08 # Welded Tanks for Oil Storage

API STANDARD 650
ELEVENTH EDITION, JUNE 2007

ADDENDUM 1: NOVEMBER 2008
ADDENDUM 2: NOVEMBER 2009
ADDENDUM 3: AUGUST 2011
ERRATA, OCTOBER 2011

EFFECTIVE DATE: FEBRUARY 1, 2012

AMERICAN PETROLEUM INSTITUTE

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**Downstream Segment**

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07 employing the information contained herein.

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## INSTRUCTIONS FOR SUBMITTING A PROPOSED REVISION TO THIS STANDARD UNDER CONTINUOUS MAINTENANCE

This Standard is maintained under continuous maintenance procedures by the American Petroleum Institute for which the Standards Department. These procedures establish a documented program for regular publication of addenda or revisions, including timely and documented consensus action on requests for revisions to any part of the Standard. Proposed revisions shall be submitted to the Director, Standards Department, American Petroleum Institute, 1220 L Street, NW, Washington, D.C. 20005-4070, standards@api.org.

# FOREWORD

07 This Standard is based on the accumulated knowledge and experience of Purchasers and
08 Manufacturers of welded oil storage tanks of various sizes and capacities for internal pres-
sures not more than 17.2 kPa ($2^1/_2$ pounds per square inch) gauge. This Standard is meant to
07 be a purchase specification to facilitate the manufacture and procurement of storage tanks
for the petroleum industry.

If the tanks are purchased in accordance with this Standard, the Purchaser is required to specify certain basic requirements. The Purchaser may want to modify, delete, or amplify sections of this Standard, but reference to this Standard shall not be made on the nameplates of or on the Manufacturer's certification for tanks that do not fulfill the minimum requirements of this Standard or that exceed its limitations. It is strongly recommended that any modifications, deletions, or amplifications be made by supplementing this Standard rather than by rewriting or incorporating sections of it into another complete standard.

The design rules given in this Standard are minimum requirements. More stringent design rules specified by the Purchaser or furnished by the Manufacturer are acceptable when mutually agreed upon by the Purchaser and the Manufacturer. This Standard is not to be interpreted as approving, recommending, or endorsing any specific design or as limiting the method of design or construction.

Shall: As used in a standard, "shall" denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the specification.

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• This Standard is not intended to cover storage tanks that are to be erected in areas subject to regulations more stringent than the specifications in this Standard. When this Standard is specified for such tanks, it should be followed insofar as it does not conflict with local requirements. The Purchaser is responsible for specifying any jurisdictional requirements applicable to the design and construction of the tank.

After revisions to this Standard have been issued, they may be applied to tanks that are to be completed after the date of issue. The tank nameplate shall state the date of the edition of the Standard and any revision to that edition to which the tank has been designed and constructed.

• Each edition, revision, or addenda to this API Standard may be used beginning with the
date of issuance shown on the cover page for that edition, revision, or addenda. Each edi-
tion, revision, or addenda to this API Standard becomes effective six months after the date
07 of issuance for equipment that is certified as being constructed, and tested per this Stan-
dard. During the six-month time between the date of issuance of the edition, revision, or
addenda and the effective date, the Purchaser and the Manufacturer shall specify to which
07 edition, revision, or addenda the equipment is to be constructed and tested.

11 **DELETED**

Suggested revisions are invited and should be submitted to the Downstream Segment, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

## IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of extreme usefulness in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products (Sections 763.160-179).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

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## SECTION 1—SCOPE

### 1.1 GENERAL

**1.1.1** This Standard establishes minimum requirements for material, design, fabrication, erection, and testing for vertical, cylindrical, aboveground, closed- and open-top, welded storage tanks in various sizes and capacities for internal pressures approximating atmospheric pressure (internal pressures not exceeding the weight of the roof plates), but a higher internal pressure is permitted when additional requirements are met (see 1.1.12). This Standard applies only to tanks whose entire bottom is uniformly supported and to tanks in non-refrigerated service that have a maximum design temperature of 93°C (200°F) or less (see 1.1.19). 07 08 07

• **1.1.2** This Standard is designed to provide industry with tanks of adequate safety and reasonable economy for use in the storage of petroleum, petroleum products, and other liquid products. This Standard does not present or establish a fixed series of allowable tank sizes; instead, it is intended to permit the Purchaser to select whatever size tank may best meet his needs. This Standard is intended to help Purchasers and Manufacturers in ordering, fabricating, and erecting tanks; it is not intended to prohibit Purchasers and Manufacturers from purchasing or fabricating tanks that meet specifications other than those contained in this Standard.

Note: A bullet (•) at the beginning of a paragraph indicates that there is an expressed decision or action required of the Purchaser. The Purchaser's responsibility is not limited to these decisions or actions alone. When such decisions and actions are taken, they are to be specified in documents such as requisitions, change orders, data sheets, and drawings.

• **1.1.3** This Standard has requirements given in two alternate systems of units. The Manufacturer shall comply with either:

1. all of the requirements given in this Standard in SI units, or
2. all of the requirements given in this Standard in US Customary units.

The selection of which set of requirements (SI or US Customary) to apply shall be a matter of mutual agreement between the Manufacturer and Purchaser and indicated on the Data Sheet, Page 1.

**1.1.4** All tanks and appurtenances shall comply with the Data Sheet and all attachments. 07

• **1.1.5** Field-erected tanks shall be furnished completely erected, tested, and ready for service connections, unless specified otherwise. Shop-fabricated tanks shall be furnished tested and ready for installation.

• **1.1.6** The appendices of this Standard provide a number of design options requiring decisions by the Purchaser, standard requirements, recommendations, and information that supplements the basic standard. Except for Appendix L, an appendix becomes a requirement only when the Purchaser specifies an option covered by that appendix or specifies the entire appendix. See Table 1-1 for the status of each appendix.

**1.1.7** Appendix A provides alternative simplified design requirements for tanks where the stressed components, such as shell plates and reinforcing plates, are limited to a maximum nominal thickness of 12.5 mm ($^1/_2$ in.), including any corrosion allowance, and whose design metal temperature exceeds the minimums stated in the appendix.

**1.1.8** Appendix AL provides requirements for aluminum tanks. 11

**1.1.9** Appendix B provides recommendations for the design and construction of foundations for flat-bottom oil storage tanks.

**1.1.10** Appendix C provides minimum requirements for pontoon-type and double-deck-type external floating roofs.

**1.1.11** Appendix D provides requirements for submission of technical inquiries regarding this Standard.

• **1.1.12** Appendix E provides minimum requirements for tanks subject to seismic loading. An alternative or supplemental design may be mutually agreed upon by the Manufacturer and the Purchaser.

**1.1.13** Appendix F provides requirements for the design of tanks subject to a small internal pressure.

**1.1.14** Appendix G provides requirements for aluminum dome roofs.

**Table 1-1—Status of Appendices to API Std 650**

| | Appendix | Title | Status |
|---|---|---|---|
| | A | Optional Design Basis for Small Tanks | Purchaser's Option |
| 11 | AL | Aluminum Storage Tanks | Requirements |
| | B | Recommendations for Design and Construction of Foundations for Aboveground Oil Storage Tanks | Recommendations |
| | • C | External Floating Roofs | Requirements |
| | D | Technical Inquiries | Required Procedures |
| | • E | Seismic Design of Storage Tanks | Purchaser's Option |
| 08 | EC | Commentary on Appendix E | Information |
| | F | Design of Tanks for Small Internal Pressures | Requirements |
| | • G | Structurally-Supported Aluminum Dome Roofs | Requirements |
| | H | Internal Floating Roofs | Requirements |
| | • I | Undertank Leak Detection and Subgrade Protection | Purchaser's Option |
| | J | Shop-Assembled Storage Tanks | Requirements |
| | K | Sample Application of the Variable-Design-Point Method to Determine Shell-Plate Thickness | Information |
| 08 | • L | API Std 650 Storage Tank Data Sheets | Required Information |
| | M | Requirements for Tanks Operating at Elevated Temperatures | Requirements |
| | N | Use of New Materials That are Not Identified | Requirements |
| | • O | Recommendation for Under-Bottom Connections | Purchaser's Option |
| | • P | Allowable External Load on Tank Shell Openings | Purchaser's Option |
| | R | Load Combinations | Requirements |
| | S | Austenitic Stainless Steel Storage Tanks | Requirements |
| 09 | SC | Stainless Steel and Carbon Steel Mixed Material Storage Tanks | Requirements |
| | T | NDE Requirements Summary | Requirements |
| | U | Ultrasonic Examination in Lieu of Radiography | Purchaser's Option |
| | • V | Design of Storage Tanks for External Pressure | Purchaser's Option |
| 07 | • W | Commercial and Documentation Recommendations | Recommendations |
| 08 | X | Duplex Stainless Steel Tanks | Requirements |

**1.1.15** Appendix H provides minimum requirements that apply to an internal floating roof in a tank with a fixed roof at the top of the tank shell.

• **1.1.16** Appendix I provides acceptable construction details that may be specified by the Purchaser for design and construction of tank and foundation systems that provide leak detection and subgrade protection in the event of tank bottom leakage, and provides for tanks supported by grillage.

**1.1.17** Appendix J provides requirements covering the complete shop assembly of tanks that do not exceed 6 m (20 ft) in diameter.

**1.1.18** Appendix K provides a sample application of the variable-design-point method to determine shell-plate thicknesses.

07 • **1.1.19** Appendix L provides the Data Sheet and the Data Sheet instructions for listing required information to be used by the Purchaser and the Manufacturer. The use of the Data Sheet is mandatory, unless waived by the Purchaser.

**1.1.20** Appendix M provides requirements for tanks with a maximum design temperature exceeding 93°C (200°F) but not exceeding 260°C (500°F).

**1.1.21** Appendix N provides requirements for the use of new or unused plate and pipe materials that are not completely identified as complying with any listed specification for use in accordance with this Standard.

**1.1.22** Appendix O provides recommendations for the design and construction of under-bottom connections for storage tanks.

● **1.1.23** Appendix P provides requirements for design of shell openings that conform to Tables 5-6a and 5-6b that are subject to external piping loads. An alternative or supplemental design may be agreed upon by the Purchaser or Manufacturer. 08 07

**1.1.24** Appendix R provides a description of the load combinations used for the design equations appearing in this Standard.

**1.1.25** Appendix S provides requirements for stainless steel tanks.

**1.1.26** Appendix SC provides requirements for mixed material tanks using stainless steel (including austenitic and duplex) and carbon steel in the same tank for shell rings, bottom plates, roof structure, and other parts of a tank requiring high corrosion resistance. 09

**1.1.27** Appendix T summarizes the requirements for inspection by method of examination and the reference sections within the Standard. The acceptance standards, inspector qualifications, and procedure requirements are also provided. This appendix is not intended to be used alone to determine the inspection requirements within this Standard. The specific requirements listed within each applicable section shall be followed in all cases.

**1.1.28** Appendix U provides requirements covering the substitution of ultrasonic examination in lieu of radiographic examination.

**1.1.29** Appendix V provides additional requirements for tanks that are designed to operate under external pressure (vacuum) conditions.

● **1.1.30** Appendix W provides recommendations covering commercial and documentation issues. Alternative or supplemental requirements may be mutually agreed upon by the Manufacturer and the Purchaser. 07

**1.1.31** Appendix X provides requirements for duplex stainless steel tanks.

## 1.2 LIMITATIONS

The rules of this Standard are not applicable beyond the following limits of piping connected internally or externally to the roof, shell, or bottom of tanks constructed according to this Standard:

a. The face of the first flange in bolted flanged connections, unless covers or blinds are provided as permitted in this Standard.
b. The first sealing surface for proprietary connections or fittings.
c. The first threaded joint on the pipe in a threaded connection to the tank shell.
d. The first circumferential joint in welding-end pipe connections if not welded to a flange.

## 1.3 RESPONSIBILITIES

**1.3.1** The Manufacturer is responsible for complying with all provisions of this Standard. Inspection by the Purchaser's inspector does not negate the Manufacturer's obligation to provide quality control and inspection necessary to ensure such compliance. The Manufacturer shall also communicate specified requirements to relevant subcontractors or suppliers working at the request of the Manufacturer.

● **1.3.2** The Purchaser shall specify on the Data Sheet, Line 23, the applicable jurisdictional regulations and owner requirements that may affect the design and construction of the tank and those that are intended to limit the evaporation or release of liquid contents from the tank. Which regulations/requirements, if any, apply depend on many factors such as the business unit the tank is assigned to, the vapor pressure of the liquids stored in the tank, the components of the liquid stored in the tank, the geographic location of the tank, the date of construction of the tank, the capacity of the tank, and other considerations. These rules may affect questions such as 1) which tanks require floating roofs and the nature of their construction; 2) the types and details of seals used in the floating roof annular rim space and at openings in the roof, 3) details of tank vents, and 4) requirements regarding release prevention barriers. 07

● **1.3.3** The Purchaser shall provide any jurisdictional site permits that may be required to erect the tank(s), including permits for disposal of the hydro-test water. The Manufacturer shall provide all other permits that may be required to complete or transport the tank.

**1.3.4** The Purchaser retains the right to provide personnel to observe all shop and job site work within the scope of the contracted work (including testing and inspection). Such individuals shall be afforded full and free access for these purposes, subject to safety and schedule constraints.

**1.3.5** In this Standard, language indicating that the Purchaser accepts, agrees, reviews, or approves a Manufacturer's design, work process, manufacturing action, etc., shall not limit or relieve the Manufacturer's responsibility to conform to specified design codes, project specifications and drawings, and professional workmanship.

**1.3.6** The Manufacturer shall advise the Purchaser of any identified conflicts between this Standard and any Purchaser-referenced document and request clarification.

07 **1.3.7** In this Standard, language indicating that any particular issue is subject to agreement between the Purchaser and the Manufacturer shall be interpreted to require any such agreement to be documented in writing.

## • 1.4 DOCUMENTATION REQUIREMENTS

See Appendix W and the Data Sheet for the requirements covering the various documents to be developed for the tank.

## 09 1.5 FORMULAS

Where units are not defined in formulas in this standard, use consistent units (e.g. in., in.$^2$, in.$^3$, lbf/in.$^2$).

# SECTION 2—REFERENCES

The following standards, codes, specifications, and publications are cited in this Standard. The most recent edition shall be used unless otherwise specified.

