,000 psi minimum and 90,000 psi maximum (and to 85,000 psi minimum and 100,000 psi maximum for ASTM A 537, Class 2). When this is done, the allowable stresses shall be determined as indicated in Par. G.3.
2. Boron additions not permitted.
3. The manganese and silicon limits listed in Table G-3 shall be applicable to A 537 and A 573 materials of Table G-1 and the material shall be marked as A 537 Mod or A 573 Mod.
4. Insert plates permitted to 2 in. thick, incl.
5. The tensile, bend, and impact tests (if any) shall be on each plate as heat-treated.

killed steel made to fine grain practice, heat-treated by normalizing, normalizing and tempering, or quenching and tempering, and shall be impact-tested by procedure 1 of Par. G.2(b). Plate used for reinforcement of openings shall be of the same material as the shell plate to which it is attached, except insert plates thicker than the shell plates shall be of appropriate material listed in Table G-1 and Fig. G-1.

b. For plates 1½ in. and less in thickness, the material listed in Table G-1 may be used at the design metal temperature (lowest one-day mean temperature plus 15 F) from Fig. G-1, or higher, without impact testing. Below the stated temperatures, the material shall demonstrate adequate notch-toughness at the design metal temperature in accordance with the following procedure 2 unless procedure 1 or 3 is specified by the purchaser:

R 1. Each plate as-rolled * shall be impact tested in accordance with Par. G.10.10 at the design metal temperature, or lower, to show Charpy V-notch values fulfilling the minimum longitudinal (or transverse) requirements for full-size specimens as listed in the following tabulation (refer to Par. G.10.10 for the minimum value for one specimen and for subsize values):

Plate Material and Thickness (Inches)	Requirements for Acceptance (Average of three specimens in ft-lbs) Longitudinal	Transverse
Table G-1 materials (except quenched and tempered)		
To 1½, inclusive	30	20
Over 1½ to 1¾, inclusive †	35	25
Over 1¾ to 2, inclusive (insert plates only) †	40	30
Table G-1 quenched and tempered material		
To 1½, inclusive	35	25
Over 1½ to 1¾, inclusive †	40	30
Over 1¾ to 2, inclusive (insert plates only) †	45	35

R 2. The thickest plate from each heat shall be impact tested in accordance with Par. G.10.10 and shall fulfill the impact requirements of Par. G.2(b)(1) at the design metal temperature.

3. The manufacturer shall submit to the purchaser test data from plates of this material demonstrating that based on past production from the same mill, the material has provided the required toughness at the design metal temperature.

c. Unless experience or special local conditions justify otherwise, the design metal temperature shall be assumed to be the lowest one-day mean ambient temperature in the locality where the tank is to be installed, plus 15 F. Isothermal lines of lowest one-day mean temperatures are shown in Fig. D-1.

* The term *plate as-rolled*, as used here, refers to the unit plate rolled from a slab or directly from an ingot in its relation to the location and number of specimens—not to its condition.

† Interpolation permitted to nearest ft-lb.

d. The top angle and the wind girders shall conform, in material and size, to the requirements in this standard.

e. The bottom plate, to which the shell attaches, shall be of the same material as the shell or of the material specified in Appendix D for the thickness and design metal temperature.

f. Material for nozzle and manhole necks shall be seamless pipe complying with ASTM A 106, grade B, or A 524; or shall be plate material, fusion-welded, conforming to the material used for the tank shell. R

g. Flanges shall conform to the requirements for an API Standard 650 tank.

h. Forgings shall conform to ASTM A 181, grade II; A 105, grade II; or A 350 LF 2.

i. Material specified in Par. (f) through (h) for flanges, nozzles, manhole necks, and all forgings shall have a minimum Charpy V-notch impact strength of 15 ft-lb (full-sized specimen) at the design metal temperature when the design metal temperature is below 0 F.

G.3 ALLOWABLE STRESS

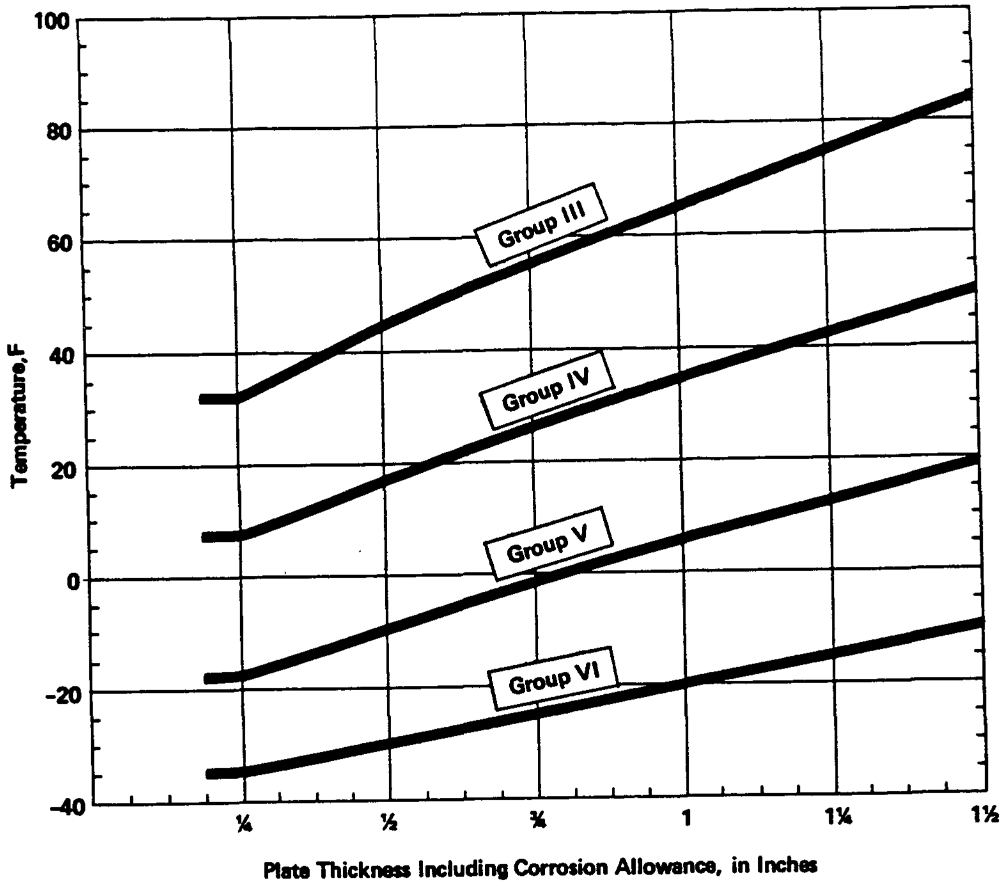
a. The maximum allowable design stress, S_d, including the joint efficiency factor, shall be as shown in Table G-1. The net plate thicknesses—actual thickness less corrosion allowance—shall be used in the calculation. Design basis, S_d, for the first course shall be the lesser of ⅔ yield strength or ⅜ tensile strength; for the upper courses it shall be the lesser of ⅔ yield strength or ⅖ tensile strength.

b. The maximum allowable hydrostatic test stress, S_t, including the joint efficiency factor, shall be as shown in Table G-1. The gross plate thicknesses including any corrosion allowance shall be used in the calculation. Design basis, S_t, for the first course shall be the lesser of ¾ yield strength or ⅖ tensile strength; for the upper courses it shall be the lesser of ¾ yield strength or 3/7 tensile strength.

G.4 CORROSION ALLOWANCE

a. The purchaser shall specify, when necessary, the corrosion allowance to be provided on the shell plates, giving consideration to the total effect of liquid stored, the vapor above the liquid, and the atmospheric environment.

b. When the service conditions might include the presence of hydrogen sulfide, it is recommended that consideration be given to the hardness of the inside welds, including the heat-affected zones, in order to minimize the possibility of stress corrosion cracking. The weld metal and adjacent heat-affected zone often contain a zone of hardness well in excess of RC 22 and could be expected to be more susceptible to cracking than unwelded material. Any hardness criteria should be a matter of agreement between the purchaser and



Materials:

Group III, as-rolled, semi-killed, or fully killed:
API Std 650, Sect. G.10

Group IV, as-rolled, fully killed, fine grain:
API Std 650, Sect. G.10; ASTM A 573, grade 70

Group V, normalized, fully killed, fine grain:
API Std 650, Sect. G.10; ASTM A 573, grade 70
ASTM A 633, grades C and D.

Group VI, normalized or quench-tempered, fully killed, fine grain, reduced carbon:
ASTM A 537, Classes 1 and 2, ABS grade EH
ASTM A 678, grades A and B R

FIG. G-1—Minimum Permissible Design Metal Temperature for Plates Used in Tank Shells Without Impact Testing (In Degrees Fahrenheit)

the manufacturer and should be based on an evaluation of the expected hydrogen sulfide concentration in the product, the possibility of moisture being present on the inside metal surface, and the strength and hardness characteristics of base metal and weld metal.

G.5 SHELL THICKNESSES

R **a.** The required shell thicknesses shall be the greater of design shell thicknesses [Par. G.5(b)] including corrosion allowance, or hydrostatic test shell thicknesses [Par. G.5(c)], but in no case shall the total shell thickness be less than that shown in Par. 3.3.3(b).

b. The design shell thicknesses shall be computed on the basis that the tank is filled with liquid which has a specific gravity as specified by the purchaser.

c. The hydrostatic test shell thicknesses shall be computed on the basis that the tank is filled with water.

d. Where it is practicable, the tank shall be filled with water for hydrostatic testing. Although it is recognized that the hydrostatic test may be impracticable in some instances, the computed hydrostatic test shell thicknesses shall be used when they are greater than design shell thicknesses.

e. The required minimum thickness of shell plates shall be the greater of the values computed by the following formulas:

Design shell thickness, in inches

$$= \frac{(2.6)(D)(H-1)(G)}{S_d} + c$$

Hydrostatic test shell thickness, in inches

$$= \frac{(2.6)(D)(H-1)}{S_t}$$

Where:

D = nominal diameter of tank, in feet.
H = height, in feet, from the bottom of the course

under consideration to the top of the top angle or to the filling height limited by the tank overflow.

G = design specific gravity of liquid.

c = corrosion allowance, in inches, as specified by the purchaser.

f. Upper shell courses may be of other steels approved in Appendix D; but if such steels are used, the calculated stress 12 in. above the bottom of any course shall not be greater than permitted in Appendix D for the particular material, nor shall any plate course be thinner than the course above it.

g. The tank shell shall be checked for stability against buckling from the design wind velocity by the rules of Sect. D.11. If required, intermediate girders, increased plate thickness, or both, shall be utilized.

G.6 SHELL CONNECTIONS

a. All shell opening connections that require reinforcement shall conform to Par. D.6(e), including the minimum permissible details of Appendix D (see Fig. D-3) and of API Standard 620 (see Fig. 3.16.2). The width or thickness of the insert or reinforcing plate may be reduced and the neck thickness increased a corresponding amount within the limits of Par. 3.3.7(b) to still provide the area requirements of Par. D.6(e).

Note: Openings near the bottom of the tank shell will tend to rotate with vertical bending of the shell under hydrostatic loading. Shell openings in this area, having attached piping or other external loads, should be reinforced not only for the static condition but also for any loads imposed on the shell connections by the restraint of the attached piping to the shell rotation. Preferably, the external loads should be eliminated or the shell connections relocated outside the rotation area.

b. All opening connections requiring reinforcement in a shell plate exceeding ½ in. in thickness shall be prefabricated into the shell plate or insert plate and the prefabricated assembly shall be stress-relieved prior to installation. The stress-relieving requirements do not apply to the weld to the bottom annular plate, except for flush-type cleanout openings. All flush-type cleanout openings shall be stress-relieved including the bottom reinforcing plate (or annular plate).

c. The outer edge (toe) of a weld around penetration, around the periphery of a thickened insert plate, or around the periphery of a reinforcing plate shall be at least 6 in. from vertical joints or 3 in. from horizontal joints provided that, in either case, the spacing is not less than 2½ times the shell thickness. These rules shall also apply to the bottom-to-shell joint except that, as an alternative, the insert plate or reinforcing plate may extend to and intersect the bottom-to-shell joint at approximately 90 deg. Low connections fulfilling the requirement of Par. 3.3.7 and Sect. G.6 are permissible. Bolted door sheets are not permitted.

d. Flush-type cleanout openings in accordance with Sect. D.9 are permissible with the following exceptions:

1. The material for the shell plate in the cleanout opening assembly, the shell reinforcing plate, the tank bottom reinforcing plate, and the neck plate shall be in conformance with Sect. G.2.

2. The maximum height of the opening in the shell shall not exceed 36 in.

3. The upper corner radius (r_1 in Table D-2) of a 36-in. by 48-in. opening shall be 24 in.

e. Permanent attachments, including stairways and similar appurtenances, may be attached to shell courses designed in accordance with the requirements of Appendix G provided that the details of these attachments conform to the following requirements and that consideration is given to the movement of the shell (particularly movement of the bottom course) under hydrostatic loading:

1. Prior to the hydrotest, permanent attachments may be welded directly to the shell with fillet welds having a maximum leg dimension of ½ in. The edge of any permanent attachment welds shall not be closer than 3 in. from the horizontal joints of the shell nor closer than 6 in. from the vertical joints, insert plate joints, or reinforcing plate fillet welds.

2. The welding and inspection of permanent attachments to these shell courses shall conform to Par. G.7(d).

3. Temporary attachments to shell courses described in Appendix G shall be made prior to the hydrostatic test and preferably prior to welding of the shell joints. Weld spacing for temporary attachments made after welding of the shell joints shall be the same as that required for permanent attachments. Temporary attachments to Appendix G shell courses shall be removed, and any resulting damage shall be repaired and ground to a smooth profile prior to the hydrostatic test.

G.7 WELDING AND WELD INSPECTION

a. Welding procedures and weld inspection shall conform to Par. D.6(a), (b), (c), (d), (g), and (h). The requirements for 1½ in. thick material shall also apply to material over 1½ in. including the requirements in the note following Par. G.7(c)(2) and the requirements in Par. G.7(e).

b. Low-hydrogen electrodes shall be used for all manual, metal-arc welds of shell courses having a thickness of ½ in. or more.

c. The specification of each welding procedure shall be qualified in accordance with the latest practice as given in the applicable rules of Sect. IX of the ASME Code. The materials in Table G-1 shall be accepted as

P-Number 1 for the procedure classification. The required tests to qualify such welding procedures shall be conducted by the manufacturer.

1. A test plate shall be made from typical plates of each specification and grade of Table G-1 plate material used in the tank shell. The test plate from each specification and grade shall be at least as thick as the plate of the same type used in the tank shell. A test plate shall be made for each position and for each process employed in welding the tank.

2. When impact testing is required by Fig. G-1 for the plate material, Charpy V-notch test specimens shall be taken from the weld metal and heat-affected zone of vertical seam qualification plates and from only the weld metal of circumferential seam qualification plates. The impact tests shall show an average of at least 20 ft-lb at the design metal temperature, except that the impact tests on quenched and tempered material such as
R ASTM A 537, Class 2, and ASTM A 678, grades A and B, shall show an average of at least 25 ft-lb at the design metal temperature.

Note: For tank shell plates over 1½ in., the preceding impact values for welds and heat-affected zones shall be increased 5 ft-lb per ¼ in. over 1½ in. (Interpolation permitted to nearest ft-lb.)

3. Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. The specimen shall be oriented so that the notch is normal to the surface of the material. One face of the specimen shall be substantially parallel to and within ¹⁄₁₆ in. of the surface.

4. Heat-affected-zone impact specimens shall be taken across the weld and as near the surface of the material as is practical. The specimens shall be of sufficient length to locate, after etching, the notch in the heat-affected zone. The notch shall be cut approximately normal to the material surface to include as much heat-affected-zone material as possible in the resulting fracture.

5. Production weld test plates need not be made. The production welding shall conform to the qualified welding procedure.

d. Permanent attachments to shell courses covered in Appendix G shall be welded with low-hydrogen electrodes. The welds shall be inspected by magnetic particle or liquid penetrant method at the option of the purchaser and any cracks or undercuts shall be removed. Both permanent and temporary attachments shall be welded by a procedure that does not cause underbead cracking. The necessity of preheat for thick plates or for a low atmospheric temperature during welding shall be considered when selecting the procedure.

e. For circumferential and vertical joints in tank shell courses constructed of material over 1½ in. in thickness (based on the thickness of the thicker plate at the joint), multipass weld procedures are required with no pass permitted over ¾ in. in thickness. A minimum preheat of 200 F is required for these welds.

G.8 FOUNDATION

a. The selection of the tank site and the design and construction of the foundation shall be given careful consideration as outlined in Appendix B in order to ensure adequate tank support. Concrete ringwall foundations shall be considered. The adequacy of the foundation is the responsibility of the purchaser.

G.9 MARKING

a. The nameplate shall indicate that the tank shell has been designed in accordance with this appendix. The API monogram may be applied to tank shells constructed in accordance with this appendix.

b. Where only the lower courses of the tank shell have been designed in accordance with this appendix, the nameplate shall indicate the total height of these courses. A second nameplate shall indicate the design of the upper courses of the shell; see Sect. 8 and Sect. D.8.

c. In addition to information required by Fig. D-4, the monogrammed nameplate shall state the design specific gravity of the liquid to be stored, the type of material used in the shell courses designed (using the stresses in this appendix), and the heat treatment, if any.

G.10 REQUIREMENTS FOR STEEL PLATES FOR STORAGE TANKS

G.10.1 Scope

a. This section lists the requirements for high-strength steel plates of structural quality suitable for welded construction of tanks.

b. Plates covered in this appendix are limited to a maximum thickness of 1¾ in.

c. This material is intended for fusion welding. Welding technique is of fundamental importance, and welding procedures must provide welds having the strength and toughness consistent with the plate material joined.

G.10.2 General Requirements for Delivery

a. Material furnished under this specification shall conform to the applicable requirements of the current edition of *ASTM A 6: General Requirements for Delivery of Rolled Steel Plates, Shapes, Sheet Piling and Bars for Structural Use*. Material furnished to this specification is not restricted as to locality of manufacture.

b. All welding performed for the repair of surface defects shall be done with low-hydrogen welding electrodes of the E70XX series.

G.10.3 Process

a. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, or basic oxygen.

b. When specified by the plate purchaser, the steel shall be fully killed. The silicon content of the fully killed steel shall be in the range of 0.15 to 0.30 percent by ladle analysis.

c. When specified by the plate purchaser, fully killed steel shall be made to fine grain practice.

d. Plates over 1½ in. in thickness shall be fully killed and made to fine grain practice.

G.10.4 Heat Treatment

a. When specified by the plate purchaser, fully killed plates shall be heat-treated to produce grain refinement either by normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in conjunction with hot forming, the temperature to which the plates are heated for hot forming shall be equivalent to and shall not significantly exceed the normalizing temperature. If the treatment of the plates is not specified to be done at the plate producer's plant, the testing shall be carried out in accordance with Par. (b).

b. When a plate purchaser elects to perform the required normalizing, or fabricates by hot forming as provided in Par. (a), the plates shall be accepted on the basis of mill tests made on full-thickness specimens heat-treated in accordance with the plate purchaser's order. If the heat treatment temperatures are not indicated on the purchase order, the plate producer shall heat-treat the specimens under conditions he considers appropriate for grain refinement, and to meet the test requirements. The plate producer shall inform the plate purchaser of the procedure followed in treating the specimens at the steel mill.

c. The plate purchaser shall indicate in his orders to the plate producer whether the plate producer shall perform the heat treatment of the plates.