API

| | | |
|---|---|---|
| RP 582 | *Welding Guidelines for the Chemical, Oil and Gas Industries* | 08 |
| Std 620 | *Design and Construction of Large, Welded, Low-Pressure Storage Tanks* | |
| RP 651 | *Cathodic Protection of Aboveground Petroleum Storage Tanks* | |
| RP 652 | *Lining of Aboveground Petroleum Storage Tank Bottoms* | |
| Publ 937 | *Evaluation of the Design Criteria for Storage Tanks with Frangible Roofs* | 08 |
| Publ 937-A | *Study to Establish Relations for the Relative Strength of API 650 Cone Roof, Roof-to-Shell, and Shell-to-Bottom Joints* | |
| Std 2000 | *Venting Atmospheric and Low-Pressure Storage Tanks: Non-refrigerated and Refrigerated* | |
| RP 2003 | *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents* | |
| Publ 2026 | *Safe Access/Egress Involving Floating Roofs of Storage Tanks in Petroleum Service* | |
| RP 2350 | *Overfill Protection for Storage Tanks in Petroleum Facilities* | |
| Spec 5L | *Specification for Line Pipe* | |

*Manual of Petroleum Measurements Standards (MPMS)*

Chapter 19 "Evaporative Loss Measurement"

AAI[1]

*Aluminum Design Manual*

*Aluminum Standards and Data*

*Specifications for Aluminum Sheet Metal Work in Building Construction*

ACI[2]

| | |
|---|---|
| 318 | *Building Code Requirements for Reinforced Concrete (ANSI/ACI 318)* |
| 350 | *Environmental Engineering Concrete Structures* |

AISC[3]

*Manual of Steel Construction, Allowable Stress Design*

AISI[4]

T-192 *Steel Plate Engineering Data Series—Useful Information—Design of Plate Structures, Volumes I &II*

ANSI[5]

ANSI/AISC 360 *Specification for Structural Steel Buildings* 11

ASCE[6]

ASCE Std. 7-05 *Minimum Design Loads for Buildings and Other Structures*

ASME[7]

| | | |
|---|---|---|
| B1.20.1 | *Pipe Threads, General Purpose (Inch)* (ANSI/ASME B1.20.1) | |
| B16.1 | *Cast Iron Pipe Flanges and Flanged Fittings* (ANSI/ASME B16.1) | |
| B16.5 | *Pipe Flanges and Flanged Fittings* (ANSI/ASME B16.5) | |
| B16.21 | *Nonmetallic Flat Gaskets for Pipe Flanges* | 07 |

[1]The Aluminum Association Inc., 1525 Wilson Boulevard, Suite 600, Arlington, Virginia 22209, www.aluminum.org.
[2]American Concrete Institute, P.O. Box 9094, Farmington Hills, Michigan 48333, www.aci-int.org.
[3]American Institute of Steel Construction, One East Wacker Drive, Suite 3100, Chicago, Illinois 60601-2001, www.aisc.org.
[4]American Iron and Steel Institute, 1540 Connecticut Avenue, N.W., Suite 705, Washington, D.C. 20036, www.steel.org.
[5]American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org. 11
[6]American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, www.asce.org.
[7]ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

B16.47 *Large Diameter Steel Flanges: NPS 26 Through NPS 60* (ANSI/ASME B16.47)

08 **Reference Deleted**

*Boiler and Pressure Vessel Code*, Section V, "Nondestructive Examination;" Section VIII, "Pressure Vessels," Division 1; and Section IX, "Welding and Brazing Qualifications"

11 ASNT[8]

CP-189 *Standard for Qualification and Certification of Nondestructive Testing Personnel*

RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*

11 ASTM[9]

A 6M/A 6 *General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use*

A 20M/A 20 *General Requirements for Steel Plates for Pressure Vessels*

A 27M/A 27 *Steel Castings, Carbon, for General Application*

A 36M/A 36 *Structural Steel*

A 53 *Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*

A 105M/A 105 *Forgings, Carbon Steel, for Piping Components*

A 106 *Seamless Carbon Steel Pipe for High-Temperature Service*

A 131M/A 131 *Structural Steel for Ships*

A 181M/A 181 *Forgings, Carbon Steel, for General-Purpose Piping*

A 182M/A 182 *Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*

A 193M/A 193 *Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service*

A 194M/A 194 *Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service*

A 213M/A 213 *Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*

A 216M/A 216 *Standard Specifications for Steel Castings for High-Temperature Service*

A 234M/A 234 *Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High-Temperature Service*

A 240M/A 240 *Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels*

A 276 *Stainless Steel Bars and Shapes*

A 283M/A 283 *Low and Intermediate Tensile Strength Carbon Steel Plates*

A 285M/A 285 *Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

07 A 307 *Carbon Steel Bolts and Studs, 60,000 lbf/in.$^2$ Tensile Strength*

A 312M/A 312 *Seamless and Welded Austenitic Stainless Steel Pipes*

A 320M/A 320 *Alloy Steel Bolting Materials for Low-Temperature Service*

A 333M/A 333 *Seamless and Welded Steel Pipe for Low-Temperature Service*

A 334M/A 334 *Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service*

A 350M/A 350 *Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components*

A 351M/A 351 *Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts*

A 358M/A 358 *Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service*

A 370 *Test Methods and Definitions for Mechanical Testing of Steel Products*

A 380 *Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems*

A 403M/A 403 *Wrought Austenitic Stainless Steel Piping Fittings*

A 420M/A 420 *Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service*

A 479M/A 479 *Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels*

A 480M/A 480 *Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*

A 516M/A 516 *Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

A 524 *Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures*

A 537M/A 537 *Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

A 573M/A 573 *Structural Carbon Steel Plates of Improved Toughness*

---

[8]American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, Ohio 43228-0518, www.asnt.org.

[9]ASTM, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, www.astm.org.

A 633M/A 633 *Normalized High-Strength Low-Alloy Structural Steel*
A 662M/A 662 *Pressure Vessel Plates, Carbon-Manganese, for Moderate and Lower Temperature Service*
A 671 *Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures*
A 678M/A 678 *Quenched and Tempered Carbon-Steel and High-Strength Low-Alloy Steel Plates for Structural Applications*
A 737M/A 737 *Pressure Vessel Plates, High-Strength, Low-Alloy Steel*
A 841M/A 841 *Standard Specification for Steel Plates for Pressure Vessels, Produced by the Thermo-Mechanical Control Process (TMCP)*
A 924M/A 924 *General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process*
A 992M/A 992 *Steel for Structural Shapes for Use in Building Framing*
A 1011M/A 1011 *Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability*
C 509 *Cellular Electrometric Preformed Gasket and Sealing Material* 07
D 3453 *Flexible Cellular Materials—Urethane for Furniture and Automotive Cushioning, Bedding, and Similar Applications*
E 84 *Test Method for Surface Burning Characteristics of Building Materials* 07

AWS[10] 11
A5.1 *Specification for Carbon Steel Covered Arc-Welding Electrodes (ANSI/AWS A5.1)*
A5.5 *Specification for Low-Alloy Steel Covered Arc-Welding Electrodes (ANSI/AWS A5.5)*
D1.2 *Structural Welding Code—Aluminum (ANSI/AWS D1.2)*

CSA[11] 11
G40.21 *Structural Quality Steels,* Supplement to *National Building Code of Canada*

EN[12] 11
EN 10025 *Hot Rolled Products of Structural Steels*

ISO[13] 11
630 *Structural Steels*

NFPA[14]
NFPA 11 *Standard for Low Expansion Foam*
NFPA 30 *Flammable and Combustible Liquids Code*
NFPA 780 *Standard for the Installation of Lightning Protection Systems*

Process Industry Practices[15]
PIP STF05501 *Fixed Ladders and Cages Details*
PIP STF05520 *Pipe Railing for Walking and Working Surface Details*
PIP STF05521 *Details for Angle Railings for Walking and Working Surfaces* 07

U.S. EPA[16]
40 *CFR* Part 63 *National Emission Standards for Hazardous Air Pollutants for Source Categories (HON)*
Subpart F *National Emission Standards for Organic Hazardous Air Pollutants from the Synthetic Organic Chemical Manufacturing Industry*

[10]American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126, www.aws.org.
[11]Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario M9W 1R3, www.csa.ca.
[12]European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu. 11
[13]International Organization for Standardization. ISO publications can be obtained from the American National Standards Institute (ANSI) and national standards organizations such as the British Standards Institute (BSI), Japanese Industrial Standards (JIS), and Deutsches Institut fuer Normung (German Institute for Standardization [DIN]), www.iso.ch.
[14]National Fire Protection Agency, 1 Batterymarch Park, Quincy, Massachusetts 02169-7474, www.nfpa.org.
[15]Process Industry Practices, 3925 West Braker Lane (R4500), Austin, Texas 78759, www.pip.org.
[16]U.S. Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue, Washington, D.C. 20460, www.epa.gov.

Subpart G *National Emission Standards for Organic Hazardous Air Pollutants from the Synthetic Organic Chemical Manufacturing Industry for Process Vents, Storage Vessels, Transfer Operators, and Waste Water*

Subpart H *National Emission Standards for Organic Hazardous Air Pollutants for Equipment Leaks*

40 *CFR* Part 68 *Chemical Accident Prevention Provisions*

07 Subpart G *Risk Management Plan (RMP)*

40 *CFR* Part 264 *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (RCRA)*

Subpart J *Tank Systems*

U.S. Federal Specifications[17]

TT-S-00230C *Sealing Compound Electrometric Type, Single Component for Caulking, Sealing, and Glazing in Buildings and Other Structures*

ZZ-R-765C *Rubber, Silicone (General Specification)*

U.S. OSHA[18]

29 *CFR* 1910 *Subpart D: Walking-Working Surfaces*

29 *CFR* 1910.119 *Process Safety Management of Highly Hazardous Chemicals*

07 Other Government Documents

Hershfield, D. M. 1961. "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," *Technical Paper* No. 40, Weather Bureau, U.S. Department of Commerce, Washington, D.C., 115 pp.

WRC[19]

Bulletin 297 *Local Stresses in Cylindrical Shells Due to External Loadings—Supplement to WRC Bulletin No. 107*

[17]Specifications Unit (WFSIS), 7th and D Streets, S.W., Washington, D.C. 20407.

[18]U.S Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, N.W., Washington, D.C. 20210 www.osha.gov.

[19] The Welding Research Council, 3 Park Avenue, 27th Floor, New York, New York 10016-5902, www.forengineers.org.

## SECTION 3—DEFINITIONS

**3.1 centerline-stacked:** The mid-thickness centerlines of plates in all shell courses coincide.

**3.2 coating:** A term that includes protective materials applied to or bonded to tank surfaces, including paint, protective metals (e.g., galvanizing or cadmium plating), adhered plastic or polyolefin materials. Coatings are used for atmospheric, immersion, or vapor-space service.

**3.3 contract:** The commercial instrument, including all attachments, used to procure a tank.

**3.4 corroded thickness:** A design condition equal to the nominal thickness less any specified corrosion allowance.

**3.5 corrosion allowance:** Any additional thickness specified by the Purchaser for corrosion during the tank service life. Refer to 5.3.2.

**3.6 design metal temperature:** The lowest temperature considered in the design, which, unless experience or special local conditions justify another assumption, shall be assumed to be 8°C (15°F) above the lowest one-day mean ambient temperature of the locality where the tank is to be installed. Isothermal lines of lowest one-day mean temperature are shown in Figure 4-2. The temperatures are not related to refrigerated-tank temperatures (see 1.1.1).

**3.7 design thickness:** The thickness necessary to satisfy tension and compression strength requirements by this Standard or, in the absence of such expressions, by good and acceptable engineering practice for specified design conditions, without regard to construction limitations or corrosion allowances.

**3.8 double-deck floating roof:** The entire roof is constructed of closed-top flotation compartments.

**3.9 floating suction line:** Internal piping assembly that allows operator to withdraw product from the upper levels of the tank.

**3.10 flush-stacked on the inside:** The inside surfaces of plates in all shell courses coincide.

**3.11 inlet diffusers:** Internal fill line piping with impingement plate, baffles, slots, or lateral openings to reduce the velocity of the flow entering a tank. 11

**3.12 inspector:** The person(s) designated by the Purchaser to perform inspections.

**3.13 liner:** A protective material used as a barrier but not adhered, nor bonded, to the protected surface. Typically used (1) inside a tank to protect steel, (2) under a tank for leak detection (as a "release prevention barrier"), (3) in a dike yard, or (4) on the dikes as secondary containment. Common examples are sheeting made from lead, rubber, plastic, polyolefin, or geosynthetic clay (bentonite). A liner is not a coating.

**3.14 lining:** An internal coating that consists of an applied liquid material which dries and adheres to the substrate, or a sheet material that is bonded to the substrate. It is designed for immersion service or vapor-space service. A lining can be reinforced or unreinforced.

**3.15 mandatory:** Required sections of the Standard become mandatory if the Standard has been adopted by a Legal Jurisdiction or if the Purchaser and the Manufacturer choose to make reference to this Standard on the nameplate or in the Manufacturer's certification.

**3.16 Manufacturer:** The party having the primary responsibility to construct the tank (see 1.3 and 10.2).

**3.17 maximum design temperature:** The highest temperature considered in the design, equal to or greater than the highest expected operating temperature during the service life of the tank.

**3.18 nominal thickness:** The ordered thickness of the material. This thickness includes any corrosion allowance. and is used for determination of PWHT requirements, weld spacing, minimum and maximum thickness limitations, etc.

Note: The thickness used in the final structure is the nominal thickness plus or minus any tolerance allowed by this standard.

**3.19 Purchaser:** The owner or the owner's designated agent, such as an engineering contractor.

**3.20 Purchaser's option:** A choice to be selected by the Purchaser and indicated on the Data Sheet. When the Purchaser specifies an option covered by an appendix, the appendix then becomes a requirement.

**3.21 recommendation:** The criteria provide a good acceptable design and may be used at the option of the Purchaser and the Manufacturer.

**3.22 requirement:** The criteria must be used unless the Purchaser and the Manufacturer agree upon a more stringent alternative design.

**3.23 single-deck pontoon floating roof:** The outer periphery of the roof consists of closed-top pontoon compartments, with the inner section of the roof constructed of a single deck without flotation means.

### 3.24 Welding Terms

The terms defined in 3.24.1 through 3.24.21 are commonly used welding terms mentioned in this standard. See 5.1.5.2 for descriptions of fusion-welded joints.

**3.24.1 automatic welding:** Welding with equipment which performs the welding operation without adjustment of the controls by a welding operator. The equipment may or may not perform the loading and unloading of the work.

**3.24.2 backing:** The material—metal, weld metal, carbon, granular flux, and so forth—that backs up the joint during welding to facilitate obtaining a sound weld at the root.

**3.24.3 base metal:** The metal or alloy that is welded or cut.

**3.24.4 depth of fusion:** The distance that fusion extends into the base metal from the surface melted during welding.

**3.24.5 filler metal:** Metal or alloy to be added in making a weld.

**3.24.6 fusion:** The melting together of filler metal and base metal, or the melting of base metal only, which results in coalescence.

**3.24.7 heat-affected zone:** The portion of the base metal that has not been melted but whose mechanical properties or
11 microstructures have been altered by the heat of welding or cutting.

**3.24.8 joint penetration:** The minimum depth a groove weld extends from its face into a joint, exclusive of reinforcement.

**3.24.9 lap joint:** A joint between two overlapping members. An overlap is the protrusion of weld metal beyond the bond at the toe of the weld.

**3.24.10 machine welding:** Welding with equipment that performs the welding operation under constant observation and control of a welding operator. The equipment may or may not perform the loading and unloading of the work.

**3.24.11 manual welding:** Welding wherein the entire welding operation is performed and controlled by hand.

**3.24.12 oxygen cutting:** A group of cutting processes wherein the severing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures. In case of oxidation-resistant metals, the reaction is facilitated by the use of a flux.

**3.24.13 porosity:** The existence of gas pockets or voids in metal.

**3.24.14 reinforcement of weld:** Weld metal on the face of a groove weld in excess of the metal necessary for the specified weld size.

**3.24.15 semiautomatic arc welding:** Arc welding with equipment that controls only the filler metal feed. The advance of the welding is manually controlled.

**3.24.16 slag inclusion:** Nonmetallic solid material entrapped in weld metal or between weld metal and base metal.

**3.24.17 undercut:** A groove melted into the base metal adjacent to the toe of a weld and left unfilled by weld metal.

**3.24.18 weld metal:** The portion of a weld that has been melted during welding.

**3.24.19 welded joint:** A union of two or more members produced by the application of a welding process.

**3.24.20 welder:** One who performs manual or semiautomatic welding.

**3.24.21 welding operator:** One who operates automatic or machine welding equipment.

# SECTION 4—MATERIALS

## 4.1 GENERAL

### 4.1.1 Miscellaneous

**4.1.1.1** See the Data Sheet for material specifications.

**4.1.1.2** Rimmed or capped steels are not permitted.

**4.1.1.3** Use of cast iron for any pressure part or any part attached to the tank by welding is prohibited.

● **4.1.1.4** Because of hydrogen embrittlement and toxicity concerns, cadmium-plated components shall not be used without the expressed consent of the Purchaser. 07

● **4.1.2** Materials used in the construction of tanks shall conform to the specifications listed in this section, subject to the modifications and limitations indicated in this Standard. Material produced to specifications other than those listed in this section may be employed, provided that the material is certified to meet all of the requirements of an applicable material specification listed in this Standard and the material's use is approved by the Purchaser. The Manufacturer's proposal shall identify the material specifications to be used. When this Standard does not address material requirements for miscellaneous items and appurtenances, the Purchaser and/or the Manufacturer shall supply additional material requirements using a supplement to the Data Sheet.