G.10.5 Chemical Composition

a. The steel shall conform to the requirements for chemical composition prescribed in Table G-3.

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TABLE G-3—Chemical Requirements

		Heat Analyses	
	Notes	Minimum Percent	Maximum Percent
Carbon	1	. . .	0.23
Manganese (≤ ¾ in.)	1	0.50	1.35
Manganese (> ¾ in.)	1	0.80	1.35
Manganese	1,2	0.80	1.60
Phosphorus	1	. . .	00.4
Sulfur	1	. . .	0.05
Silicon	1	. . .	0.30
Silicon	1,3	0.15	0.30
Silicon	1,4	0.15	0.50

NOTES:
1. The material shall conform on product analysis to these requirements subject to the product analyses tolerances of Table B of ASTM A6.
2. At the option of the plate producer in order to maintain the required strength level, provided the maximum carbon content be reduced to 0.20 percent. The weldability of the plates shall be given consideration.
3. When plates are specified to be fully killed.
4. At the option of the plate producer in order to maintain the required strength level. The weldability of the plates shall be given consideration.

b. The use or presence of columbium, vanadium, nitrogen, copper, nickel, chromium, or molybdenum shall be at the option of the plate producer but shall not exceed the limitations of Table G-2. These elements shall be reported when requested by the purchaser.

G.10.6 Tensile Properties

a. The material, as represented by the test specimens, shall conform to the tensile requirements as given in Table G-4.

b. For material under 5⁄16 in. in thickness, a deduction from the percentage of elongation in 8 in., specified in Table G-4, of 1.25 percent shall be made for each decrease of 1⁄32 in. of the specified thickness below 5⁄16 in.

c. For material over ¾ in. in thickness, a deduction from the percentage of elongation in 8 in., specified in Table G-4, of 0.50 percent shall be made for each increase of ⅛ in. of the specified thickness above ¾ in. This deduction shall not exceed 3 percent.

G.10.7 Bending Properties

a. The bend test specimens and their testing shall conform to the requirements of the material specification. The test piece shall be at room temperature and shall be bent through 180 degrees to the internal radius specified without cracking on the outside of the bent portion. The maximum bend radius shall not exceed 1.5 times the thickness of the test piece.

G.10.8 Number of Tests

a. Two tension and two bend tests shall be made from each heat unless the finished material from a heat is less than 30 tons, when one tension test and one bend test will be sufficient. If, however, material from one heat in any thickness range differs by ⅜ in. or more, one tension heat and one bend test shall be made from both the thickest and the thinnest material rolled in that range, regardless of the weight represented.

G.10.9 Test Certificates

a. Test certificates reporting the results required by Sect. G.10.8 shall be furnished by the plate producer to the tank manufacturer, and also to the tank purchaser if requested.

TABLE G-4—Tensile Requirements

	Minimum	Maximum
Yield strength, in pounds per square inch	50,000	. . .
Tensile strength, in pounds per square inch	70,000	90,000
Elongation in 8 in., in percent	18	. . .

R G.10.10 Impact Testing of Plates

a. When required by the purchaser, a set of Charpy V-notch impact specimens shall be taken from plates after heat treatment, if any, and shall fulfill the stated energy requirements of Par. G.2(b). Test coupons shall be obtained adjacent to a tension test coupon. Full-size impact specimens shall have their central axis as close to the plane of ¼ plate thickness as the plate thickness will permit.

b. When it is necessary to prepare test specimens from separate coupons, or when plates are furnished by the plate manufacturer in a hot-rolled condition with subsequent heat treatment by the fabricator, the procedure shall conform to ASTM A 20.

c. An impact test shall consist of three specimens taken from a single test coupon or test location. The average value of the specimens (no more than one specimen value being below the specified minimum value) shall comply with the specified minimum value. If more than one value is below the specified minimum value, or if one value is below ⅔ of the specified minimum value, a retest of three additional specimens shall be made, each of which must have a value equal to or exceeding the specified minimum value.

d. The test specimens shall be Charpy V-notch Type A (ASTM A 370) with the notch perpendicular to the surface of the plate being tested.

e. For plates of insufficient thickness to permit preparation of full-size (10 mm by 10 mm) specimens, tests shall be made on the largest of the subsize specimens that can be prepared from the plate. The subsize specimens shall have a width along the notch of at least 80 percent of the material thickness.

f. The impact energy values obtained on subsize specimens shall not be less than values that are proportional to energy values required for full-size specimens of the same material.

g. The testing apparatus, including the calibration of impact machines and the permissible variations in the temperature of specimens, shall conform to ASTM A 370, except that equivalent testing apparatus conforming to nationally recognized (or ISO) standards are acceptable.

h. (Deleted) R

G.11 ANNULAR BOTTOM PLATES R

a. Tanks shall have butt-welded annular bottom plates with a radial width providing at least 24 inches between the inside of the shell and any lap-welded joint in the remainder of the bottom and at least a 2-inch projection outside the shell.

b. The thickness of the annular bottom plates shall not be less than the following:

Nominal Thickness of First Shell Course (Inches)	Minimum Thickness of Annular Plates (Inches)
$t \leq \frac{1}{2}$	¼
$\frac{1}{2} < t \leq \frac{7}{8}$	5/16
$\frac{7}{8} < t \leq 1\frac{1}{4}$	⅜
$1\frac{1}{4} < t$	7/16

c. The ring of annular plates shall have a circular outside circumference but may have a regular polygonal shape inside the tank shell with the number of sides equal to the number of annular plates. These pieces shall be butt-welded in accordance with Par. 3.2.2(b). The backup bar shall be compatible for welding the annular plates together.

d. The plates of the first shell course shall be attached to the annular bottom plates by a fillet weld inside and outside as required by Par. 3.2.3, except that each weld shall be made with a minimum of two passes.

APPENDIX H
COVERED FLOATING ROOFS

H.1 SCOPE

The requirements given herein are minimum and, unless otherwise qualified in the text, apply to the fixed roof, the floating roof, and the tank appurtenances. These requirements are intended to limit only those factors that affect the safety and durability of the installation, and which are considered to be consistent with the quality and safety requirements of API Standard 650. They shall apply whether the covered floater is part of a new tank or is installed in an existing fixed-roof tank. However, regarding such items as ventilation, these requirements can also be applied to covering an existing open-top floating roof.

H.2 MATERIAL

Material requirements as set forth in Part 2 of this standard shall apply, except as specifically covered in this appendix.

H.3 DESIGN

H.3.1 General

The roof and accessories shall be so designed and constructed as to allow the tank to operate up to its net capacity without manual attention and without damage to any part of the fixed or floating roofs, tank, or appurtenances.

H.3.2 Joint Design

Sect. 3.1 of this standard shall apply.

H.3.3 Fixed-Roof Design

Sect. 3.5 of this standard shall apply, except as modified in this appendix.

H.3.4 Floating Roof

a. It is recommended that the floating roof be of the contact type, designed to minimize the presence of any air-vapor mixture under the deck.

b. Unless otherwise specified on the purchase order, all deck and rim plates shall have a minimum nominal thickness of $\frac{3}{16}$ in. (7.65 lb per sq ft of plate, 0.180-in. plate, or 0.1799-in. gage sheet).

c. Deck plates shall be joined by continuous full-fillet welds on the top side.

d. The deck may be designed and built to float and rest in a flat position (no slope).

e. The rim of the floating roof and the necks of any appurtenances installed through the deck shall have a minimum height of 8 in.

H.3.5 Pontoons

No pontoons or bulkheads are required since the floating roof is not exposed to the elements.

H.3.6 Drains

No primary or emergency drains are required since the floating roof is not exposed to the elements.

H.3.7 Ladders

The floating roof shall be supplied with a ladder unless otherwise specified by the purchaser. The ladder shall be designed for full floating-roof travel, regardless of any settling of the roof supports. If a rolling ladder is furnished, it shall have adequate handrails on both sides and shall be designed for a 1,000-lb midpoint load with the ladder in any operating position.

H.3.8 Vents

a. Floating roof: Suitable vents shall be provided to prevent overstressing of the roof deck or seal membrane. These vents shall be adequate to evacuate air and gases from underneath the roof when the roof is on its supports during filling operations. They shall also be adequate to relieve any vacuum generated underneath the roof after it settles on its supports during withdrawal operations. The purchaser shall specify filling and emptying rates so that the fabricator may size the vents properly.

b. Tank shell: Circulation vents or openings shall be located above the seal of the floating roof when the tank is full. The maximum spacing shall be 32 ft, but in no case shall there be less than four equally spaced vents. The total open area of these vents shall be equal to, or greater than, 0.2 sq ft per ft of tank diameter. This empirical figure has been established on the basis of successful practice.

c. Fixed roof: An open vent shall be provided at the center or at the highest elevation of the fixed roof. It shall have a weather cover and a minimum open area of 50 sq in.

d. Vents may be provided with coarse mesh screens to prevent ingress of birds or animals, if specified by the purchaser.

H.3.9 Liquid-Level Indicators

Overflows or other means shall be provided to indicate when the tank is filled to net capacity. The purchaser shall specify whether the tank shell diameter and height are nominal or whether a net capacity is required up to the bottom of the overflows.

H.3.10 Roof Supports

a. The floating roof shall be provided with fixed supports. The length of these supports, or the low operating level of the roof, shall be specified by the purchaser. The manufacturer shall make certain that all tank appurtenances, such as mixers, interior piping, fill nozzles, and so forth, are cleared by the roof in its lowest position.

b. Supports and attachments shall be designed to support a uniform live load of 12.5 lb per sq ft on the deck. Support attachments in the deck areas shall be given particular attention to prevent failure at the points of attachment. On the bottom side of the deck plates, where flexure is anticipated adjacent to supports or other relatively rigid members, full-fillet welds not less than 2 in. long on 10-in. centers shall be used on any plate laps which occur within 12 in. of any such rigid support or member. Steel pads or other means shall be used to distribute the loads on the bottom of the tank. Pads, if used, shall be continuously seal-welded to the tank bottom. Supports fabricated from pipe shall be notched or perforated at the bottom to provide drainage.

c. Adjustable supports shall be supplied if the purchaser specifies the desired operating and cleaning levels. Length of supports shall be adjustable from the top side of the floating roof. Design of the supports shall be such as to prevent damage to the fixed roof when the tank is full.

H.3.11 Seals

a. Peripheral: The space between the outer periphery of the roof and the tank shell shall be sealed by a flexible device which shall provide a reasonably close fit to the shell surfaces. If this sealing device is a coated fabric or other nonmetallic material, it shall be durable in its environment and shall not discolor or contaminate the product stored. A minimum of four static electricity drains shall be provided when a nonmetallic seal is used. The maximum spacing of the static electricity drains shall be 32 ft. Any alternate means of draining static electricity that is approved by the purchaser may be provided.

If the sealing device employs steel shoes in contact with the shell, such shoes shall be made from galvanized sheets unless otherwise specified. Galvanized sheets shall conform to the latest edition of *ASTM A 525: Standard Specification for General Requirements for Delivery of Zinc-Coated (Galvanized) Iron or Steel Sheets, Coils and Cut Lengths Coated by the Hot-Dip Method*, with a minimum nominal thickness of 16 gage and a class 1.25 (commercial) coating. An adequate but minimum number of expansion joints shall be provided.

b. Deck penetrations: If columns or other appurtenances penetrate the deck, seals shall be provided to ensure a reasonably close fit to these appurtenances through all horizontal and vertical movements of the deck. The seals shall be durable in their environment and shall not discolor or contaminate the product stored.

H.3.12 Centering and Antirotation Device

A seal or other suitable device shall be provided to maintain the roof in a centered position. The roof shall be prevented from rotating.

H.3.13 Manways

a. Fixed roof: At least one roof manhole, minimum 24 in. ID, shall be provided for access to the tank interior.

b. Floating roof: At least one manhole shall be provided underneath the deck for access to and ventilation of the tank when the roof is on its supports and the tank is empty. It shall be at least 24 in. ID and may be of the loose-cover type.

H.3.14 Gaging and Sampling Devices

The fixed and floating roofs shall be provided with gaging and sampling devices which are subject to the approval of the purchaser.

H.4 FABRICATION, ERECTION, WELDING, INSPECTION, AND TESTING

a. Applicable fabrication, erection, welding, inspection, and testing requirements of this standard shall apply.

b. Deck seams and other joints, which are required to be liquid- or vapor-tight, shall be tested for leaks by penetrating oil or by any other method consistent with the methods described in this standard for testing cone-roof seams and tank-bottom seams.

c. The roof shall be given a flotation test while the tank is being filled with water and emptied. During this test, the upper side of the lower deck shall be examined for leaks. The appearance of a damp spot on the upper side of the lower deck shall be considered evidence of leakage.

APPENDIX J

SHOP-ASSEMBLED STORAGE TANKS

J.1 SCOPE

a. This appendix provides design and fabrication specifications for vertical storage tanks of such a size as to permit complete shop assembly and delivery to the installation site in one piece. Storage tanks designed on this basis are not to exceed 20 ft in diameter within the scope of API Standard 650.

b. In the design and fabrication of shop-assembled storage tanks, the use of this appendix shall be predicated upon mutual agreement between the purchaser and the fabricator.

J.2 MATERIAL

Material requirements as set forth in Part 2 of this standard shall apply.

J.3 DESIGN

J.3.1 Joint Design

Sect. 3.1 shall apply, except that lap-welded joints in bottoms are not permissible.

J.3.2 Bottom Design

a. All bottom plates shall have a minimum nominal thickness of ¼ in. (10.2 lb per sq ft; see Sect. 2.1).

b. Bottom plates shall be built in a minimum number of pieces; wherever feasible they shall be constructed in one piece.

c. Bottoms may be flat or flat-flanged. Flat bottoms shall project at least 1 in. beyond the outside diameter of the weld attaching the bottom to the shell plate. Flat-flanged bottoms shall have an inside corner radius of not less than three times bottom thickness and a straight flange of ¾ in. minimum.

d. Joints in bottom plates shall be butt-welded. Welding shall be accomplished in such a manner as to produce complete penetration of the parent metal.

e. For flat bottoms the attachment between the bottom edges of the lowest course shell plate and the bottom plate shall be a continuous fillet weld laid on each side of the shell plate. Each fillet weld shall be sized in accordance with the specifications given in Par. 3.2.3. Flat-flanged bottoms shall be attached to the shell by full-penetration butt welds.

J.3.3 Shell Design

a. Shell plates shall be designed in accordance with the specifications given in Sect. 3.3, except that minimum thickness shall be no less than those listed in the following tabulation:

Nominal Tank Diameter (Feet)	Nominal Plate Thickness (Inches)
Up to 10.5, incl.	3⁄16
Over 10.5	¼

b. An alternative method of computing the minimum required shell thickness based on a joint efficiency of 0.70 may be used. By this method, the required minimum thicknesses shall be:

$$t = \frac{2.6D(H-1)G}{(0.70)(21{,}000)}$$

Where:

t = minimum thickness, in inches.
D = nominal diameter of tank, in feet.*
H = height, in feet, from bottom of course under consideration to top of top angle or to bottom of any overflow which limits tank filling height.
G = specific gravity of liquid to be stored, but in no case less than 1.0.

c. The minimum requirements of the tabulation in item (a) must be observed.

d. Calculation of shell thickness by this method is intended to eliminate the requirement for spot radiographing or sectioning as specified in Sect. J.5 and Par. 5.3.1. This alternative may be used at the option of the fabricator unless specifically prohibited by the purchaser.

e. In addition to the provisions in item (a), the following modifications to these requirements shall apply:

1. All shell joints shall be butt-welded in such a manner as to produce full penetration without the use of backup bars.

2. Shell plates shall be sized so as to limit the number of plates required to the smallest practical quantity consistent with sound economic practice. Preferably, each course shall be constructed in one plate.

3. Top angles shall not be required for flanged-roof tanks.

J.3.4 Wind Girder Design for Open-Top Tanks

Open-top tanks shall be provided with wind girders as specified in Sect. 3.4.

J.3.5 Roof Design

a. Roofs for tanks constructed in accordance with this appendix shall be of the self-supporting type. They shall conform in configuration to one of the following shapes:

1. *Conical:* Self-supporting cone roofs shall be designed as specified in Par. 3.5.5, except that they may be provided with a flange which will permit butt-welded attachment to the shell. When a flange is provided, the top angle will not be required. Flanges must be formed with a minimum inside corner radius of the larger of

* Nominal tank diameter shall be the centerline diameter of the shell plates, unless otherwise specified by the purchaser.

three times the roof thickness, or ¾ in., and a straight flange of ¾ in. minimum.

2. *Dome and Umbrella:* Self-supporting dome and umbrella roofs shall be designed as specified in Par. 3.5.6, except that they may be flanged as provided for conical roofs in which case the top angle may be omitted. For domed roofs that have been flanged, the radius of curvature shall not be limited to the maximum requirements given in Par. 3.5.6; instead, they shall be limited by minimum depth, including crown and knuckle depth, as follows:

Diameter (Feet)	Depth (Inches)
To 6, incl.	2
To 8, incl.	3½
To 10, incl.	5½
To 12, incl.	8
To 14, incl.	11
To 16, incl.	15
To 20, incl.	20

b. Top angles, when required, shall be attached as specified in Par. 3.5.7.

J.3.6 Tank Connections and Appurtenances

Manholes, nozzles, and other connections shall be constructed and attached as indicated in Sect. 3.6.

Note: As this appendix pertains only to relatively small tanks constructed entirely in the shop, it is most unlikely that reinforcing pads will be required for manholes and nozzles in the tank shell. The requirements for reinforcement should be checked in compliance with the procedure given in Par. 3.3.7. Also, since the minimum shell plate thickness given in Par. J.3.3(a) normally will exceed the calculated thickness, the excess material in the shell should satisfy the requirements in nearly all cases. The roofs of tanks constructed in accordance with this appendix will be inherently strong due to the limitations in diameter inflicted by shipping clearances. Thus, reinforcement of roof manholes and nozzles shall not be required unless specifically requested by the purchaser or unless roof loads exceed 25 lb per sq ft, in which case the amount and type of reinforcement shall be as agreed upon between the purchaser and the fabricator.

J.3.7 Corrosion Allowance

a. If the purchaser requires that a corrosion allowance be provided, he shall specify the allowances and the areas to which the allowances are to be added. If a corrosion allowance is specified without such designation of its application, assume that it shall be added only to the calculated shell plate thickness.

b. When a corrosion allowance is specified for the roof and bottom plates, it shall be added to the minimum nominal thicknesses as noted in Par. J.3.2(a) and Par. J.3.5(a).

J.3.8 Lifting Lugs

a. Lugs or clips for use in loading, unloading, and placing on foundations shall be provided on all tanks constructed in accordance with this appendix.

b. There shall be a minimum of two lugs on each tank, the location of which shall be as agreed upon between the purchaser and the manufacturer. Preferably, they shall be located at the top of the tank, in pairs 180 deg apart.

c. Lugs and attachment welds shall be designed such that, regardless of the quantity used, each lug will be capable of carrying a load, applied in any reasonable manner, of twice the empty weight of the tank based on a safety factor of 4.

d. Lugs capable of carrying a load as described in item (c) shall be designed and attached in a manner that will not cause damage to the vessel.