● **4.1.3** When any new or unused plate and pipe material cannot be completely identified by records that are satisfactory to the Purchaser as material conforming to a specification listed in this Standard, the material or product may be used in the construction of tanks covered by this Standard only if the material passes the tests prescribed in Appendix N.

**4.1.4** Where materials of construction are used that are certified to two or more material specifications, the material specification chosen for the design calculations shall also be used consistently in the application of all other provisions of this Standard. The Purchaser shall be notified of this choice and receive confirmation that the material fully complies with the chosen material specification in all respects.

**4.1.5** When a tank is designed to the requirements of this Standard using plate material from Group-I through Group-IIIA steels, the tank Manufacturer responsible for any proposed material substitution to use Group-IV through Group-VI steels must:

a. Maintain all of the original design criteria for the lower stress Group-I through Group IIIA steels.

● b. Obtain the prior written approval of the Purchaser.

c. Ensure that all of the design, fabrication, erection and inspection requirements for the material being substituted will meet the lower stress Group-I through Group IIIA specifications for items including but not limited to:

1. Material properties and production process methods.
2. Allowable stress levels.
3. Notch toughness.
4. Welding procedures and consumables.
5. Thermal stress relief.
6. Temporary and permanent attachment details and procedures.
7. Nondestructive examinations.

d. Include the pertinent information in the documents provided to the Purchaser, including a certification statement that the substituted material fully complies with 4.1.5 in all respects, and provide all other records covered by the work processes applied to the material such as impact testing, weld procedures, nondestructive examinations, and heat treatments. 11

## 4.2 PLATES

### 4.2.1 General

**4.2.1.1** Except as otherwise provided for in 4.1, plates shall conform to one of the specifications listed in 4.2.2 through 4.2.6, subject to the modifications and limitations in this Standard. 11

**4.2.1.2** Plate for shells, roofs, and bottoms may be ordered on an edge-thickness basis or on a weight (kg/m$^2$ [lb/ft$^2$]) basis, as specified in 4.2.1.2.1 through 4.2.1.2.3.

**4.2.1.2.1** The edge thickness ordered shall not be less than the computed design thickness or the minimum permitted thickness.

**4.2.1.2.2** The weight ordered shall be great enough to provide an edge thickness not less than the computed design thickness or the minimum permitted thickness.

08 **4.2.1.2.3** Whether an edge-thickness or a weight basis is used, an underrun not more than 0.3 mm (0.01 in.) from the computed design thickness or the minimum permitted thickness is acceptable.

● **4.2.1.3** All plates shall be manufactured by the open-hearth, electric-furnace, or basic oxygen process. Steels produced by the thermo-mechanical control process (TMCP) may be used, provided that the combination of chemical composition and integrated controls of the steel manufacturing is mutually acceptable to the Purchaser and the Manufacturer, and provided that the specified mechanical properties in the required plate thicknesses are achieved. Copper-bearing steel shall be used if specified by the Purchaser.

**4.2.1.4** Shell plates are limited to a maximum thickness of 45 mm (1.75 in.) unless a lesser thickness is stated in this Standard or in the plate specification. Plates used as inserts or flanges may be thicker than 45 mm (1.75 in.). Plates, as designated in 4.2.9.1 and thicker than 40 mm (1.5 in.), shall be normalized or quench tempered, killed, made to fine-grain practice, and impact tested.

11 **4.2.1.5** Plate components not listed in Section 4.2.9.1 (i.e., nonpressure boundary compression components) shall be limited to the maximum thickness as designated by ASTM, CSA, ISO, EN, or other recognized national standard.

### 4.2.2 ASTM Specifications

Plates that conform to the following ASTM specifications are acceptable as long as the plates are within the stated limitations:

08 a. ASTM A 36M/A 36 for plates to a maximum thickness of 40 mm (1.5 in.). None of the specifications for the appurtenant materials listed in Table 1 of ASTM A 36M/A 36 are considered acceptable for tanks constructed under this Standard unless it is expressly stated in this Standard that the specifications are acceptable.

11 b. ASTM A 131M/A 131, Grade A, for plates to a maximum thickness of 13 mm (0.5 in.); Grade B for plates to a maximum thickness of 25 mm (1 in.); and Grade EH36 for plates to a maximum thickness of 45 mm (1.75 in.) (insert plates and flanges to a maximum thickness of 50 mm [2 in.]).

c. ASTM A 283M/A 283, Grade C, for plates to a maximum thickness of 25 mm (1 in.).

d. ASTM A 285M/A 285, Grade C, for plates to a maximum thickness of 25 mm (1 in.).

e. ASTM A 516M Grades 380, 415, 450, 485/A 516, Grades 55, 60, 65, and 70, for plates to a maximum thickness of 40 mm (1.5 in.) (insert plates and flanges to a maximum thickness of 100 mm [4 in.]).

f. ASTM A 537M/A 537, Class 1 and Class 2, for plates to a maximum thickness of 45 mm (1.75 in.) (insert plates to a maximum thickness of 100 mm [4 in.]).

g. ASTM A 573M Grades 400, 450, 485/A 573, Grades 58, 65, and 70, for plates to a maximum thickness of 40 mm (1.5 in.).

h. ASTM A 633M/A 633, Grades C and D, for plates to a maximum thickness of 45 mm (1.75 in.) (insert plates to a maximum thickness of 100 mm [4.0 in.]).

i. ASTM A 662M/A 662, Grades B and C, for plates to a maximum thickness of 40 mm (1.5 in.).

j. ASTM A 678M/A 678, Grade A, for plates to a maximum thickness of 40 mm (1.5 in.) (insert plates to a maximum thickness of 65 mm [2.5 in.]) and Grade B for plates to a maximum thickness of 45 mm (1.75 in.) (insert plates to a maximum thickness of 65 mm [2.5 in.]). Boron additions are not permitted.

k. ASTM A 737M/A 737, Grade B, for plates to a maximum thickness of 40 mm (1.5 in.).

l. ASTM A 841M/A 841 Grade A, Class 1 and Grade B, Class 2 for plates to a maximum thickness of 40 mm (1.5 in.) (insert plates to a maximum thickness of 65 mm [2.5 in.]).

### 4.2.3 CSA Specifications

Plate furnished to CSA G40.21 in Grades 260W/(38W), 300W(44W), and 350W/(50W) is acceptable within the limitations stated below. (If impact tests are required, Grades 260W/[38W], 300W/[44W], and 350W/[50W] are designated as Grades 260WT/[38WT], 300WT/[44WT], and 350WT/[50WT], respectively.) Imperial unit equivalent grades of CSA Specification G40.21, shown in parenthesis, are also acceptable.

a. The W grades may be semi-killed or fully killed.

b. Fully killed steel made to fine-grain practice must be specified when required.

c. Elements added for grain refining or strengthening shall be restricted in accordance with Table 4-1.

d. Plates shall have tensile strengths that are not more than 140 MPa (20 ksi) above the minimum specified for the grade.

e. Grades 260W/(38W) and 300W(44W) are acceptable for plate to a maximum thickness of 25 mm (1 in.) if semi-killed and to a maximum thickness of 40 mm (1.5 in.) if fully killed and made to fine-grain practice.

Grade 350W(50W) is acceptable for plate to a maximum thickness of 45 mm (1.75 in.) (insert plates to a maximum thickness of 100 mm [4 in.]) if fully killed and made to fine-grain practice. 08

Table 4-1—Maximum Permissible Alloy Content

| Alloy | Heat Analysis (%) | Notes |
|---|---|---|
| Columbium | 0.05 | 1, 2, 3 |
| Vanadium | 0.10 | 1, 2, 4 |
| Columbium (≤ 0.05%) plus Vanadium | 0.10 | 1, 2, 3 |
| Nitrogen | 0.015 | 1, 2, 4 |
| Copper | 0.35 | 1, 2 |
| Nickel | 0.50 | 1, 2 |
| Chromium | 0.25 | 1, 2 |
| Molybdenum | 0.08 | 1, 2 |

1. When the use of these alloys or combinations of them is not included in the material specification, their use shall be at the option of the plate producer, subject to the approval of the Purchaser. These elements shall be reported when requested by the Purchaser. When more restrictive limitations are included in the material specification, those shall govern.
2. On product analysis, the material shall conform to these requirements, subject to the product analysis tolerances of the specification.
3. When columbium is added either singly or in combination with vanadium, it shall be restricted to plates of 13 mm (0.50 in.) maximum thickness unless combined with 0.15% minimum silicon. 08
4. When nitrogen (≤ 0.015%) is added as a supplement to vanadium, it shall be reported, and the minimum ratio of vanadium to nitrogen shall be 4:1.

### 4.2.4 ISO Specifications

Plate furnished to ISO 630 in Grades E 275 and E 355 is acceptable within the following limitations:

a. Grade E 275 in Qualities C and D for plate to a maximum thickness of 40 mm (1.5 in.). 11

b. Grade E 355 in Qualities C and D for plate to a maximum thickness of 45 mm (1.75 in.) (insert plates to a maximum thickness of 50 mm [2 in.]).

### 4.2.5 EN Specifications

Plate furnished to EN 10025 in Grades S 275 and S 355 is acceptable within the following limitations:

a. Grade S 275 in Qualities J0 and J2 for plate to a maximum thickness of 40 mm (1.5 in.). 11

b. Grade S 355 in Qualities J0, J2 and K2 for plate to a maximum thickness of 45 mm (1.75 in.) [insert plates to a maximum thickness of 50 mm (2 in.)].

### 11 • 4.2.6 National Standards

Plates produced and tested in accordance with the requirements of a recognized national standard and within the mechanical and chemical limitations of one of the grades listed in Table 4-2 are acceptable when approved by the Purchaser. The require-
11 ments of this group do not apply to the ASTM, CSA, ISO, and EN specifications listed in 4.2.2, 4.2.3, 4.2.4, and 4.2.5. For the purposes of this Standard, a *national standard* is a standard that has been sanctioned by the government of the country from which the standard originates.

11 **Table 4-2—Acceptable Grades of Plate Material Produced to National Standards (See 4.2.6)**

| | Mechanical Properties | | | | | | | | Chemical Composition | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tensile Strength[a] | | | | Minimum Yield Strength[c] | | Maximum Thickness | | Maximum Percent Carbon | | Maximum Percent Phosphorus and Sulfur | |
| | Minimum[c] | | Maximum | | | | | | | | | |
| Grade[b] | MPa | ksi | MPa | ksi | MPa | ksi | mm | in. | Heat | Product | Heat | Product |
| 235[d] | 360 | 52 | 510 | 74 | 235 | 34 | 20 | 0.75 | 0.20 | 0.24 | 0.04 | 0.05 |
| 250 | 400 | 58 | 530 | 77 | 250 | 36 | 40 | 1.5 | 0.23 | 0.27 | 0.04 | 0.05 |
| 275 | 430 | 62 | 560 | 81 | 275 | 40 | 40 | 1.5 | 0.25 | 0.29 | 0.04 | 0.05 |

[a]The location and number of test specimens, elongation and bend tests, and acceptance criteria are to be in accordance with the appropriate national standard, ISO standard, or ASTM specification.
11 [b]Semi-killed or fully killed quality; as rolled or TMCP (20 mm [0.75 in.] maximum when TMCP is used in place of normalized steel), or normalized.
• [c]Yield strength ÷ tensile strength ≤ 0.75, based on the minimum specified yield and tensile strength unless actual test values are required by the Purchaser.
[d]Nonrimming only.

### 4.2.7 General Requirements for Delivery

**4.2.7.1** The material furnished shall conform to the applicable requirements of the listed specifications but is not restricted with respect to the location of the place of manufacture.

**4.2.7.2** This material is intended to be suitable for fusion welding. Welding technique is of fundamental importance, and welding procedures must provide welds whose strength and toughness are consistent with the plate material being joined. All welding performed to repair surface defects shall be done with low-hydrogen welding electrodes compatible in chemistry, strength, and quality with the plate material.

**4.2.7.3** When specified by the plate purchaser, the steel shall be fully killed. When specified by the plate purchaser, fully killed steel shall be made to fine-grain practice.

**4.2.7.4** For plate that is to be made to specifications that limit the maximum manganese content to less than 1.60%, the limit of the manganese content may be increased to 1.60% (heat) at the option of the plate producer to maintain the required strength level, provided that the maximum carbon content is reduced to 0.20% (heat) and the weldability of the plate is given consideration. The material shall be marked "Mod" following the specification listing. The material shall conform to the product analysis tolerances of Table B in ASTM A 6M/A 6.

**4.2.7.5** The use or presence of columbium, vanadium, nitrogen, copper, nickel, chromium, or molybdenum shall not exceed the
09 limitations of Table 4-1 for all Group VI materials (see Table 4-4a and Table 4-4b) and ISO 630, Grade E 355.

### 4.2.8 Heat Treatment of Plates

**4.2.8.1** When specified by the plate purchaser, fully killed plates shall be heat treated to produce grain refinement by either 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, testing shall be carried out in
11 accordance with 4.2.8.2.

**4.2.8.2** When a plate purchaser elects to perform the required normalizing or fabricates by hot forming (see 4.2.8.1), the plates 11
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 contract, the specimens shall be heat treated under conditions considered appropriate for grain refinement and for meeting the test requirements. The plate producer shall inform the plate purchaser of the procedure followed in treating the specimens at the steel mill.

**4.2.8.3** On the purchase order, the plate purchaser shall indicate to the plate producer whether the producer shall perform the heat treatment of the plates.

● **4.2.8.4** The tensile tests shall be performed on each plate as heat treated.

**4.2.8.5** Deleted.

11

### 4.2.9 Impact Testing of Plates

● **4.2.9.1** When required by the Purchaser or by 4.2.8.4 and 4.2.10, a set of Charpy V-notch impact specimens shall be taken from plates after heat treatment (if the plates have been heat treated), and the specimens shall fulfill the stated energy requirements. Test coupons shall be obtained adjacent to a tension-test coupon. Each full-size impact specimen shall have its central axis as close to the plane of one-quarter plate thickness as the plate thickness will permit.

**4.2.9.2** When it is necessary to prepare test specimens from separate coupons or when plates are furnished by the plate producer in a hot-rolled condition with subsequent heat treatment by the fabricator, the procedure shall conform to ASTM A 20.

**4.2.9.3** An impact test shall be performed on three specimens taken from a single test coupon or test location. The average value of the specimens (with no more than one specimen value being less than the specified minimum value) shall comply with the specified minimum value. If more than one value is less than the specified minimum value, or if one value is less than two-thirds the specified minimum value, three additional specimens shall be tested, and each of these must have a value greater than or equal to the specified minimum value.

**4.2.9.4** The test specimens shall be Charpy V-notch Type A specimens (see ASTM A 370), with the notch perpendicular to the surface of the plate being tested.

**4.2.9.5** For a plate whose thickness is insufficient to permit preparation of full-size specimens [10 mm × 10 mm (0.394 in. × 08
0.394 in.], tests shall be made on the largest subsize specimens that can be prepared from the plate. Subsize specimens shall have a width along the notch of at least 80% of the material thickness.