J.3.9 Anchoring

The proportions of shop-assembled storage tanks often are such that overturning as a result of wind loading must be considered. In such cases, adequate provisions for anchoring shall be provided.

J.4 FABRICATION

a. In essence, fabrication shall be accomplished in accordance with the applicable specifications given in Part 4 and Part 5 of this standard. Erection shall be interpreted as assembly, and it shall be understood that the entire vessel is fabricated in the shop and not at the field site.

b. Par. 5.2.2 and 5.2.4 are not applicable to shop-assembled tanks and are to be considered as not included.

J.4.1 Testing

a. For this appendix, Par. 5.3.2 through 5.3.9 shall be replaced as specified in Par. J.4.1, J.4.2, and J.4.3.

b. As an alternative to the requirements of Par. 5.3.2 through 5.3.4, unless otherwise specified by the purchaser, tanks may be shop tested for leaks by the following method:

1. Brace bottom by securely attaching external stiffening member as required to eliminate permanent deformation during test.

2. Close all openings with plugs or covers as needed. Bolts and gaskets of the size and type required for final installation are to be used during test.

3. Apply 2 to 3 psig internal air pressure to tank. A maximum pressure of 5 psig is to be used on tanks with a diameter of 12 ft 0 in. or smaller.

4. For the detection of leaks, apply soapsuds, linseed oil, or other suitable material to all shell, bottom, roof, and attachment welds. Carefully examine for leaks.

5. After release of air pressure, bottom stiffening shall be removed and scars repaired.

J.4.2 Repairs

All defects found in welds by leak test, sectioning method, or radiographic examination shall be repaired as specified in Part 6.

J.4.3 Inspection

The purchaser's inspector shall have, at all times, free entry to the fabricator's shop. The fabricator shall afford the purchaser's inspector, free of cost, reasonable facilities to assure him that the work is being performed in accordance with the requirements of this standard.

All material and workmanship shall be subject to the replacement requirement of Par. 4.2(c).

J.5 METHOD OF INSPECTING SHELL JOINTS

The methods of inspection described in Part 6 shall apply to this appendix, except as specified in Par. J.3.3(b).

J.6 WELDING PROCEDURE AND WELDER QUALIFICATIONS

Part 7 shall apply.

J.7 MARKING

Part 8 shall apply, except that Par. 8.1 and 8.2 are not applicable. In addition to the stamping specified, the suffix "J" shall be added to the official API monogram.

APPENDIX K

ALTERNATIVE PROCEDURE FOR CALCULATING TANK SHELL THICKNESS

K.1 SCOPE

a. This appendix outlines a design procedure for calculating the thickness of tank shells as an alternative to the basic method of API Standard 650, which uses a fixed design point located one foot above the bottom of each course.

b. The procedure * uses a variable design point for each shell course to calculate shell thicknesses which result in actual circumferential shell stresses closer to the design stress than those actual stresses resulting from the basic API-650 design method.

c. The procedure may be applied to the basic API-650 tank and Appendixes D and G tanks.

d. This appendix is applicable only when acceptable to the purchaser.

K.2 ALLOWABLE STRESS

The maximum allowable design stress and the maximum allowable hydrostatic test stress for the shell course under consideration shall be in accordance with those specified for the particular tank (basic API-650 tank or Appendixes D or G tanks) to which this procedure is to be applied except for Appendix G. For Appendix G tanks the allowable stresses for the first course shall be the same as those for the upper courses as shown in Table G-1.

K.3 SHELL THICKNESSES

a. The required shell thickness for each course shall be the greater of design shell thickness plus corrosion allowance or hydrostatic test shell thickness, but in no case shall the total shell thickness be less than that shown in Par. 3.3.3(b).

b. Corrosion allowance for each course shall be specified by the purchaser.

c. The minimum plate thicknesses for both design and hydrostatic test conditions shall be determined as outlined in Par. K.4 through K.6. Independent calculations shall be carried completely through for all courses for the design condition, exclusive of corrosion allowance, and for the hydrostatic test condition. Upon completion of calculations, the required shell thicknesses shall be determined in accordance with Par. K.3(a).

R **d.** The use of the calculations shown in Par. K.5 requires that the permitted allowable stress for the bottom and 2nd courses shall be the same.

K.4 BOTTOM COURSE THICKNESS (t_1)

a. Calculate a preliminary value for the bottom course thickness, t_1, for both the design and hydrostatic test conditions from formulas (K-1) and (K-2), respectively:

Design shell thickness, t_d, inches

$$=\frac{2.6D(H-1)G}{S_dE} \qquad \text{(K-1)}$$

Hydrostatic test shell thickness, t_t, in inches

$$=\frac{2.6D(H-1)}{S_tE} \qquad \text{(K-2)}$$

Where:

D = nominal diameter of tank, in feet.

H = height, in feet, from the bottom of the course under consideration to the top of the top angle or to the filling height limited by the tank overflow.

G = design specific gravity of liquid to be stored as specified by the purchaser. (G shall not be less than 1.0 for basic API-650 tank.)

E = longtitudinal joint factor. For basic API-650 tank, $E=0.85$. For Appendixes D and G tanks, $E=1.0$.

S_d = allowable stress for the design condition.

S_t = allowable stress for the hydrostatic test condition.

b. Calculate the bottom course thickness, t_1, for both the design and hydrostatic test conditions using formuas (K-3) and (K-4), respectively:

Design shell thickness, t_{1d}, in inches

$$=\left[1.06-\frac{(0.463D)}{H}\sqrt{\frac{HG}{S_dE}}\right]\frac{(2.6HDG)}{S_dE} \qquad \text{(K-3)}$$

Note: t_{1d} need not be greater than t_d.

Hydrostatic test shell thickness, t_{1t}, in inches

$$=\left[1.06-\frac{(0.463D)}{H}\sqrt{\frac{H}{S_tE}}\right]\frac{(2.6HD)}{S_tE} \qquad \text{(K-4)}$$

Note: t_{1t} need not be greater than t_t.

K.5 SECOND COURSE THICKNESS (t_2)

For both the design and hydrostatic test conditions, calculate for the bottom course the value of the ratio:

$$\frac{h_1}{\sqrt{rt_1}}$$

Where:

h_1 = height of bottom shell course, in inches.

r = nominal radius of tank, in inches.

Then,

$t_2=t_1$, if the ratio value is ≤ 1.375;

or

$t_2=t_{2a}$, if the ratio value is ≥ 2.625;

* This procedure normally provides a reduction in course thicknesses and total material weight. More important is its potential to permit construction of larger diameter tanks within the maximum plate thickness limitation. For background information, see: L. P. Zick and R. V. McGrath, "Design of Large-Diameter Cylindrical Shells," *Proc. API Ref.* **48** 1114-40 (1968).

R **TABLE K-1—Typical Shell-Plate Thicknesses for Appendix D Tanks Based on Appendix K Method Using 96-in. Courses and an Allowable Stress of 23,000 PSI for Test Condition**

Tank (Diameter) (Feet)	Tank Height (Feet)	Weight of Shell (Tons)	Shell-Plate Thickness for Each Course (Inches)								Nominal Tank Volume (Barrels)
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	
200	40	272	0.871	0.659	0.487	0.317	0.313				224,000
220		333	0.949	0.720	0.533	0.375	0.375				271,000
240		388	1.025	0.807	0.574	0.375	0.375				322,600
260		452	1.099	0.907	0.613	0.399	0.375				378,600
280		521	1.171	1.004	0.653	0.427	0.375				439,000
300		594	1.241	1.098	0.692	0.455	0.375				504,000
320		671	1.310	1.189	0.731	0.482	0.375				573,400
340		751	1.377	1.278	0.768	0.509	0.375				647,400
360		835	1.433	1.367	0.804	0.536	0.375				725,800
380		923	1.506*	1.452	0.840	0.536	0.375				808,600
180	48	312	0.956	0.755	0.600	0.443	0.313	0.313			217,700
200		376	1.055	0.832	0.664	0.487	0.317	0.313			268,800
220		462	1.150	0.943	0.721	0.533	0.375	0.375			325,200
240		543	1.243	1.064	0.776	0.579	0.375	0.375			387,100
260		632	1.334	1.181	0.833	0.625	0.397	0.375			454,300
280		729	1.423	1.295	0.889	0.670	0.424	0.375			526,800
298		820	1.502*	1.395	0.938	0.710	0.448	0.375			596,800
160	56	332	0.995	0.817	0.678	0.537	0.398	0.313	0.313		200,700
180		411	1.119	0.912	0.760	0.599	0.443	0.313	0.313		254,000
200		502	1.239	1.033	0.836	0.663	0.487	0.317	0.313		313,600
220		614	1.351	1.175	0.908	0.727	0.532	0.375	0.375		379,500
240		723	1.462	1.313	0.982	0.790	0.577	0.375	0.375		451,600
247		763	1.500	1.361	1.007	0.812	0.592	0.379	0.375		478,300
160	64	423	1.139	0.957	0.820	0.677	0.537	0.398	0.313	0.313	229,400
180		527	1.282	1.079	0.918	0.759	0.599	0.443	0.313	0.313	290,300
200		646	1.423	1.242	1.008	0.841	0.662	0.487	0.317	0.313	358,400
212		734	1.502*	1.338	1.061	0.890	0.700	0.514	0.375	0.375	402,700

* Exceeds maximum thickness permitted by Paragraph D.1(d). In order to comply, tank diameter or height would have to be reduced slightly.

or, if the ratio value is >1.375 but <2.625,

$$t_2 = t_{2a} + (t_1 - t_{2a})\left[2.1 - \frac{h_1}{1.25\sqrt{rt_1}}\right] \quad \text{(K-5)}$$

Where:

t_2 = minimum thickness of second shell course (excluding corrosion allowance), in inches.

t_{2a} = thickness of second course, in inches, as calculated for an upper shell course described in Par. K.6.

K.6 UPPER COURSE THICKNESS (t_x)

a. For both the design and hydrostatic test conditions, calculate a preliminary value, t_U, for the upper course thickness using formulas (K-1) and (K-2), respectively, of Par. K.4.

b. Calculate the distance, x, of the variable design point from the bottom of the course using the lowest value obtained from the following three expressions:

$$x_1 = 0.61\sqrt{rt_U} + 0.32Ch_U$$
$$x_2 = Ch_U$$
$$x_3 = 1.22\sqrt{rt_U}$$

Where:

x = minimum value of x_1, x_2, or x_3.

t_L = thickness of lower course at girth joint, in inches.

t_U = thickness of upper course at girth joint, in inches.

$K = \frac{t_L}{t_U}$

$C = \frac{\sqrt{K}(K-1)}{1+K\sqrt{K}}$

h_U = height from bottom of course under consideration to the top angle or to the bottom of the overflow, in inches.

c. The minimum thickness, t_x, for the upper shell courses shall be computed for both the design and hydrostatic test conditions using formulas (K-6) and (K-7), respectively:

Design shell thickness, t_{dx}, in inches

$$= \frac{2.6D\left(H - \frac{x}{12}\right)G}{S_dE} \quad \text{(K-6)}$$

Hydrostatic test shell thickness, t_{tx}, in inches

$$= \frac{2.6D\left(H - \frac{x}{12}\right)}{S_tE} \quad \text{(K-7)}$$

d. Use the first calculated value of t_x to repeat the steps outlined in preceding Par. (b) and (c) until there is little difference between the calculated values of t_x in succession. (Normally two additional steps are sufficient.) Repetitive steps will provide a more exact location of the design point for the course under consideration and, consequently, a more accurate shell thickness.

K.7 SPECIAL REQUIREMENTS

a. When this appendix is applied to a basic API-650 tank or Appendixes D or G tanks, the letter "K" shall be stamped on the nameplate by the manufacturer as follows:

API STD 650-K

API STD 650 ADB-K

API STD 650 G-K

b. The manufacturer shall furnish to the purchaser a general plan that shall list for each course: 1, the required shell thicknesses for both the design condition (including corrosion allowance) and the hydrostatic test condition; 2, the nominal thickness used; 3, material specification; and, 4, the allowable stresses.

K.8 TABLES AND CALCULATION FORM

a. Typical shell-plate thicknesses of various size tanks for the test condition are listed in Tables K-1, K-2, and K-3. These thicknesses are based on application of the procedure outlined in this appendix to a basic API-650 tank and to Appendixes D and G tanks, respectively. The tables are included for illustration only; they shall not be used to relieve the manufacturer of his responsibility to provide the required shell thicknesses.

b. At the end of this appendix, step-by-step computations exemplify the application of the variable design point procedure. For the example, the procedure is applied to an Appendix G tank (280 ft by 64 ft) to determine shell-plate thicknesses of the first three courses.

R TABLE K-2—Typical Shell-Plate Thicknesses for Appendix G Tanks Based on Appendix K Method Using 96-in. Courses and an Allowable Stress of 30,000 PSI for Test Condition

Tank Diameter (Feet)	Tank Height (Feet)	Weight of Shell (Tons)	Shell-Plate Thickness for Each Course (Inches)								Nominal Tank Volume (Barrels)
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	
240	40	320	0.798	0.603	0.447	0.375	0.375				322,600
260		365	0.856	0.652	0.482	0.375	0.375				378,600
280		417	0.914	0.730	0.511	0.375	0.375				439,000
300		472	0.971	0.806	0.541	0.375	0.375				504,000
320		530	1.026	0.880	0.572	0.375	0.375				573,400
340		594	1.080	0.952	0.602	0.395	0.375				647,400
360		661	1.133	1.023	0.632	0.416	0.375				725,800
380		730	1.188	1.090	0.661	0.437	0.375				800,200
400		808	1.235	1.156	0.689	0.458	0.375				886,600
220	48	374	0.892	0.704	0.561	0.412	0.375	0.375			325,200
240		436	0.966	0.773	0.608	0.447	0.375	0.375			387,100
260		505	1.038	0.867	0.650	0.482	0.375	0.375			454,300
280		578	1.109	0.958	0.692	0.518	0.375	0.375			526,800
300		656	1.178	1.048	0.736	0.552	0.375	0.375			604,800
320		738	1.247	1.135	0.779	0.587	0.375	0.375			688,100
340		827	1.314	1.220	0.820	0.621	0.392	0.375			776,800
360		920	1.379	1.303	0.862	0.655	0.413	0.375			870,900
380		1018	1.444	1.383	0.902	0.688	0.432	0.375			960,200
400		1120	1.507	1.462	0.942	0.721	0.452	0.375			1,064,000
200	56	399	0.953	0.778	0.648	0.511	0.378	0.313	0.313		313,600
220		489	1.048	0.858	0.709	0.560	0.412	0.375	0.375		379,500
240		575	1.135	0.968	0.764	0.609	0.446	0.375	0.375		451,600
260		667	1.220	1.075	0.819	0.658	0.481	0.375	0.375		530,000
280		766	1.305	1.181	0.876	0.706	0.515	0.375	0.375		614,700
300		870	1.387	1.283	0.932	0.754	0.549	0.375	0.375		705,600
320		980	1.469	1.384	0.987	0.802	0.583	0.375	0.375		802,800
340		1099	1.549	1.481	1.041	0.848	0.616	0.393	0.375		896,800
360		1224	1.627	1.577	1.094	0.895	0.649	0.413	0.375		1,005,500
380		1356	1.705	1.671	1.148	0.950	0.680	0.434	0.375		1,120,300
392		1439	1.750	1.726	1.180	0.985	0.698	0.446	0.375		1,192,100
200	64	507	1.092	0.913	0.784	0.647	0.511	0.378	0.313	0.313	358,400
220		623	1.201	1.035	0.854	0.710	0.560	0.412	0.375	0.375	433,700
240		734	1.304	1.159	0.922	0.772	0.608	0.447	0.375	0.375	516,100
260		853	1.403	1.280	0.991	0.834	0.655	0.481	0.375	0.375	605,700
280		980	1.501	1.399	1.061	0.896	0.703	0.516	0.375	0.375	702,500
300		1115	1.597	1.515	1.129	0.957	0.749	0.550	0.375	0.375	798,000
320		1257	1.692	1.629	1.196	1.017	0.796	0.583	0.375	0.375	907,900
332		1349	1.748	1.696	1.236	1.058	0.823	0.604	0.375	0.375	977,300

R **TABLE K-3—Typical Shell-Plate Thicknesses for Appendix G Tanks Based on Appendix K Method Using 96-in. Courses and an Allowable Stress of 34,300 PSI for Test Condition**

Tank Diameter (Feet)	Tank Height (Feet)	Weight of Shell (Tons)	Shell-Plate Thickness for Each Course (Inches)								Nominal Tank Volume (Barrels)
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	
220	48	341	0.784	0.619	0.492	0.375	0.375	0.375			325,200
240		394	0.850	0.670	0.535	0.393	0.375	0.375			387,100
260		453	0.914	0.737	0.547	0.423	0.375	0.375			454,300
280		518	0.977	0.819	0.611	0.454	0.375	0.375			526,800
300		588	1.039	0.898	0.649	0.485	0.375	0.375			604,800
320		661	1.100	0.976	0.687	0.515	0.375	0.375			688,100
340		738	1.160	1.053	0.724	0.545	0.375	0.375			776,800
360		818	1.218	1.128	0.761	0.575	0.375	0.375			870,900
380		903	1.276	1.200	0.797	0.605	0.381	0.375			970,400
400		994	1.333	1.271	0.833	0.634	0.399	0.375			1,075,200
200	56	358	0.834	0.684	0.568	0.449	0.333	0.313	0.313		313,600
220		440	0.917	0.747	0.623	0.491	0.363	0.375	0.375		379,500
240		514	0.998	0.826	0.674	0.534	0.393	0.375	0.375		451,600
260		595	1.074	0.921	0.723	0.577	0.422	0.375	0.375		530,000
280		683	1.149	1.015	0.771	0.619	0.453	0.375	0.375		614,700
300		776	1.222	1.107	0.821	0.661	0.483	0.375	0.375		705,600
320		874	1.295	1.197	0.869	0.703	0.512	0.375	0.375		802,800
340		977	1.366	1.284	0.918	0.745	0.542	0.375	0.375		906,300
360		1085	1.436	1.370	0.965	0.786	0.571	0.375	0.375		1,016,100
380		1199	1.505	1.454	1.012	0.827	0.599	0.382	0.375		1,132,100
400		1321	1.573	1.536	1.068	0.873	0.627	0.400	0.375		1,254,400
200	64	453	0.955	0.801	0.687	0.567	0.449	0.375	0.375	0.375	358,400
220		556	1.051	0.884	0.752	0.622	0.491	0.375	0.375	0.375	433,700
240		653	1.146	0.994	0.812	0.677	0.533	0.393	0.375	0.375	516,100
260		758	1.235	1.102	0.872	0.731	0.575	0.423	0.375	0.375	605,700
280		871	1.321	1.208	0.933	0.785	0.617	0.453	0.375	0.375	702,500
300		991	1.406	1.311	0.994	0.839	0.658	0.483	0.375	0.375	806,400
320		1118	1.490	1.413	1.053	0.893	0.699	0.513	0.375	0.375	917,500
340		1251	1.573	1.513	1.112	0.946	0.740	0.540	0.375	0.375	1,035,800
360		1392	1.655	1.610	1.170	1.006	0.779	0.572	0.375	0.375	1,161,200
380		1541	1.735	1.705	1.228	1.070	0.817	0.601	0.382	0.375	1,292,800
384		1573	1.750	1.724	1.240	1.083	0.824	0.607	0.385	0.375	1,321,200

EXAMPLE OF THE APPLICATION OF VARIABLE DESIGN POINT PROCEDURE TO DETERMINE SHELL-PLATE THICKNESSES

For Design condition ☐ Test condition ☑ (check one); Specific gravity of liquid, G: 1.0

For API-650 tank ☐ Appendix D tank ☐ Appendix G tank ☑ (check one)

Tank diameter, D: 280 ft; Total height of tank, H: 64 ft; Number of courses: 8

Joint efficiency, E: 1.0; Allowable stress for design, S_d: ____ psi; Allowable stress for testing, S_t: 30,000 psi

For design condition, $S=S_dE=$ ____ psi; For test condition, $S=S_tE=$ 30,000 psi

Height of bottom course, h_1: 96 in.; Nominal radius of tank, r: 1680 in.