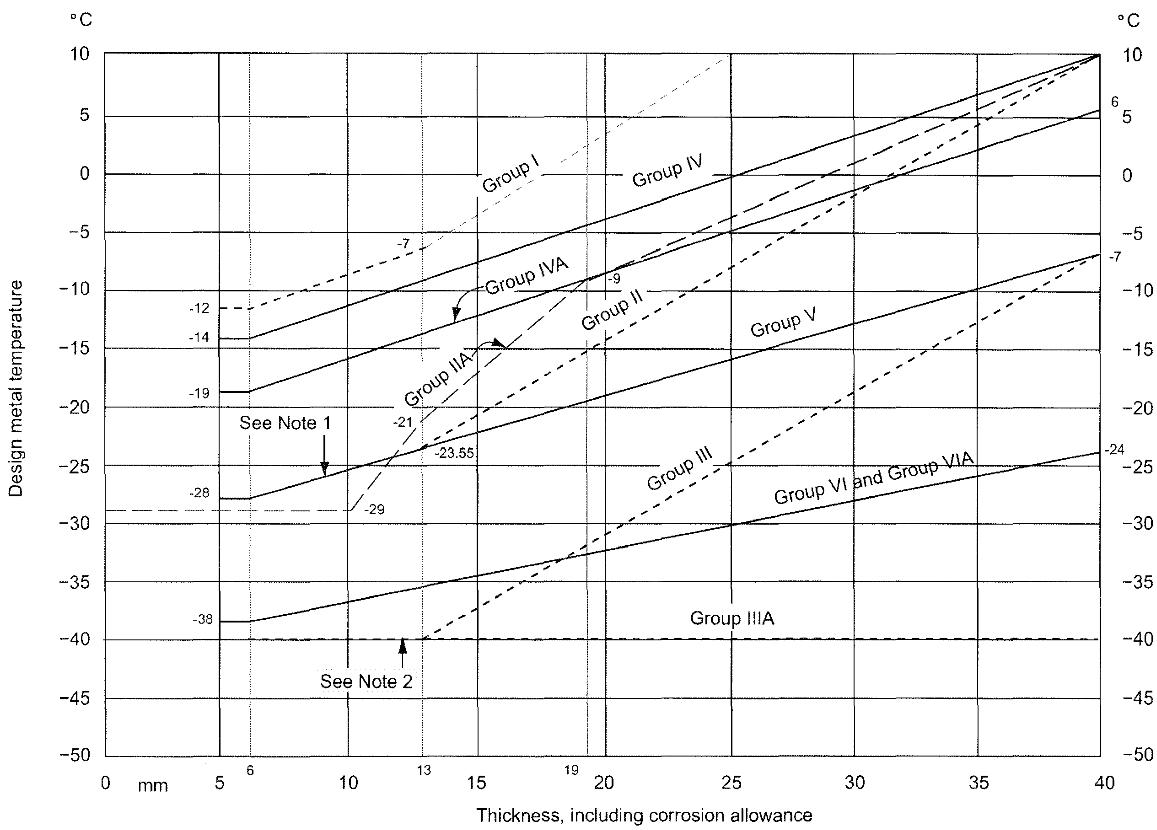
**4.2.9.6** The impact energy values obtained from subsize specimens shall not be less than values that are proportional to the energy values required for full-size specimens of the same material.

**4.2.9.7** The testing apparatus, including the calibration of impact machines and the permissible variations in the temperature of specimens, shall conform to ASTM A 370 or an equivalent testing apparatus conforming to national standards or ISO standards.

### 4.2.10 Toughness Requirements

**4.2.10.1** The thickness and design metal temperature of all shell plates, shell reinforcing plates, shell insert plates, bottom plates welded to the shell, plates used for manhole and nozzle necks, plate-ring shell-nozzle flanges, blind flanges, and manhole cover plates shall be in accordance with Figures 4-1a and 4-1b. Notch toughness evaluation of plate-ring flanges, blind flanges, and manhole cover plates shall be based on "governing thickness" as defined in 4.5.4.3. In addition, plates more than 40 mm (1.5 09
in.) thick shall be of killed steel made to fine-grain practice and heat treated by normalizing, normalizing and tempering, or quenching and tempering, and each plate as heat treated shall be impact tested according to 4.2.11.2. Each TMCP A 841 plate-as-rolled shall be impact tested. Impact test temperature and required energy shall be in accordance with 4.2.11.2 in lieu of the 11
default temperature and energy given in A 841.

**4.2.10.2** Subject to the Purchaser's approval, thermo-mechanical-control-process (TMCP) plates (plates produced by a mechanical-thermal rolling process designed to enhance notch toughness) may alternatively be used where heat treated plates are normally required by 4.2.10.1 because of thickness over 40 mm (1.5 in.). In this case, each TMCP plate-as-rolled shall receive 11
Charpy V-notch impact energy testing in accordance with 4.2.9, 4.2.10, and 4.2.11. When TMCP steels are used, consideration should be given to the service conditions outlined in 5.3.3.

09



Notes:

1. The Group II and Group V lines coincide at thicknesses less than 13 mm.
2. The Group III and Group IIIA lines coincide at thicknesses less than 13 mm.
3. The materials in each group are listed in Table 4-4a and Table 4-4b.

11 4. **Note 4 deleted.**

5. Use the Group IIA and Group VIA curves for pipe and flanges (see 4.5.4.2 and 4.5.4.3).
6. Linear equations provided in Table 4-3a can be used to calculate Design Metal Temperature (DMT) for each API material group and the thickness range.

09 Figure 4-1a— (SI) Minimum Permissible Design Metal Temperature for Materials Used in Tank Shells without Impact Testing

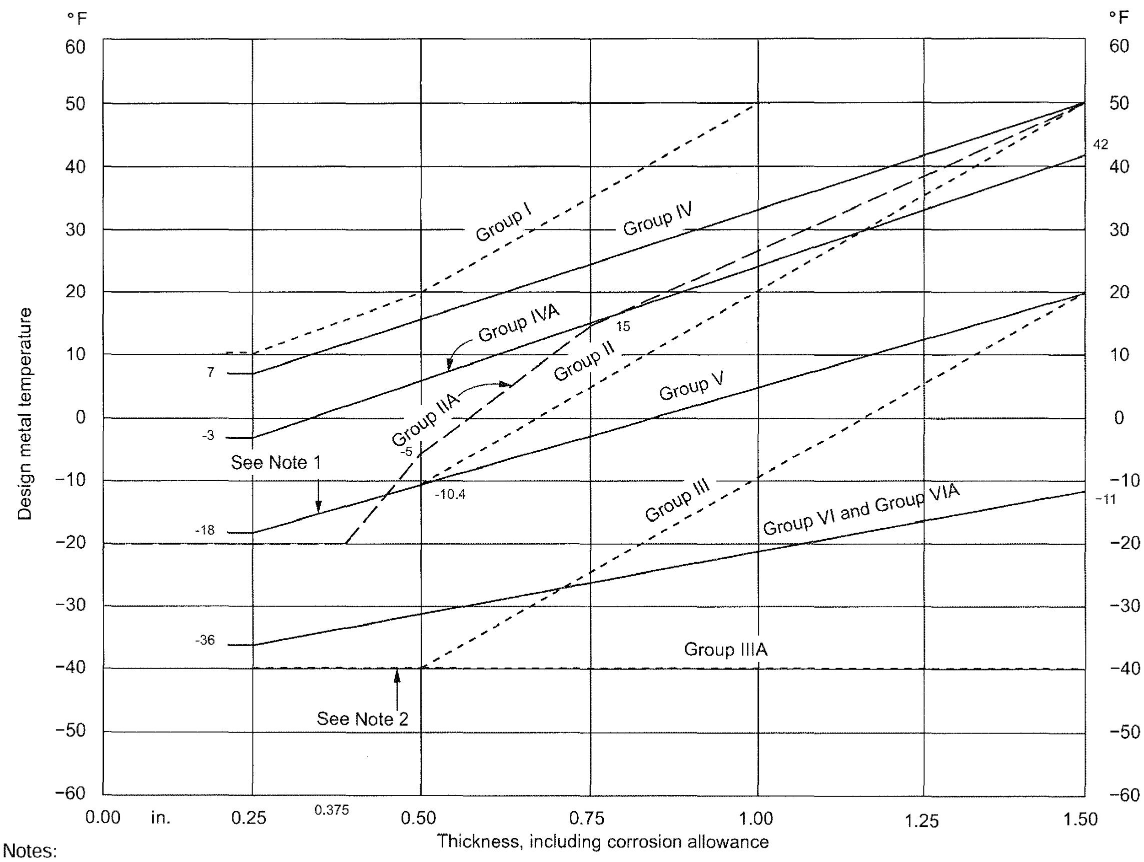
● **4.2.10.3** Plates less than or equal to 40 mm (1.5 in.) thick may be used at or above the design metal temperatures indicated in Figures 4-1a and 4-1b without being impact tested. To be used at design metal temperatures lower than the temperatures indicated in Figures 4-1a and 4-1b, plates shall demonstrate adequate notch toughness in accordance with 4.2.11.3 unless 4.2.11.2 or 4.2.11.4 has been specified by the Purchaser. For heat-treated material (normalized, normalized and tempered, or quenched and tempered), notch toughness shall be demonstrated on each plate as heat treated when 4.2.11.2 requirements are specified. Isothermal lines of lowest one-day mean temperature are shown in Figure 4-2.

**4.2.10.4** Plate used to reinforce shell openings and insert plates shall be of the same material as the shell plate to which they are
11 attached or shall be of any appropriate material listed in Table 4-4a, Table 4-4b, Figure 4-1a, and Figure 4-1b. Except for nozzle and manway necks, the material shall be of equal or greater yield and tensile strength and shall be compatible with the adjacent shell material (see 4.2.10.1 and 5.7.2.3, Item d).

**4.2.10.5** The requirements in 4.2.10.4 apply only to shell nozzles and manholes. Materials for roof nozzles and manholes do not require special toughness.

### 4.2.11 Toughness Procedure

**4.2.11.1** When a material's toughness must be determined, it shall be done by one of the procedures described in 4.2.11.2 through 4.2.11.4, as specified in 4.2.10.


 09

Notes:

1. The Group II and Group V lines coincide at thicknesses less than 1/2 in.
2. The Group III and Group IIIA lines coincide at thicknesses less than 1/2 in.
3. The materials in each group are listed in Table 4-4a and Table 4-4b.
4. **Note 4 deleted.** 11
5. Use the Group IIA and Group VIA curves for pipe and flanges (see 4.5.4.2 and 4.5.4.3).
6. Linear equations provided in Table 4-3b can be used to calculate Design Metal Temperature (DMT) for each API material group and the thickness range. 09

Figure 4-1b—(USC) Minimum Permissible Design Metal Temperature for Materials Used in Tank Shells without Impact Testing

**4.2.11.2** Each plate as rolled or heat treated shall be impact tested in accordance with 4.2.9 at or below the design metal temperature to show Charpy V-notch longitudinal (or transverse) values that fulfill the minimum requirements of Table 4-5a and Table 4-5b (see 4.2.9 for the minimum values for one specimen and for subsize specimens). As used here, the term plate as rolled 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 the condition of the plate.

**4.2.11.3** For plate in the as-rolled condition, the thickest plate from each heat shall be impact tested. For TMCP material, each plate-as-rolled shall be impact tested. Impact testing shall be in accordance with 4.2.9 and shall fulfill the impact requirements of 4.2.11.2 at the design metal temperature. 11

● **4.2.11.4** The Manufacturer shall submit to the Purchaser test data for plates of the material demonstrating that based on past production from the same mill, the material has provided the required toughness at the design metal temperature.

## 4.3 SHEETS

Sheets for fixed and floating roofs shall conform to ASTM A 1011M, Grade 33. They shall be made by the open-hearth or basic oxygen process. Copper-bearing steel shall be used if specified on the purchase order. Sheets may be ordered on either a weight or a thickness basis, at the option of the tank Manufacturer.

09

Table 4-3a—(SI) Linear Equations for Figure 4-1a

| API Group # | Thickness Range | Equation |
|---|---|---|
| I | 6 ≤ X < 13 | Y = 0.714X - 16.286 |
| I | 13 ≤ X ≤ 25 | Y = 1.417X - 25.417 |
| II | 6 ≤ X < 13 | Y = 0.634X - 31.81 |
| II | 13 ≤ X ≤ 40 | Y = 1.243X - 39.72 |
| IIA | 10 ≤ X < 13 | Y = 2.667X - 55.667 |
| IIA | 13 ≤ X ≤ 19 | Y = 2X - 47 |
| IIA | 19 ≤ X ≤ 40 | Y = 0.905X - 26.19 |
| III | 6 ≤ X < 13 | Y = - 40 |
| III | 13 ≤ X < 40 | Y = 1.222X - 55.89 |
| IIIA | 6 ≤ X ≤ 40 | Y = - 40 |
| IV | 6 ≤ X ≤ 40 | Y = 0.7059X - 18.235 |
| IVA | 6 ≤ X ≤ 40 | Y = 0.7353X - 23.412 |
| V | 6 ≤ X ≤ 40 | Y = 0.6176X - 31.71 |
| VI, VIA | 6 ≤ X ≤ 40 | Y = 0.4112X - 40.471 |

Y = Design Metal Temperature (°C)
X = Thickness including corrosion (mm)

Table 4-3b—(USC) Linear Equations for Figure 4-1b

| API Group # | Thickness Range | Equation |
|---|---|---|
| I | 0.25 ≤ X < 0.5 | Y = 40X |
| I | 0.5 ≤ X ≤ 1.0 | Y = 60X - 10 |
| II | 0.25 ≤ X < 0.5 | Y = 30.4X - 25.6 |
| II | 0.5 ≤ X ≤ 1.5 | Y = 60.4X - 40.6 |
| IIA | 0.375 ≤ X < 0.5 | Y = 120X - 65 |
| IIA | 0.5 ≤ X ≤ 0.75 | Y = 80X - 45 |
| IIA | 0.75 ≤ X ≤ 1.5 | Y = 46.667X - 20 |
| III | 0.25 ≤ X < 0.5 | Y = - 40 |
| III | 0.5 ≤ X ≤ 1.5 | Y = 60X - 70 |
| IIIA | 0.25 ≤ X ≤ 1.5 | Y = - 40 |
| IV | 0.25 ≤ X ≤ 1.5 | Y = 34.4X - 1.6 |
| IVA | 0.25 ≤ X ≤ 1.5 | Y = 36X - 12 |
| V | 0.25 ≤ X ≤ 1.5 | Y = 30.4X - 25.6 |
| VI, VIA | 0.25 ≤ X ≤ 1.5 | Y = 20X - 41 |

Y = Design Metal Temperature (°F)
X = Thickness including corrosion (in.)

## 4.4 STRUCTURAL SHAPES

**4.4.1** Structural steel shall conform to one of the following:

a. ASTM A 36M/A 36.

b. ASTM A 131M/A 131.

c. ASTM A 992M/ A 992.

d. Structural Steels listed in AISC *Specification for Structural Steel Buildings, Allowable Stress Design.*

e. CSA G40.21, Grades 260W(38W), 300W(44W), 350W(50W), 260WT(38WT), 300WT(44WT), and 350WT(50WT). Imperial unit equivalent grades of CSA Specification G40.21, shown in parenthesis, are also acceptable.

f. ISO 630, Grade E 275, Qualities B, C, and D.

11 g. EN 10025, Grade S 275, Qualities JR, J0, and J2.

● h. Recognized national standards. Structural steel that is produced in accordance with a recognized national standard and that
11 meets the requirements of Table 4-2 is acceptable when approved by the Purchaser.

● **4.4.2** All steel for structural shapes shall be made by the open-hearth, electric-furnace, or basic oxygen process. Copper-bearing steel is acceptable when approved by the Purchaser.

**4.4.3** Not all of the structural steel shapes listed in AISC (4.4.1 [d]) and other national standards (4.4.1[h]) are well suited for welding. Material selection for structural shapes requiring welded connections shall include confirmation of the material's weldability from the structural shape Manufacturer, other reputable sources, or by weld testing. Structural steel shapes having poor weldability shall only be used for bolted connection designs.

09 **4.4.4** Weldable-quality pipe that conforms to the physical properties specified in any of the standards listed in 4.5.1 may be used for structural purposes with the allowable stresses stated in 5.10.3.