For definition of nomenclature, see Appendix K.

FOR FIRST COURSE (t_1):

For design condition, $t_1 = t_{1d}$ but not greater than t_d.

For test condition, $t_1 = t_{1t}$ but not greater than t_t.

$$t_t = \frac{2.6D(H-1)}{S_tE} = \frac{2.6(280)(63)}{(30{,}000)(1.0)} = 1.529$$

$$t_{1t} = \left[1.06 - \frac{(0.463D)}{H}\sqrt{\frac{H}{S_tE}}\right]\left[\frac{(2.6HD)}{S_tE}\right] = \left[1.06 - \frac{0.463(280)}{(64)}\sqrt{\frac{(64)}{(30{,}000)(1.0)}}\right]\left[\frac{2.6(64)(280)}{(30{,}000)(1.0)}\right]$$

$$= [1.06 - (2.026)(.0462)][1.553]$$

$$= [1.06 - (.0934)][1.553]$$

$$t_1 = [\ .9666\ ][1.553] = 1.501 \text{ in.}$$

FOR SECOND COURSE (t_2):

$$\frac{h_1}{\sqrt{rt_1}} = \frac{(96)}{\sqrt{(1680)(1.501)}} = \frac{(96)}{(50.216)} = 1.912; \text{ If } \frac{h_1}{\sqrt{rt_1}} \leq 1.375,\ t_2 = t_1; \text{ If } \frac{h_1}{\sqrt{rt_1}} \geq 2.625,\ t_2 = t_{2a}$$

$$\text{If } 1.375 < \frac{h_1}{\sqrt{rt_1}} < 2.625,\ t_2 = t_{2a} + (t_1 - t_{2a})\left[2.1 - \frac{h_1}{1.25\sqrt{rt_1}}\right]$$

$$= (1.263) + (.238)\left[2.1 - \frac{(96)}{1.25\sqrt{(1680)(1.501)}}\right]$$

$$= (1.263) + (.238)[2.1 - (1.529)]$$

$$t_2 = (1.263) + (.238)(.571) = (1.263) + (.136) = 1.399 \text{ in.}$$

FOR UPPER COURSES: COURSE NO. 2 (t_{2a})

1ST TRIAL

$H = \underline{56}$ ft; $h_U = H \times 12 = \underline{672}$ in.

$$t_{tx} = \frac{2.6D(H-1)}{S_t E} = \frac{2.6(280)(55)}{(30{,}000)(1.0)}$$

$t_{tx} = \underline{1.335}$ in. $= t_U$

$t_L = \underline{1.501}$ in.

$$K = \frac{t_L}{t_U} = \frac{1.501}{1.335} = \underline{1.124}$$

$\sqrt{K} = \underline{1.060}$

$$C = \frac{\sqrt{K}(K-1)}{1+K\sqrt{K}} = \frac{(1.06)(.124)}{1+(1.191)} = \underline{.060}$$

$\sqrt{rt_U} = \sqrt{(1680)(1.335)} = \underline{47.358}$

$Ch_U = (.060)(672) = \underline{40.320}$

$x_1 = 0.61\sqrt{rt_U} + 0.32Ch_U$

$= 0.61(47.358) + 0.32(40.32)$

$= (28.89) + (12.90) = \underline{41.78}$

$x_2 = Ch_U = \underline{40.32}$

$x_3 = 1.22\sqrt{rt_U} = 1.22(47.358) = \underline{57.78}$

$x = \text{Min}(x_1, x_2, x_3) = \underline{40.32}$

$\frac{x}{12} = \underline{3.36}$

$$t_{tx} = \frac{2.6D\left(H - \frac{x}{12}\right)}{S_t E}$$

$$= \frac{2.6(280)(56 - 3.36)}{(30{,}000)(1.0)} = \underline{1.277} \text{ in.}$$

WITH THIS VALUE OF t_{tx}, START 2ND TRIAL

2ND TRIAL

$H = \underline{56}$ ft; $h_U = H \times 12 = \underline{672}$ in.

$t_U = t_{tx}$ (FROM 1ST TRIAL)

$t_U = \underline{1.277}$ in.

$t_L = \underline{1.501}$ in.

$$K = \frac{t_L}{t_U} = \frac{1.501}{1.277} = \underline{1.175}$$

$\sqrt{K} = \underline{1.084}$

$$C = \frac{\sqrt{K}(K-1)}{1+K\sqrt{K}} = \frac{(1.084)(.175)}{1+(1.273)} = \underline{.0835}$$

$\sqrt{rt_U} = \sqrt{(1680)(1.277)} = \underline{46.32}$

$Ch_U = (.0835)(672) = \underline{56.112}$

$x_1 = 0.61\sqrt{rt_U} + 0.32Ch_U$

$= 0.61(46.32) + 0.32(56.11)$

$= (28.26) + (17.96) = \underline{46.21}$

$x_2 = Ch_U = \underline{56.11}$

$x_3 = 1.22\sqrt{rt_U} = 1.22(46.32) = \underline{56.51}$

$x = \text{Min}(x_1, x_2, x_3) = \underline{46.21}$

$\frac{x}{12} = \underline{3.85}$

$$t_{tx} = \frac{2.6D\left(H - \frac{x}{12}\right)}{S_t E}$$

$$= \frac{2.6(280)(56 - 3.85)}{(30{,}000)(1.0)} = \underline{1.266} \text{ in.}$$

WITH THIS VALUE OF t_{tx}, START 3RD TRIAL

3RD TRIAL

$H = \underline{56}$ ft; $h_U = H \times 12 = \underline{672}$ in.

$t_U = t_{tx}$ (FROM 2ND TRIAL)

$t_U = \underline{1.266}$ in.

$t_L = \underline{1.501}$ in.

$$K = \frac{t_L}{t_U} = \frac{1.501}{1.266} = \underline{1.185}$$

$\sqrt{K} = \underline{1.089}$

$$C = \frac{\sqrt{K}(K-1)}{1+K\sqrt{K}} = \frac{(1.089)(.185)}{1+(1.290)} = \underline{.088}$$

$\sqrt{rt_U} = \sqrt{(1680)(1.266)} = \underline{46.12}$

$Ch_U = (.088)(672) = \underline{59.14}$

$x_1 = 0.61\sqrt{rt_U} + 0.32Ch_U$

$= 0.61(46.12) + 0.32(59.14)$

$= (28.13) + (18.92) = \underline{47.05}$

$x_2 = Ch_U = \underline{59.14}$

$x_3 = 1.22\sqrt{rt_U} = 1.22(46.12) = \underline{56.27}$

$x = \text{Min}(x_1, x_2, x_3) = \underline{47.05}$

$\frac{x}{12} = \underline{3.92}$

$$t_{tx} = \frac{2.6D\left(H - \frac{x}{12}\right)}{S_t E}$$

$$= \frac{2.6(280)(56 - 3.92)}{(30{,}000)(1.0)} = \underline{1.263} \text{ in.}$$

$t_{tx} = \underline{1.263}$ in. $= t_{2a}$

USE THIS VALUE IN CALCULATING VALUE OF t_{z}.

FOR UPPER COURSES: COURSE NO. 3

1ST TRIAL

$H = \underline{48}$ ft; $h_U = H \times 12 = \underline{576}$ in.

$t_{tx} = \dfrac{2.6D(H-1)}{S_tE} = \dfrac{2.6(280)(47)}{(30{,}000)(1.0)}$

$t_{tx} = \underline{1.141}$ in. $= t_U$

$t_L = \underline{1.399}$ in.

$K = \dfrac{t_L}{t_U} = \dfrac{1.399}{1.141} = \underline{1.226}$

$\sqrt{K} = \underline{1.107}$

$C = \dfrac{\sqrt{K}(K-1)}{1+K\sqrt{K}} = \dfrac{(1.107)(.226)}{1+(1.357)} = \underline{.106}$

$\sqrt{rt_U} = \sqrt{(1680)(1.141)} = \underline{43.78}$

$Ch_U = (.106)(576) = \underline{61.056}$

$x_1 = 0.61\sqrt{rt_U} + 0.32Ch_U$

$= 0.61(43.78) + 0.32(61.06)$

$= (26.71) + (19.54) = \underline{46.25}$

$x_2 = Ch_U = \underline{61.06}$

$x_3 = 1.22\sqrt{rt_U} = 1.22(43.78) = \underline{53.41}$

$x = \text{Min}(x_1, x_2, x_3) = \underline{46.25}$

$\dfrac{x}{12} = \underline{3.85}$

$t_{tx} = \dfrac{2.6D\left(H - \dfrac{x}{12}\right)}{S_tE}$

$= \dfrac{2.6(280)(48 - 3.85)}{(30{,}000)(1.0)} = \underline{1.071}$ in.

WITH THIS VALUE OF t_{tx}, START 2ND TRIAL

2ND TRIAL

$H = \underline{48}$ ft; $h_U = H \times 12 = \underline{576}$ in.

$t_U = t_{tx}$ (FROM 1ST TRIAL)

$t_U = \underline{1.071}$ in.

$t_L = \underline{1.399}$ in.