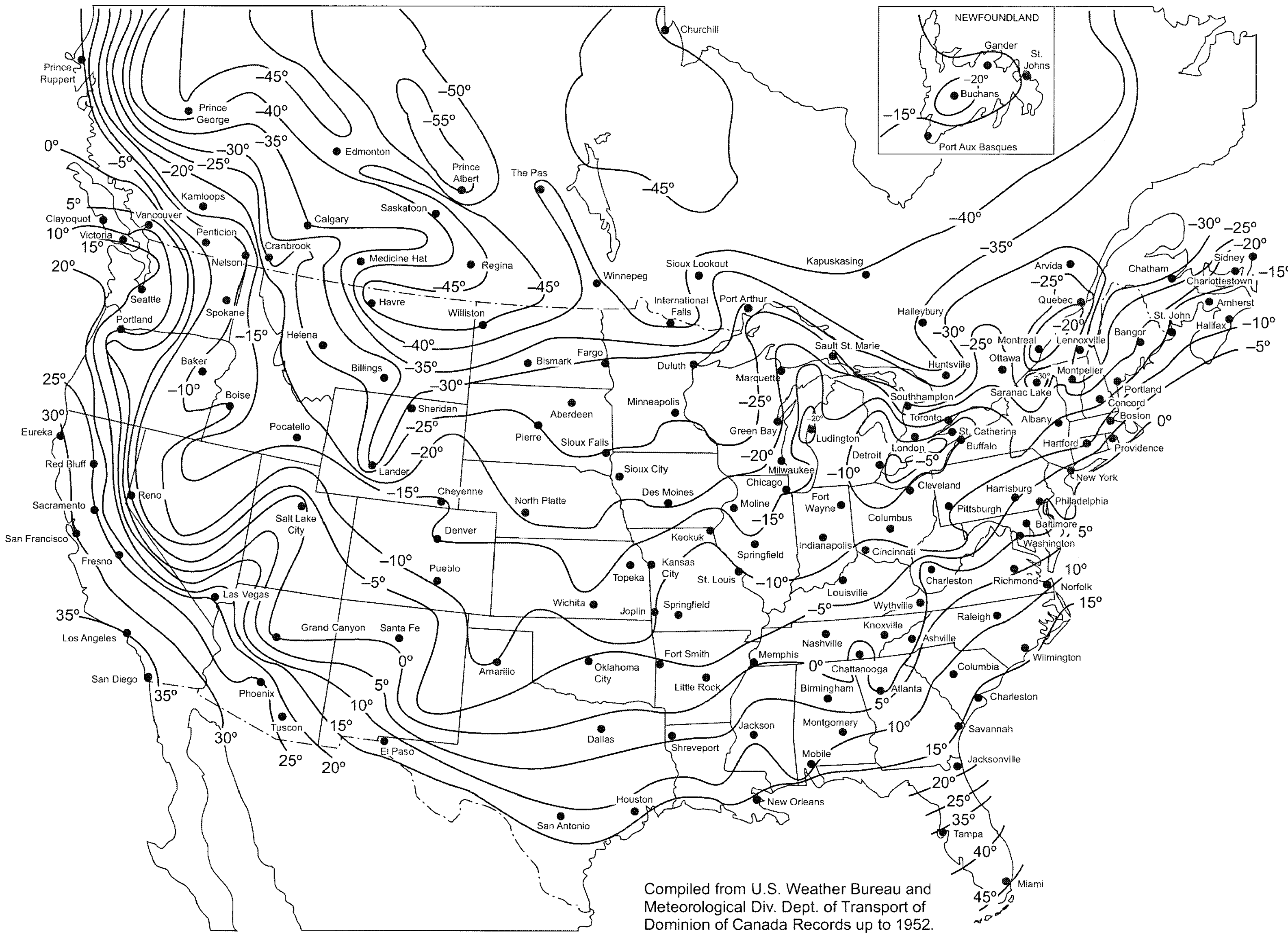



Figure 4-2—Isothermal Lines of Lowest One-Day Mean Temperatures (°F)
°C = (°F – 32)/1.8

09 Table 4-4a—(SI) Material Groups (See Figure 4-1a and Note 1 Below)

| Group I As Rolled, Semi-Killed | | Group II As Rolled, Killed or Semi-Killed | | Group III As Rolled, Killed Fine-Grain Practice | | Group IIIA Normalized, Killed Fine-Grain Practice | |
|---|---|---|---|---|---|---|---|
| Material | Notes | Material | Notes | Material | Notes | Material | Notes |
| A 283M C | 2 | A 131M B | 6 | A 573M-400 | | A 573M-400 | 9 |
| A 285M C | 2 | A 36M | 2, 5 | A 516M-380 | | A 516M-380 | 9 |
| A 131M A | 2 | G40.21-260W | | A 516M-415 | | A 516M-415 | 9 |
| A 36M | 2, 3 | Grade 250 | 7 | G40.21-260W | 8 | G40.21-260W | 8, 9 |
| Grade 235 | 3 | | | Grade 250 | 8 | Grade 250 | 8, 9 |
| Grade 250 | 5 | | | | | | |

| Group IV As Rolled, Killed Fine-Grain Practice | | Group IVA As Rolled, Killed Fine-Grain Practice | | Group V Normalized, Killed Fine-Grain Practice | | Group VI Normalized or Quenched and Tempered, Killed Fine-Grain Practice Reduced Carbon | |
|---|---|---|---|---|---|---|---|
| Material | Notes | Material | Notes | Material | Notes | Material | Notes |
| A 573M-450 | | A 662M C | | A 573M-485 | 9 | A 131M EH 36 | |
| A 573M-485 | | A 573M-485 | 10 | A 516M-450 | 9 | A 633M C | |
| A 516M-450 | | G40.21-300W | 8, 10 | A 516M-485 | 9 | A 633M D | |
| A 516M-485 | | G40.21-350W | 8, 10 | G40.21-300W | 8, 9 | A 537M Class 1 | |
| A 662M B | | E 275 D | | G40.21-350W | 8, 9 | A 537M Class 2 | 12 |
| G40.21-300W | 8 | E 355 D | | | | A 678M A | |
| 11 G40.21-350W | 8 | S 275 J2 | 8 | | | A 678M B | 12 |
| E 275 C | 8 | S 355 (J2 or K2) | 8 | | | A 737M B | |
| E 355 C | 8 | | | | | A 841M, Grade A, Class 1 | 11, 12, 13 |
| S 275 J0 | 8 | | | | | A 841M, Grade B, Class 2 | 11, 12, 13 |
| S 355 J0 | 8 | | | | | | |
| Grade 275 | 4, 8 | | | | | | |

Notes:

1. Most of the listed material specification numbers refer to ASTM specifications (including Grade or Class); there are, however, some exceptions: G40.21 (including Grade) is a CSA specification; Grades E 275 and E 355 (including Quality) are contained in ISO 630; Grades S 275 and S 355 (including quality) are contained in EN10025; and Grade 235, Grade 250, and Grade 275 are related to national standards (see 4.2.6).
2. Must be semi-killed or killed.
3. Thickness ≤ 20 mm.
4. **Deleted.**
5. Manganese content shall be 0.80% – 1.2% by heat analysis for thicknesses greater than 20 mm, except that for each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to the maximum of 1.35%. Thicknesses ≤ 20 mm shall have a manganese content of 0.80% – 1.2% by heat analysis.
6. Thickness ≤ 25 mm.
7. Must be killed.
8. Must be killed and made to fine-grain practice.
9. Must be normalized.
10. Must have chemistry (heat) modified to a maximum carbon content of 0.20% and a maximum manganese content of 1.60% (see 4.2.7.4).
11. Produced by the thermo-mechanical control process (TMCP).
12. See 5.7.4.6 for tests on simulated test coupons for material used in stress-relieved assemblies.
13. See 4.2.10 for impact test requirements (each plate-as-rolled tested).

## Table 4-4b—(USC) Material Groups (See Figure 4-1b and Note 1 Below) 08

| Group I As Rolled, Semi-killed | | Group II As Rolled, Killed or Semi-killed | | Group III As Rolled, Killed Fine-Grain Practice | | Group IIIA Normalized, Killed Fine-Grain Practice | |
|---|---|---|---|---|---|---|---|
| Material | Notes | Material | Notes | Material | Notes | Material | Notes |
| A 283 C | 2 | A 131 B | 6 | A 573-58 | | A 573-58 | 9 |
| A 285 C | 2 | A 36 | 2, 5 | A 516-55 | | A 516-55 | 9 |
| A 131 A | 2 | G40.21-38W | | A 516-60 | | A 516-60 | 9 |
| A 36 | 2, 3 | Grade 250 | 7 | G40.21-38W | 8 | G40.21-38W | 8, 9 |
| Grade 235 | 3 | | | Grade 250 | 8 | Grade 250 | 8, 9 |
| Grade 250 | 5 | | | | | | |

| Group IV As Rolled, Killed Fine-Grain Practice | | Group IVA As Rolled, Killed Fine-Grain Practice | | Group V Normalized, Killed Fine-Grain Practice | | Group VI Normalized or Quenched and Tempered, Killed Fine-Grain Practice Reduced Carbon | |
|---|---|---|---|---|---|---|---|
| Material | Notes | Material | Notes | Material | Notes | Material | Notes |
| A 573-65 | | A 662 C | | A 573-70 | 9 | A 131 EH 36 | |
| A 573-70 | | A 573-70 | 10 | A 516-65 | 9 | A 633 C | |
| A 516-65 | | G40.21-44W | 8, 10 | A 516-70 | 9 | A 633 D | |
| A 516-70 | | G40.21-50W | 8, 10 | G40.21-44W | 8, 9 | A 537 Class 1 | |
| A 662 B | | E 275 D | | G40.21-50W | 8 9 | A 537 Class 2 | 12 |
| G40.21-44W | 8 | E 355 D | | | | A 678 A | |
| G40.21-50W | 8 | S 275 J2 | 8 | | | A 678 B | 12 |
| E 275 C | 8 | S355 (J2 or K2) | 8 | | | A 737 B | |
| E 355 C | 8 | | | | | A 841, Grade A, Class 1 | 11, 12, 13 |
| S 275 J0 | 8 | | | | | A 841, Grade B, Class 2 | 11, 12, 13 |
| S 355 J0 | 8 | | | | | | |
| Grade 275 | 4, 8 | | | | | | |

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Notes:

1. Most of the listed material specification numbers refer to ASTM specifications (including Grade or Class); there are, however, some exceptions: G40.21 (including Grade) is a CSA specification; Grades E 275 and E 355 (including Quality) are contained in ISO 630; Grades S 275 and S 355 (including quality) are contained in EN10025; and Grade 235, Grade 250, and Grade 275 are related to national standards (see 4.2.6).
2. Must be semi-killed or killed.
3. Thickness ≤ 0.75 in.
4. **Deleted.**
5. Manganese content shall be 0.80% – 1.2% by heat analysis for thicknesses greater than 0.75 in., except that for each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to the maximum of 1.35%. Thicknesses ≤ 0.75 in. shall have a manganese content of 0.80% – 1.2% by heat analysis.
6. Thickness ≤ 1 in.
7. Must be killed.
8. Must be killed and made to fine-grain practice.
9. Must be normalized.
10. Must have chemistry (heat) modified to a maximum carbon content of 0.20% and a maximum manganese content of 1.60% (see 4.2.7.4).
11. Produced by the thermo-mechanical control process (TMCP).
12. See 5.7.4.6 for tests on simulated test coupons for material used in stress-relieved assemblies.
13. See 4.2.10 for impact test requirements (each plate-as-rolled tested).

Table 4-5a—(SI) Minimum Impact Test Requirements for Plates (See Note)

| Plate Material[a] and Thickness ($t$) in mm | Thickness mm | Average Impact Value of Three Specimens[b] Longitudinal J | Transverse J |
|---|---|---|---|
| Groups I, II, III, and IIIA<br>$t \leq$ maximum thicknesses in 4.2.2 through 4.2.5 | | 20 | 18 |
| Groups IV, IVA, V, and VI (except quenched and tempered and TMCP) | $t \leq 40$ | 41 | 27 |
| | $40 < t \leq 45$ | 48 | 34 |
| | $45 < t \leq 50$ | 54 | 41 |
| | $50 < t \leq 100$ | 68 | 54 |
| Group VI (quenched and tempered and TMCP) | $t \leq 40$ | 48 | 34 |
| | $40 < t \leq 45$ | 54 | 41 |
| | $45 < t \leq 50$ | 61 | 48 |
| | $50 < t \leq 100$ | 68 | 54 |

[a]See Table 4-4a.
[b]Interpolation is permitted to the nearest joule.
Note: For plate ring flanges, the minimum impact test requirements for all thicknesses shall be those for $t \leq 40$ mm.

09

Table 4-5b—(USC) Minimum Impact Test Requirements for Plates (See Note)

| Plate Material[a] and Thickness ($t$) in Inches | Thickness in. | Average Impact Value of Three Specimens[b] Longitudinal ft-lbf | Transverse ft-lbf |
|---|---|---|---|
| Groups I, II, III, and IIIA<br>$t \leq$ maximum thicknesses in 4.2.2 through 4.2.5 | | 15 | 13 |
| Groups IV, IVA, V, and VI (except quenched and tempered and TMCP) | $t \leq 1.5$ | 30 | 20 |
| | $1.5 < t \leq 1.75$ | 35 | 25 |
| | $1.75 < t \leq 2$ | 40 | 30 |
| | $2 < t \leq 4$ | 50 | 40 |
| Group VI (quenched and tempered and TMCP) | $t \leq 1.5$ | 35 | 25 |
| | $1.5 < t \leq 1.75$ | 40 | 30 |
| | $1.75 < t \leq 2$ | 45 | 35 |
| | $2 < t \leq 4$ | 50 | 40 |

[a]See Table 4-4b.
[b]Interpolation is permitted to the nearest ft-lbf.
Note: For plate ring flanges, the minimum impact test requirements for all thicknesses shall be those for $t \leq 1.5$ in.

## 4.5 PIPING AND FORGINGS

**4.5.1** Unless otherwise specified in this Standard, pipe and pipe couplings and forgings shall conform to the specifications listed in 4.5.1.1 and 4.5.1.2 or to national standards equivalent to the specifications listed.

**4.5.1.1** The following specifications are acceptable for pipe and pipe couplings:

a. API Spec 5L, Grades A, B, and X42.

b. ASTM A 53M/A 53, Grades A and B.

08 c. ASTM A 106 M/A 106, Grades A and B.

d. ASTM A 234M/A 234, Grade WPB.

e. ASTM A 333M/A 333, Grades 1 and 6.

f. ASTM A 334M/A 334, Grades 1 and 6.

g. ASTM A 420M/A 420, Grade WPL6.

h. ASTM A 524, Grades I and II.

i. ASTM A 671 (see 4.5.3).

**4.5.1.2** The following specifications are acceptable for forgings:

a. ASTM A 105M/A 105.

b. ASTM A 181M/A 181.

c. ASTM A 350M/A 350, Grades LF1 and LF2.

**4.5.2** Unless ASTM A 671 pipe is used (electric-fusion-welded pipe) (see 4.5.3), material for shell nozzles and shell manhole necks shall be seamless pipe, seamless forging, or plate material as specified in 4.2.9.1. When shell materials are Group IV, IVA, V, or VI, seamless pipe shall comply with ASTM A 106, Grade B; ASTM A 524; ASTM A 333M/ A 333, Grade 6; or ASTM A 334M/A 334, Grade 6.

**4.5.3** When ASTM A 671 pipe is used for shell nozzles and shell manhole necks, it shall comply with the following:

a. Material selection shall be limited to Grades CA 55, CC 60, CC 65, CC 70, CD 70, CD 80, CE 55, and CE 60.

b. The pipe shall be pressure tested in accordance with 8.3 of ASTM A 671.

c. The plate specification for the pipe shall satisfy the requirements of 4.2.7, 4.2.8, and 4.2.9 that are applicable to that plate specification.

d. Impact tests for qualifying the welding procedure for the pipe longitudinal welds shall be performed in accordance with 9.2.2.

**4.5.4** Except as covered in 4.5.3, the toughness requirements of pipe and forgings to be used for shell nozzles and manholes shall be established as described in 4.5.4.1 through 4.5.4.4. 09

**4.5.4.1** Piping materials made according to ASTM A 333M/A 333, A 334M/A 334, A 350M/A 350, and A 420, Grade WPL6 may be used at a design metal temperature no lower than the impact test temperature required by the ASTM specification for the 07 applicable material grade without additional impact tests (see 4.5.4.4). 09

**4.5.4.2** Other pipe and forging materials shall be classified under the material groups shown in Figures 4-1a and 4.1b as follows:

a. Group IIA—API Spec 5L, Grades A, B, and X42; ASTM A 106M/A106, Grades A and B; ASTM A 53M/A 53, Grades A and 08 B; ASTM A 181M/A 181; ASTM A 105M/A 105; and A 234M/A234, Grade WPB.

b. Group VIA—ASTM A 524, Grades I and II.

**4.5.4.3** The materials in the groups listed in 4.5.4.2 may be used at nominal thicknesses, including corrosion allowance, at a design metal temperature no lower than those shown in Figures 4-1a and 4-1b without impact testing (see 4.5.4.4 and Figure 4-3). 09 The governing thicknesses to be used in Figures 4-1a and 4.1b shall be as follows:

a. For butt-welded joints, the nominal thickness of the thickest welded joint.

b. For corner or lap welds, the thinner of the two parts joined.

c. For nonwelded parts such as bolted blind flanges and manhole covers, $^1/_4$ of their nominal thickness.

**4.5.4.4** When impact tests are required by 4.5.4.1 or 4.5.4.3, they shall be performed in accordance with the requirements, includ- 09 ing the minimum energy requirements, of ASTM A 333M/A 333, Grade 6, for pipe or ASTM A 350M/A 350, Grade LF1, for forgings at a test temperature no higher than the design metal temperature. Except for the plate specified in 4.2.9.2, the materials specified in 4.5.1 and 4.5.2 for shell nozzles, shell manhole necks, and all forgings used on shell openings shall have a minimum Charpy V-notch impact strength of 18 J (13 ft-lbf) (full-size specimen) at a temperature no higher than the design metal temperature.

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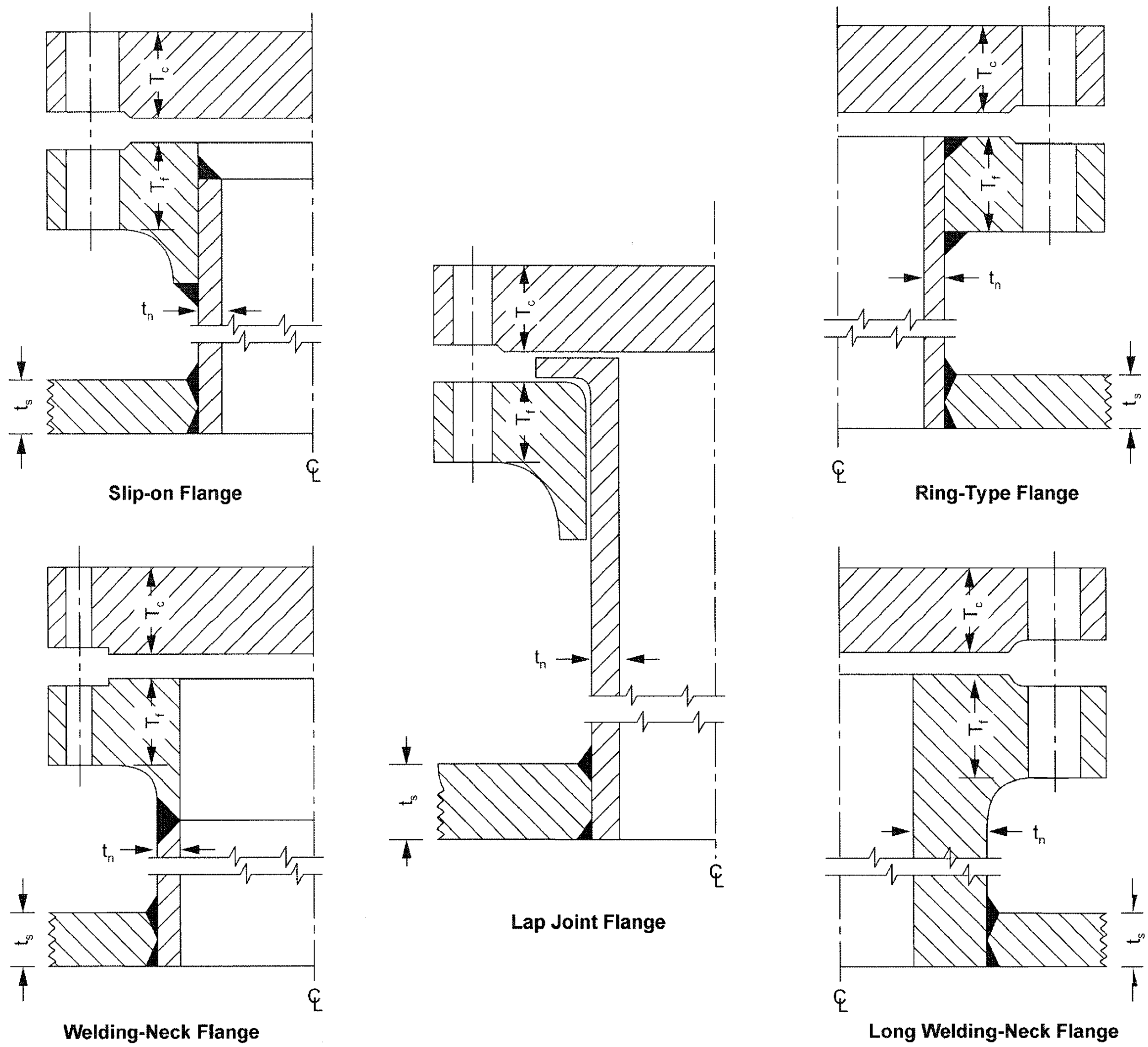


Notes:
1. Shell reinforcing plate is not included in these illustrations.
2. $t_s$ = shell thickness; $t_n$ = nozzle neck thickness; $T_f$ = flange thickness; $T_c$ = bolted cover thickness.
3. The governing thickness for each component shall be as follows:

| Components | Governing Thickness (thinner of) |
|---|---|
| Nozzle neck at shell | $t_n$ or $t_s$ |
| Slip-on flange and nozzle neck | $t_n$ or $T_f$ |
| Ring-type flange and nozzle neck | $t_n$ or $T_f$ |
| Welding-neck flange and nozzle neck | $t_n$ |
| Long welding-neck flange | $t_n$ or $t_s$ |
| Nonwelded bolted cover | $^1/_4\ T_c$ |
| Lap-type joint flange | $t_n$ or $T_f$ |

Figure 4-3—Governing Thickness for Impact Test Determination of Shell Nozzle and Manhole
09 Materials (See 4.5.4.3)

## 4.6 FLANGES

● **4.6.1** Slip on, ring-type, welding neck, long welding neck and lap joint flanges shall conform to the material requirements of ASME B16.5 for forged carbon steel flanges. Plate material used for nozzle flanges shall have physical properties better than or equal to those required by ASME B16.5. Shell-nozzle flange material shall conform to 4.2.10.1 and 4.2.10.2. Lap joint flanges shall not be used without the approval of the Purchaser. 11

● **4.6.2** For nominal pipe sizes greater than NPS 24, flanges that conform to ASME B16.47, Series B, may be used, subject to the Purchaser's approval. Particular attention should be given to ensuring that mating flanges of appurtenances are compatible.

## 4.7 BOLTING

● a. Unless otherwise specified on the Data Sheet, Table 2, flange bolting shall conform to ASTM A 193 B7 and the dimensions specified in ASME B18.2.1. Nuts shall conform to ASTM A 194 Grade 2H and the dimensions specified in ASME B18.2.2. Both shall be heavy hex pattern. All bolts and nuts shall be threaded in accordance with ASME B1.13M (SI), or with ASME B1.1(US) as follows:

| | |
|---|---|
| 1. Bolts up to and including 1 in. diameter: | UNC Class 2A fit |
| 2. Nuts for bolts up to and including 1 in. diameter: | UNC Class 2B fit |
| 3. Bolts 1.125 in. diameter and larger: | 8N Class 2A fit 07 |
| 4. Nuts for bolts 1.125 in. diameter and larger: | 8N Class 2B fit |

● b. Unless otherwise specified on the Data Sheet, Table 2, all anchors shall be threaded, galvanized ASTM A 36 round bar with galvanized heavy hex nuts.

● c. All other bolting shall conform to ASTM A 307 or A 193M/A 193. A 325M/A 325 may be used for structural purposes only. The Purchaser should specify on the order what shape of bolt heads and nuts is desired and whether regular or heavy dimensions are desired.

## 4.8 WELDING ELECTRODES

**4.8.1** For the welding of materials with a minimum tensile strength less than 550 MPa (80 ksi), the manual arc-welding electrodes shall conform to the E60 and E70 classification series (suitable for the electric current characteristics, the position of welding, and other conditions of intended use) in AWS A5.1 and shall conform to 7.2.1.10 as applicable.

**4.8.2** For the welding of materials with a minimum tensile strength of 550 MPa – 585 MPa (80 ksi – 85 ksi), the manual arc-welding electrodes shall conform to the E80XX-CX classification series in AWS A5.5.

## 4.9 GASKETS

### 4.9.1 General

● **4.9.1.1** Gasket materials shall be specified in Table 3 on the Data Sheet. Unless otherwise specified by the Purchaser, gasket materials shall not contain asbestos.

**4.9.1.2** Sheet gaskets shall be continuous. Metal gaskets made continuous by welding are acceptable if the weld is ground flush and finished the same as the unwelded portion of the gasket. Rope or tape gaskets shall have overlapped ends.

**4.9.1.3** Each gasket shall be made with an integral centering or positioning device. 07

● **4.9.1.4** No joint sealing compound, gasket adhesive, adhesive positioning tape, or lubricant shall be used on the sealing surfaces of gaskets, or flanges during joint make-up unless specifically allowed by the Purchaser. When these materials are approved by the Purchaser, consideration should be given to chemical compatibility with the gasket and flange materials.

● **4.9.1.5** Spare gaskets are not required unless specified in the Data Sheet, Line 23.

### 4.9.2 Service

● When service gaskets are designated to be furnished by the Manufacturer, the gaskets provided shall be as specified in the Data Sheet, Table 3.

### 4.9.3 Test

● **4.9.3.1** Test gaskets must have comparable dimensions and compressibility characteristics as service gaskets. Descriptions of gaskets for temporary use only as test gaskets shall be submitted for Purchaser's approval.

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**4.9.3.2** For joints that will not be disassembled after testing, the test gasket must be the specified service gasket.

**4.9.3.3** Except for stainless steel bolting, flange bolts and nuts used for testing are acceptable for use in the completed tank.

# SECTION 5—DESIGN

## 5.1 JOINTS

### 5.1.1 Definitions

The definitions in 5.1.1.1 through 5.1.1.8 apply to tank joint designs (see 9.1 for definitions that apply to welders and welding procedures. Also see Section 3 for additional definitions). 11

**5.1.1.1 butt-weld:** A weld placed in a groove between two abutting members. Grooves may be square, V-shaped (single or double), or U-shaped (single or double), or they may be either single or double beveled.

**5.1.1.2 double-welded butt joint:** A joint between two abutting parts lying in approximately the same plane that is welded from both sides.

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

**5.1.1.4 fillet weld:** A weld of approximately triangular cross-section that joins two surfaces at approximately right angles, as in a lap joint, tee joint, or corner joint.

**5.1.1.5 full-fillet weld:** A fillet weld whose size is equal to the thickness of the thinner joined member.

**5.1.1.6 single-welded butt joint with backing:** A joint between two abutting parts lying in approximately the same plane that is welded from one side only with the use of a strip bar or another suitable backing material.

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

**5.1.1.8 tack weld:** A weld made to hold the parts of a weldment in proper alignment until the final welds are made.

### 5.1.2 Weld Size

**5.1.2.1** The size of a groove weld shall be based on the joint penetration (that is, the depth of chamfering plus the root penetration when specified).

**5.1.2.2** The size of an equal-leg fillet weld shall be based on the leg length of the largest isosceles right triangle that can be inscribed within the cross-section of the fillet weld. The size of an unequal-leg fillet weld shall be based on the leg lengths of the largest right triangle that can be inscribed within the cross-section of the fillet weld.

### 5.1.3 Restrictions on Joints

**5.1.3.1** Restrictions on the type and size of welded joints are given in 5.1.3.2 through 5.1.3.8. 07

**5.1.3.2** Tack welds shall not be considered as having any strength value in the finished structure.

**5.1.3.3** The minimum size of fillet welds shall be as follows: On plates 5 mm ($^3/_{16}$ in.) thick, the weld shall be a full-fillet weld, and on plates more than 5 mm ($^3/_{16}$ in.) thick, the weld thickness shall not be less than one-third the thickness of the thinner plate at the joint and shall be at least 5 mm ($^3/_{16}$ in.).

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

**5.1.3.5** Lap-welded joints, as tack-welded, shall be lapped at least five times the nominal thickness of the thinner plate joined; however, with double-welded lap joints, the lap need not exceed 50 mm (2 in.), and with single-welded lap joints, the lap need not exceed 25 mm (1 in.).

**5.1.3.6** Weld passes are restricted as follows:

● **5.1.3.6.1** For bottom plate welds and roof plate welds for all materials, and for shell-to-bottom welds for Groups I, II, III, and IIIA materials, the following weld size requirements apply:

a. For manual welding processes, fillet weld legs or groove weld depths greater than 6 mm ($^1/_4$ in.) shall be multipass, unless otherwise specified on the Data Sheet, Line 15. 07

b. For semi-automatic, machine, and automatic welding processes, with the exception for electro-gas welding in 7.2.3.4, fillet weld legs or groove weld depths greater than 10 mm ($^3/_8$ in.) shall be multipass, unless otherwise specified on the Data Sheet, Line 15. 11

**5.1.3.6.2** For Groups IV, IVA, V, or VI shell-to-bottom welds for all welding processes, all welds shall be made using a minimum of two passes.

07 **5.1.3.7** All attachments to the exterior of the tank shall be completely seal welded. Intermittent welding is not permitted. The only exception to this requirement are wind girders as permitted in 5.1.5.8.

• **5.1.3.8** Except as permitted in 5.1.5.5 and 5.1.5.6, permanent weld joint backing strips are permitted only with the approval of the Purchaser.

### 5.1.4 Welding Symbols

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

### 5.1.5 Typical Joints

#### 5.1.5.1 General

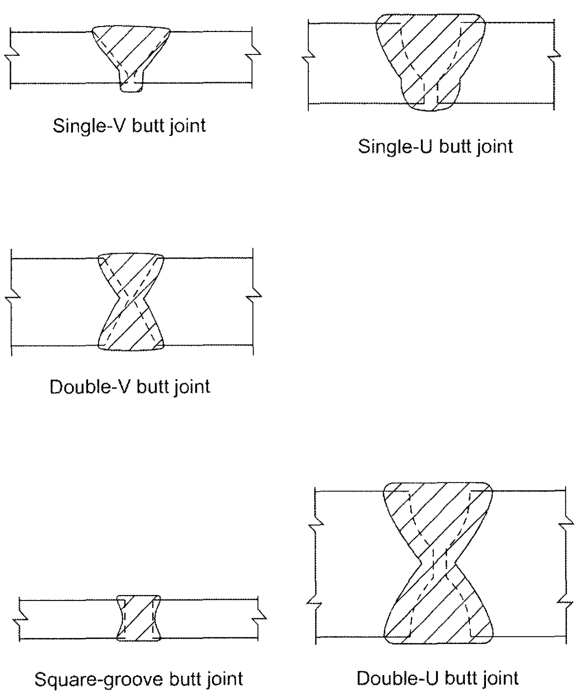
a. Typical tank joints are shown in Figures 5-1, 5-2, 5-3A, 5-3B, and 5-3C.