$K = \dfrac{t_L}{t_U} = \dfrac{1.399}{1.071} = \underline{1.306}$

$\sqrt{K} = \underline{1.143}$

$C = \dfrac{\sqrt{K}(K-1)}{1+K\sqrt{K}} = \dfrac{(1.143)(.306)}{1+(1.493)} = \underline{.140}$

$\sqrt{rt_U} = \sqrt{(1680)(1.071)} = \underline{42.418}$

$Ch_U = (.140)(576) = \underline{80.640}$

$x_1 = 0.61\sqrt{rt_U} + 0.32Ch_U$

$= 0.61(42.42) + 0.32(80.64)$

$= (25.88) + (25.80) = \underline{51.68}$

$x_2 = Ch_U = \underline{80.64}$

$x_3 = 1.22\sqrt{rt_U} = 1.22(42.42) = \underline{51.75}$

$x = \text{Min}(x_1, x_2, x_3) = \underline{51.68}$

$\dfrac{x}{12} = \underline{4.31}$

$t_{tx} = \dfrac{2.6D\left(H - \dfrac{x}{12}\right)}{S_tE}$

$= \dfrac{2.6(280)(48 - 4.31)}{(30{,}000)(1.0)} = \underline{1.060}$ in.

WITH THIS VALUE OF t_{tx}, START 3RD TRIAL

3RD TRIAL

$H = \underline{48}$ ft; $h_U = H \times 12 = \underline{576}$ in.

$t_U = t_{tx}$ (FROM 2ND TRIAL)

$t_U = \underline{1.060}$ in.

$t_L = \underline{1.399}$ in.

$K = \dfrac{t_L}{t_U} = \dfrac{1.399}{1.060} = \underline{1.320}$

$\sqrt{K} = \underline{1.149}$

$C = \dfrac{\sqrt{K}(K-1)}{1+K\sqrt{K}} = \dfrac{(1.149)(.320)}{1+(1.517)} = \underline{.146}$

$\sqrt{rt_U} = \sqrt{(1680)(1.06)} = \underline{42.20}$

$Ch_U = (.146)(576) = \underline{84.10}$

$x_1 = 0.61\sqrt{rt_U} + 0.32Ch_U$

$= 0.61(42.20) + 0.32(84.10)$

$= (25.74) + (26.91) = \underline{52.65}$

$x_2 = Ch_U = \underline{84.10}$

$x_3 = 1.22\sqrt{rt_U} = 1.22(42.20) = \underline{51.48}$

$x = \text{Min}(x_1, x_2, x_3) = \underline{51.48}$

$\dfrac{x}{12} = \underline{4.29}$

$t_x = \dfrac{2.6D\left(H - \dfrac{x}{12}\right)}{S_tE}$

$= \dfrac{2.6(280)(48 - 4.29)}{(30{,}000)(1.0)} = \underline{1.061}$ in.

$t_x = \underline{1.061}$ in. for Course No. 3.

APPENDIX L

STORAGE TANK SPECIFICATION DATA SHEET

The following data sheet should be used by both the purchaser and vendor when ordering, or bidding on, a storage tank constructed in accordance with the specifications of this standard.

Conditions which must be met are set forth in a convenient form, and can be noted either by inserting information in spaces provided or by checking the appropriate answer where a selection is indicated.

Space is provided where computations or fabricating practices may dictate size or dimension of the tank or its components. Further information concerning appurtenances or accessories shall be included.

The data sheet does not cover items of a contractual nature or nonoptional features unequivocally covered by this standard.

Upon completion of the construction, the vendor shall furnish the purchaser with a copy of the data sheet corrected to reflect the "as-built" conditions.

API STANDARD 650
STORAGE TANK SPECIFICATION DATA SHEET

DATE ____________ SHEET 1 OF 1
BY ____________ FILE NO. ____________

GENERAL INFORMATION (BY PURCHASER)

① PURCHASER/AGENT ____________ ② ADDRESS ____________
③ CITY & STATE ____________ ④ PHONE ____________ ⑤ USER ____________
⑥ ERECTION SITE: NAME OF PLANT ____________ LOCATION ____________
⑦ TANK NO. ______ TANK CAPACITY (BBL): NOMINAL ____________ NETWORKING ____________
⑧ PUMPING RATES: IN ____________ BBL/HR OUT ____________ BBL/HR
⑨ PRODUCT STORED ____________ DESIGN SP. GR. ____@____ F DESIGN METAL TEMP. ______ F VAPOR PRESSURE ______ IN. WATER
⑩ CORROSION ALLOWANCE (IN.): SHELL ____________ ROOF ____________ BOTTOM ____________ STRUCTURALS ____________
⑪ SHELL DESIGN: BASIC API 650 ______ APP. D ______ APP. F ______ APP. G ______ APP. K ______
⑫ ROOF DESIGN: BASIC API 650 ______ FLOATING ROOF APP. C ______ COVERED FLOATING ROOF APP. H ______
⑬ ROOF LOADS: UNIFORM LIVE (CONSIDER SNOW) ______ LB/SQ FT SPECIAL LOADING ____________ (PROVIDE SKETCH)
⑭ WIND LOAD: VELOCITY ______ MPH; PROVIDE INTERMEDIATE WINDGIRDER AS PER PAR. D.11 YES ______ NO ______
⑮ ENVIRONMENTAL EFFECTS: RAINFALL, MAX. ______ IN. PER HR SNOWFALL, TOTAL ACCUMULATION ______ IN.
⑯ DIAMETER AND/OR HEIGHT RESTRICTIONS ____________ DIA., MAX. ____________ HEIGHT, MAX.
⑰ FOUNDATION TYPE: EARTH ______ CONCRETE RINGWALL ______ OTHER ____________
REMARKS: ____________

CONSTRUCTION DETAILS (BY VENDOR AND/OR PURCHASER, AS APPLICABLE)

⑱ MATERIAL SPECS: SHELL ______ & ______ ROOF ______ BOTTOM ______ STRUCTURALS ______
⑲ SHELL COURSES (NUMBER) ____________
⑳ PLATE WIDTH & THICK.:* (1) ______ (2) ______ (3) ______ (4) ______ (5) ______ (6) ______ (7) ______ (8) ______ (9) ______
㉑ TANK BOTTOM: PLATE THICK ______ SEAMS (CHECK ONE): ___LAP ___BUTT; SLOPE ______ IN. PER FT (CHECK ONE): TO___FROM___ CTR
㉒ BOTTOM ANNULUS RING, MIN. WIDTH & THICK. ____________
㉓ ROOF TO SHELL DETAIL: FIG. 3-3 ______ FIG. F-1 ______
㉔ INTERM. WINDGIRDER: YES ______ NO ______ TOP WINDGIRDER (USE AS WALKWAY): YES ______ NO ______
㉕ ROOF TYPE: SUPPORTED ______ SELF-SUPPORTED ______ SLOPE OR RADIUS ______ FLOATING ______
㉖ ROOF PLATE: THICKNESS ______ LAP JOINT ______ BUTT JOINT ______
㉗ PAINT—Shell: Exterior–Yes___ No___ Interior–Yes___ No___; Bottom: Interior–Yes___ No___ Underside–Yes___ No___; Surface Prep ______
㉘ TANK BOTTOM COATING: INTERIOR–YES___ NO___ MATERIAL ______ APPLICATION SPEC. ______
㉙ PAINT: STRUCTURAL STEEL INTERIOR–YES___ NO___ EXTERIOR–YES___ NO___ SPEC. ______
㉚ INSPECTION BY: SHOP ______ FIELD ______
㉛ WELD EXAMINATION: RADIOGRAPHIC ______ SECTIONING ______ SUPPLEMENTARY ULTRASONIC ______
㉜ FILMS OR SEGMENTS ______ PROPERTY OF ______
㉝ LEAK TESTING: BOTTOM ______ ROOF ______ SHELL ______
㉞ MILL TEST REPORTS REQ'D: YES ______ NO ______
㉟ PURCHASER'S REFERENCE DRAWING ____________
㊱ TANK SIZE: DIAMETER & HEIGHT (FT) ____________
REMARKS: ____________

APPURTENANCES (BY VENDOR AND/OR PURCHASER, AS APPLICABLE)

㊲ STAIRWAY STYLE (CHECK ONE): CIRCULAR ______ STRAIGHT ______ ANGLE, DEGREES TO HORIZONTAL ______ LADDER ______
㊳ WALKWAY: ______ WIDTH ______ LENGTH
㊴ DRAWOFF SUMP: STANDARD ______ SPECIAL ______
㊵ BOLTED DOOR SHEET: RAISED TYPE ______ FLUSH TYPE ______
㊶ SCAFFOLD HITCH ____________
㊷ INTERNAL PIPE: SWING LINE ______ SUCTION NOZZLE ______ HEATING COIL SQ FT SURF. ______
㊸ ROOF DRAIN: HOSE ______ JOINTED ______ SIPHON ______
㊹ SHELL MANWAYS: NO. & SIZE ______ TYPE–FIG. 3-6, ALT. A ______ ALT. B ______ ALT. C NOTE 4 ______
㊺ ROOF MANWAYS: NO. & SIZE ______ TYPE–FIG. 3-14 ______ OTHER ______
㊻ SHELL NOZZLES: SEE FIG. 3-7 AND TABLES 3-7 & 3-8

MARK	SIZE	FLANGED			SCREWED					ORIENT. N = 0°	HT. FROM BOTTOM	SERVICE
		SGL	DBL	SPL	A	B	C	D	E			

㊼ ROOF NOZZLES: SEE FIGS. 3-15 & 3-16 AND TABLES 3-15 & 3-16

MARK	SIZE	FLANGED	SCREWED	REINF.	ORIENT. N = 0°	DIST. FROM CENTER	SERVICE

NOTE: Sketch and/or separate sheet may be attached to cover special requirements.

* Specified thickness to include corrosion allowance.

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