07 b. The top surfaces of bottom welds (butt-welded annular plates, butt-welded sketch plates, or Figure 5-3B joints) shall be ground flush where they will contact the bottoms of the shell, insert plates, or reinforcing plates.

#### 5.1.5.2 Vertical Shell Joints

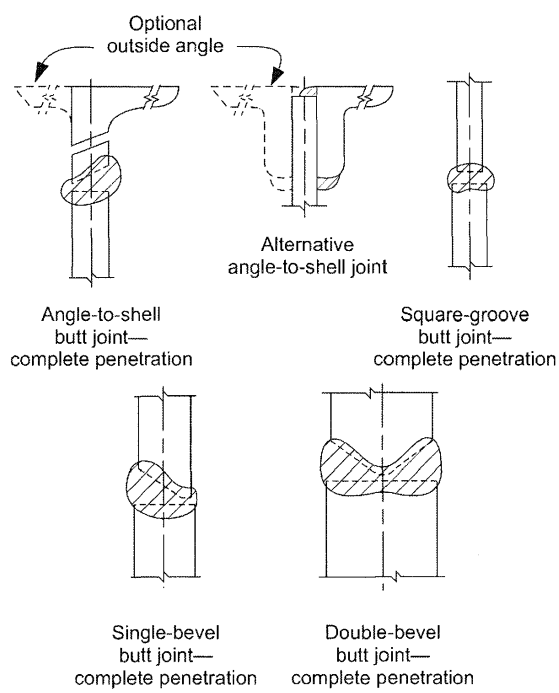
a. Vertical shell joints shall be butt joints with complete penetration and complete fusion attained by double welding or other means that will obtain the same quality of deposited weld metal on the inside and outside weld surfaces to meet the requirements of 7.2.1 and 7.2.3. The suitability of the plate preparation and welding procedure shall be determined in accordance with 9.2.

07 b. Vertical joints in adjacent shell courses shall not be aligned, but shall be offset from each other a minimum distance of $5t$, where $t$ is the plate thickness of the thicker course at the point of offset.



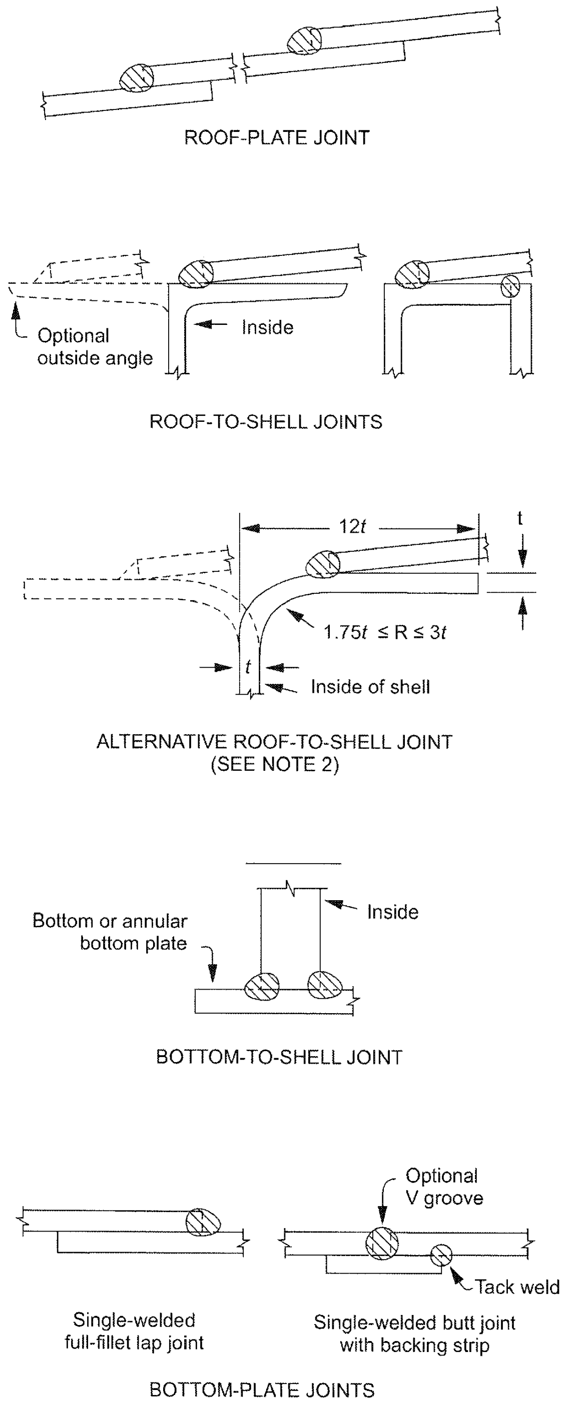

Note: See 5.1.5.2 for specific requirements for vertical shell joints.

Figure 5-1—Typical Vertical Shell Joints




Note: See 5.1.5.3 for specific requirements for horizontal shell joints.

Figure 5-2—Typical Horizontal Shell Joints




Notes:
1. See 5.1.5.4 – 5.1.5.9 for specific requirements for roof and bottom joints.
2. The alternative roof-to-shell joint is subject to the limitations of 5.1.5.9, Item f.

Figure 5-3A—Typical Roof and Bottom Joints

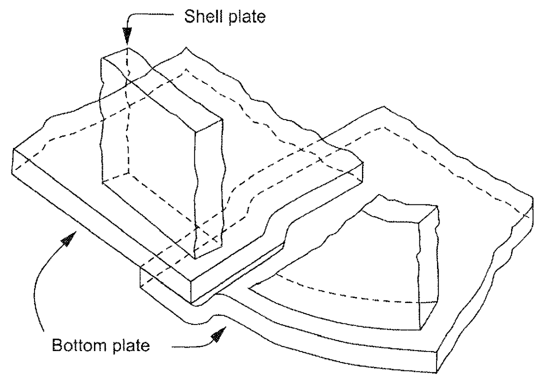



Figure 5-3B—Method for Preparing Lap-Welded Bottom Plates under Tank Shell (See 5.1.5.4)

### 5.1.5.3 Horizontal Shell Joints

a. Horizontal shell joints shall have complete penetration and complete fusion; however, as an alternative, top angles may be attached to the shell by a double-welded lap joint. The suitability of the plate preparation and welding procedure shall be determined in accordance with 9.2.

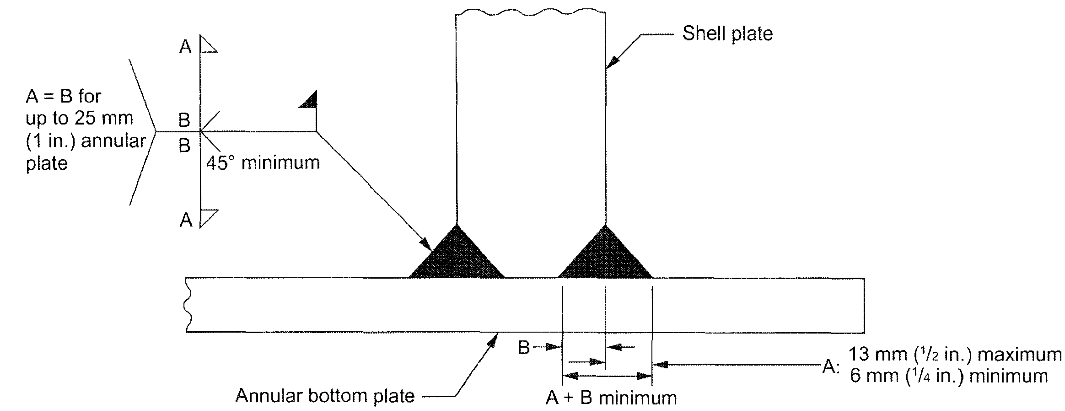
• b. Unless otherwise specified, abutting shell plates at horizontal joints shall have a common vertical centerline.

### 5.1.5.4 Lap-Welded Bottom Joints

• **5.1.5.4.1** Lap-welded bottom plates shall be reasonably rectangular. Additionally, plate may be either square cut or may have mill edges. Mill edges to be welded shall be relatively smooth and uniform, free of deleterious deposits, and have a shape such that a full fillet weld can be achieved. Unless otherwise specified by the Purchaser, lap welded plates on sloped bottoms shall be overlapped in a manner to reduce the tendency for liquid to puddle during draw-down.

**5.1.5.4.2** Three-plate laps in tank bottoms shall be at least 300 mm (12 in.) from each other, from the tank shell, and from joints between annular plates and the bottom. A three-plate lap is created where three plates come together and all plates are joined to one another by lap welds. A location where a pair of bottom plates are lap-welded to each other 11
and are lapped onto an annular plate constitutes a three-plate lap, but lapping a single bottom plate onto a butt-welded annular plate splice does not constitute a three-plate lap weld since the two annular plates are not joined together by a lap weld. These lap joint connections to the butt-weld annular plate are illustrated in Figure 5-3D.

**5.1.5.4.3** When annular plates are used or are required by 5.5.1, they shall be butt-welded and shall have a radial width that provides at least 600 mm (24 in.) between the inside of the shell and any lap-welded joint in the remainder of the bottom. Bottom plates need to be welded on the top side only, with a continuous full-fillet weld on all seams. Unless annular bottom plates are used, the bottom plates under the bottom shell ring shall have the outer ends of the joints fitted and lap-welded to form a smooth bearing surface for the shell plates, as shown in Figure 5-3B. Lap-welded bottom plates shall be seal-welded to each other on the exposed outer periphery of their lapped edges.




Notes:
1. A = Fillet weld size limited to 13 mm (1/2 in.) maximum.
2. A + B = Thinner of shell or annular bottom plate thickness.
3. Groove weld B may exceed fillet size A only when annular plate is thicker than 25 mm (1 in.).

Figure 5-3C—Detail of Double Fillet-Groove Weld for Annular Bottom Plates with a Nominal Thickness Greater Than 13 mm (1/2 in.) (See 5.1.5.7, Item b)

### • 5.1.5.5 Butt-Welded Bottom Joints

Butt-welded bottom plates shall have their parallel edges prepared for butt welding with either square or V grooves. Butt-welds shall be made using an appropriate weld joint configuration that yields a complete penetration weld. Typical permissible bottom butt-welds without a backing strip are the same as those shown in Figure 5-1. The use of a backing strip at least 3 mm (1/8 in.) thick tack welded to the underside of the plate is permitted. Butt-welds using a backing strip are shown in Figure 5-3A. If square grooves are employed, the root openings shall not be less than 6 mm (1/4 in.). A metal spacer shall be used to maintain the root opening between the adjoining plate edges unless the Manufacturer submits another method of butt-welding the bottom for the Purchaser's approval. Three-plate joints in the tank bottom shall be at least 300 mm (12 in.) from each other and from the tank shell.

### 5.1.5.6 Bottom Annular-Plate Joints

Bottom annular-plate radial joints shall be butt-welded in accordance with 5.1.5.5 and shall have complete penetration and complete fusion. The backing strip, if used, shall be compatible for welding the annular plates together.

### 5.1.5.7 Shell-to-Bottom Fillet Welds

08 a. For bottom and annular plates with a nominal thickness 13 mm (1/2 in.), and less, the attachment between the bottom edge 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
08 each weld shall not be more than 13 mm (1/2 in.) and shall not be less than the nominal thickness of the thinner of the two plates joined (that is, the shell plate or the bottom plate immediately under the shell) or less than the following values:

| Nominal Thickness of Shell Plate | | Minimum Size of Fillet Weld | |
|---|---|---|---|
| (mm) | (in.) | (mm) | (in.) |
| 5 | 0.1875 | 5 | 3/16 |
| > 5 to 20 | > 0.1875 to 0.75 | 6 | 1/4 |
| > 20 to 32 | > 0.75 to 1.25 | 8 | 5/16 |
| > 32 to 45 | > 1.25 to 1.75 | 10 | 3/8 |

08 b. For annular plates with a nominal thickness greater than 13 mm (1/2 in.), the attachment welds shall be sized so that either the legs of the fillet welds or the groove depth plus the leg of the fillet for a combined weld is of a size equal to the annular-plate thickness (see Figure 5-3C), but shall not exceed the shell plate thickness.

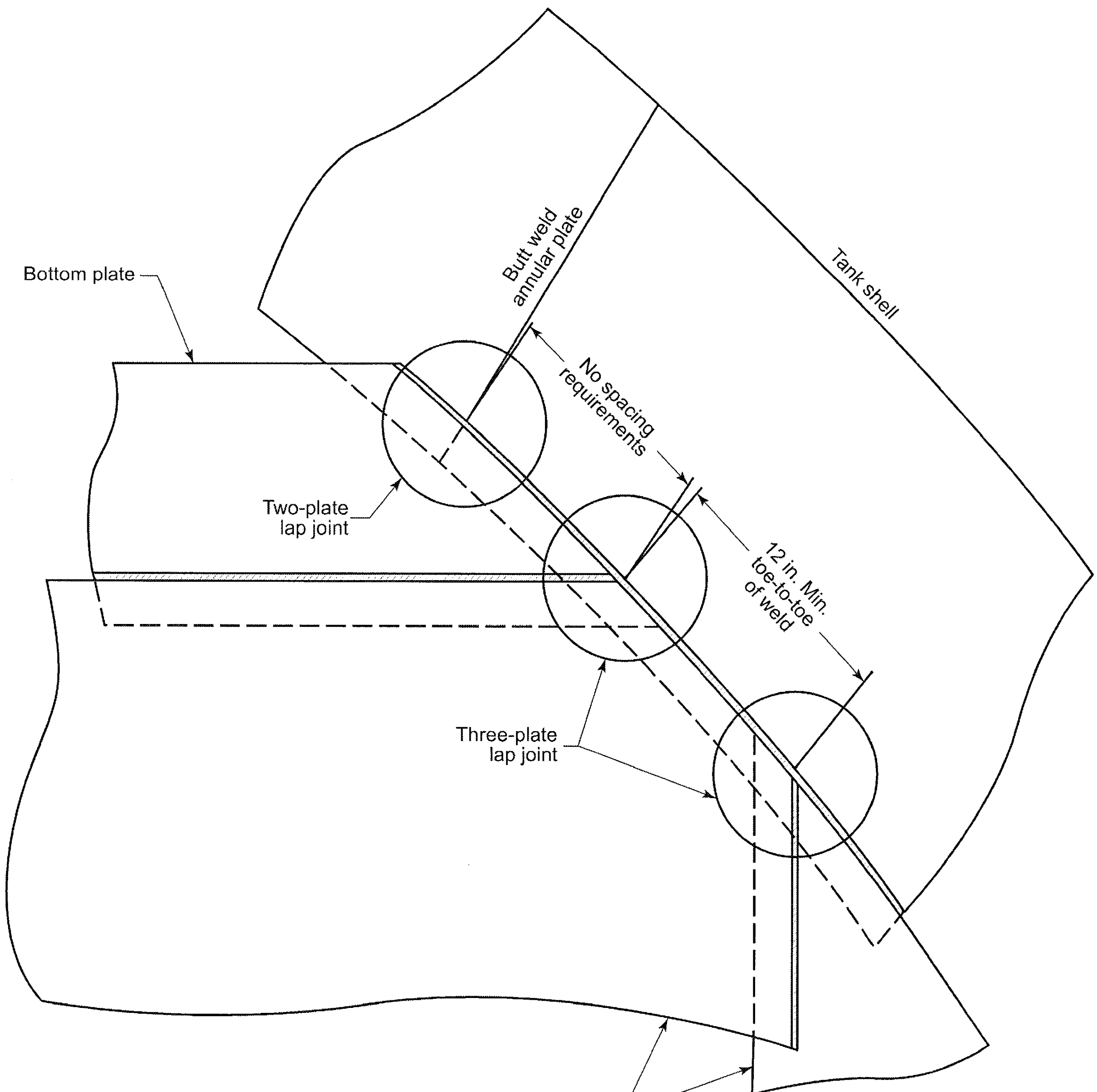



Figure 5-3D—Spacing of Three-Plate Welds at Annular Plates

11

c. Shell-to-bottom fillet weld around low-type reinforcing pads shown in Figure 5-8 Details a and b or around shell insert plates that extend beyond the outside surface of the adjacent tank shell shall be sized as required by paragraphs a or b above.
07 d. The bottom or annular plates shall be sufficient to provide a minimum 13 mm (1/2 in.) from the toe of the fillet weld referenced in 5.1.5.7c to the outside edge of the bottom or annular plates.

#### 5.1.5.8 Wind Girder Joints

a. Full-penetration butt-welds shall be used for joining ring sections.
07 • b. Continuous welds shall be used for all horizontal top-side joints and for all vertical joints. Horizontal bottom-side joints shall be seal-welded unless specified otherwise by the Purchaser.

#### 5.1.5.9 Roof and Top-Angle Joints

a. Roof plates shall, as a minimum, be welded on the top side with a continuous full-fillet weld on all seams. Butt-welds are also permitted.
b. For frangible roofs, roof plates shall be attached to the top angle of a tank with a continuous fillet weld on the top side only, as specified in 5.10.2.6. For non-frangible roofs, alternate details are permitted.
07 c. The top-angle sections, tension rings, and compression rings shall be joined by butt-welds having complete penetration and fusion. Joint efficiency factors need not be applied when conforming to the requirements of 5.10.5 and 5.10.6.
d. At the option of the Manufacturer, for self-supporting roofs of the cone, dome, or umbrella type, the edges of the roof plates may be flanged horizontally to rest flat against the top angle to improve welding conditions.
• e. Except as specified for open-top tanks in 5.9, for tanks with frangible joints per 5.10.2.6, for self-supporting roofs in 5.10.5 and 5.10.6, and for tanks with the flanged roof-to-shell detail described in Item f below, tank shells shall be supplied with top angles of not less than the following sizes:

08

| Tank Diameter ($D$) | Minimum Top Angle Size[a] (mm) | Minimum Top Angle Size[a] (in.) |
|---|---|---|
| $D \leq 11$ m, ($D \leq 35$ ft) | 50 × 50 × 5 | 2 × 2 × 3/16 |
| 11 m < $D \leq 18$ m, (35 ft < $D \leq 60$ ft) | 50 × 50 × 6 | 2 × 2 × 1/4 |
| $D > 18$ m, ($D > 60$ ft) | 75 × 75 × 10 | 3 × 3 × 3/8 |

[a]Approximate equivalent sizes may be used to accommodate local availability of materials.

For fixed roof tanks equipped with full shell height insulation or jacketing, the horizontal leg of the top shell stiffener shall project outward. For insulation system compatibility, the Purchaser shall specify if the horizontal leg is to be larger than specified above.
f. For tanks with a diameter less than or equal to 9 m (30 ft) and a supported cone roof (see 5.10.4), the top edge of the shell may be flanged in lieu of installing a top angle. The bend radius and the width of the flanged edge shall conform to the details of Figure 5-3A. This construction may be used for any tank with a self-supporting roof (see 5.10.5 and 5.10.6) if the total cross-sectional area of the junction fulfills the stated area requirements for the construction of the top angle. No additional member, such as an angle or a bar, shall be added to the flanged roof-to-shell detail.

## 5.2 DESIGN CONSIDERATIONS

### 5.2.1 Loads

Loads are defined as follows:
• a. **Dead Load ($D_L$):** The weight of the tank or tank component, including any corrosion allowance unless otherwise noted.
• b. **Design External Pressure ($P_e$):** Shall not be less than 0.25 kPa (1 in. of water) except that External Pressure ($P_e$) shall be
08 considered as 0 kPa (0 in. of water) for tanks with circulation vents meeting Appendix H requirements. Refer to Appendix V for external pressure greater than 0.25 kPa (1 in. of water). Design requirements for vacuum exceeding this value and design requirements to resist flotation and external fluid pressure shall be a matter of agreement between the Purchaser and the Manufacturer (see Appendix V).
c. **Design Internal Pressure ($P_i$):** Shall not exceed 18 kPa (2.5 lbf/in.$^2$).
d. **Hydrostatic Test ($H_t$):** The load due to filling the tank with water to the design liquid level.
• **e. Internal Floating Roof Loads:**
08 1. Dead load of internal floating roof ($D_f$) including the weight of the flotation compartments, seal and all other floating roof and attached components.

2. Internal floating roof uniform live load ($L_{f1}$) (0.6 kPa [12.5 lbf/ft$^2$]) if no automatic drains are provided, (0.24 kPa [5 lbf/f$^2$]) if automatic drains are provided).
3. Internal floating roof point load ($L_{f2}$) of at least two men walking anywhere on the roof. One applied load of 2.2 kN [500 lbf] over 0.1 m$^2$ [1 ft$^2$] applied anywhere on the roof addresses two men walking. 08
4. Internal floating roof design external pressure ($P_{fe}$) of (0.24 kPa [5 lbf/ft$^2$]) minimum.

f. **Minimum Roof Live Load ($L_r$):** 1.0 kPa (20 lb/ft$^2$) on the horizontal projected area of the roof. The minimum roof live load may alternatively be determined in accordance with ASCE 7, but shall not be less than 0.72 kPa (15 psf). The minimum roof live load shall be reported to the Purchaser.

● g. **Seismic ($E$):** Seismic loads determined in accordance with E.1 through E.6 (see Data Sheet, Line 8).

● h. **Snow (S):** The ground snow load shall be determined from ASCE 7, Figure 7-1 or Table 7-1 unless the ground snow load that equals or exceeds the value based on a 2% annual probability of being exceeded (50-year mean recurrence interval) or a national standard (such as the National Building Code of Canada) is specified by the Purchaser.

1. The balanced design snow load ($S_b$) shall be 0.84 times the ground snow load. Alternately, the balanced design snow load ($S_b$) shall be determined from the ground snow load in accordance with ASCE 7. The balanced design snow load shall be reported to the Purchaser. 11

2. The unbalanced design snow load ($S_u$) for cone roofs with a slope of 10° or less shall be equal to the balanced snow load. The unbalanced design snow load ($S_u$) for all other roofs shall be 1.5 times the balanced design snow load. Unbalanced design snow load shall be applied over a 135° sector of the roof plan with no snow on the remaining 225° sector. Alternately, the unbalanced snow load shall be determined from the ground snow load in accordance with ASCE 7

3. The balanced and unbalanced design snow loads shall be reported to the Purchaser.

● i. **Stored Liquid ($F$):** The load due to filling the tank to the design liquid level (see 5.6.3.2) with liquid with the design specific gravity specified by the Purchaser.

j. **Test Pressure ($P_t$):** As required by F.4.4 or F.7.6.

● k. **Wind ($W$):** The design wind speed ($V$) shall be 190 km/hr (120 mph), the 3-sec gust design wind speed determined from ASCE 7, Figure 6-1, or the 3-sec gust design wind speed specified by the Purchaser (this specified wind speed shall be for a 3-sec gust based on a 2% annual probability of being exceeded [50-year mean recurrence interval]). The design wind pressure shall be 0.86 kPa $(V/190)^2$, ([18 lbf/ft$^2$][$V$/120]$^2$) on vertical projected areas of cylindrical surfaces and 1.44 kPa $(V/190)^2$, ([30 lbf/ft$^2$][$V$/120]$^2$) uplift (see item 2 below) on horizontal projected areas of conical or doubly curved surfaces, where $V$ is the 3-sec gust wind speed. The 3-sec gust wind speed used shall be reported to the Purchaser. 08

● 1. These design wind pressures are in accordance with ASCE 7 for wind exposure Category C. As an alternative, pressures may be determined in accordance with ASCE 7 (exposure category and importance factor provided by Purchaser) or a national standard for the specific conditions for the tank being designed.
2. The design uplift pressure on the roof (wind plus internal pressure) need not exceed 1.6 times the design pressure $P$ determined in F.4.1.
3. Windward and leeward horizontal wind loads on the roof are conservatively equal and opposite and therefore they are not included in the above pressures.
4. Fastest mile wind speed times 1.2 is approximately equal to 3-sec gust wind speed.

### ● 5.2.2 Design Factors

The Purchaser shall state the design metal temperature (based on ambient temperatures), the maximum design temperature, the design specific gravity, the corrosion allowance (if any), and the seismic factors.

### 5.2.3 External Loads

● a. 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 the Manufacturer.

● b. Unless otherwise specified, seismic design shall be in accordance with Appendix E. 07

● c. Design for localized wind induced forces on roof components shall be a matter of agreement between the Purchaser and the Manufacturer.

d. Localized loads resulting from items such as ladders, stairs, platforms, etc., shall be considered.

e. The Purchaser shall state the magnitude and direction of any external loads other than normal personnel access for which the roof manholes and openings shall be designed. The design for such loadings shall be a matter of agreement between the Purchaser and the Manufacturer. 08

### • 5.2.4 Protective Measures

07 The Purchaser shall consider foundations, corrosion allowance, hardness testing, and any other protective measures deemed necessary. For example, for insulated tanks, means to prevent infiltration of water into the insulation shall be specified, especially around penetrations of the insulation and at the roof-to-shell junction.

### 5.2.5 External Pressure

See Appendix V for the provisions for the design of tanks subject to partial internal vacuum exceeding 0.25 kPa (1 in. of water). Tanks that meet the requirements of this Standard may be subjected to a partial vacuum of 0.25 kPa (1 in. of water), without the need to provide any additional supporting calculations.

### 5.2.6 Tank Capacity

• **5.2.6.1** The Purchaser shall specify the maximum capacity and the overfill protection level (or volume) requirement (see API RP 2350).

**5.2.6.2** Maximum capacity is the volume of product in a tank when the tank is filled to its design liquid level as defined in 5.6.3.2 (see Figure 5-4).

**5.2.6.3** The net working capacity is the volume of available product under normal operating conditions. The net working capacity is equal to the maximum capacity (see 5.2.6.2) less the minimum operating volume remaining in the tank, less the overfill protection level (or volume) requirement (see Figure 5-4).

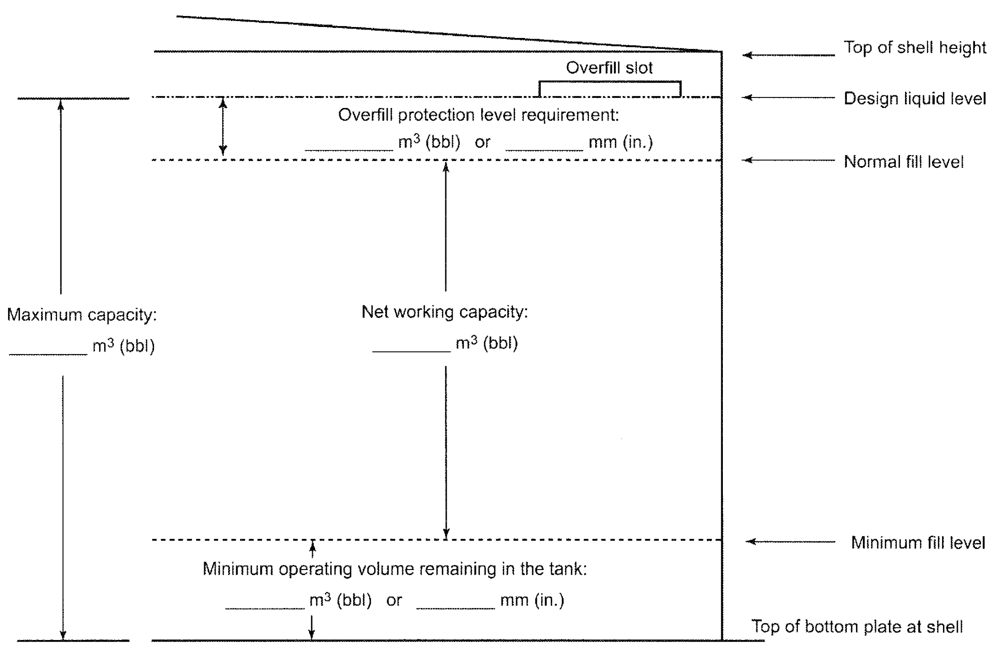



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Figure 5-4—Storage Tank Volumes and Levels

## 5.3 SPECIAL CONSIDERATIONS

### 5.3.1 Foundation

• **5.3.1.1** The selection of the tank site and the design and construction of the foundation shall be given careful consideration, as outlined= in Appendix B, to ensure adequate tank support. The adequacy of the foundation is the responsibility of the Purchaser. Foundation loading data shall be provided by the Manufacturer on the Data Sheet, Line 13.

**5.3.1.2** Sliding friction resistance shall be verified for tanks subject to lateral wind loads or seismic loads (see 5.11.4 and E.7.6).

### 5.3.2 Corrosion Allowances

• **5.3.2.1** The Purchaser, after giving consideration to the total effect of the liquid stored, the vapor above the liquid, and the atmospheric environment, shall specify in the Data Sheet, Tables 1 and 2, any corrosion allowances to be provided for all components, including each shell course, for the bottom, for the roof, for nozzles and manholes, and for structural members.

**5.3.2.2** Excluding nozzle necks, corrosion allowances for nozzles, flush-type cleanouts, manholes, and self-supporting roofs shall be added to the design thickness, if calculated, or to the minimum specified thickness. 07

• **5.3.2.3** For nozzle necks, any specified nozzle neck corrosion allowance shall, by agreement between the Purchaser and the Manufacturer, be added to either the nominal neck thickness shown in Tables 5-6a and 5-6b (or Tables 5-7a and 5-7b), or to the minimum calculated thickness required for pressure head and mechanical strength. In no case shall the neck thickness provided be less than the nominal thickness shown in the table. 08

**5.3.2.4** Corrosion allowance for anchor bolts shall be added to the nominal diameter. 07

**5.3.2.5** Corrosion allowance for anchor straps and brackets shall be added to the required strap and bracket thickness.

• **5.3.2.6** For internal structural members, the corrosion allowance shall be applied to the total thickness unless otherwise specified.

### • 5.3.3 Service Conditions

The Purchaser shall specify any applicable special metallurgical requirements pertaining to the selection of materials and the fabrication processes as required by any anticipated service conditions. When the service conditions might include the presence of hydrogen sulfide or other conditions that could promote hydrogen-induced cracking, notably near the bottom of the shell at the shell-to-bottom connections, care should be taken to ensure that the materials of the tank and details of construction are adequate to resist hydrogen-induced cracking. The Purchaser should consider limits on the sulfur content of the base and weld metals as well as appropriate quality control procedures in plate and tank fabrication. The hardness of the welds, including the heat-affected zones, in contact with these conditions should be considered. The weld metal and adjacent heat-affected zone often contain a zone of hardness well in excess of Rockwell C 22 and can be expected to be more susceptible to cracking than unwelded metal is. Any hardness criteria should be a matter of agreement between the Purchaser and 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 the base metal and weld metal. See the Data Sheet, Line 5. 07

### • 5.3.4 Weld Hardness

a. Weld metal and Heat Affected Zone (HAZ) hardnesses shall comply with the $H_2S$ Supplemental Specification listed on the Data Sheet, Line 5, when specified by the Purchaser.

b. When specified by the Purchaser, the hardness of the weld metal for shell materials in Group IV, IVA, V, or VI shall be evaluated by one or both of the following methods:

1. The welding-procedure qualification tests for all welding shall include hardness tests of the weld metal and heat-affected zone of the test plate. The methods of testing and the acceptance standards shall be agreed upon by the Purchaser and the Manufacturer. 07

2. All welds deposited by machine or an automatic process shall be hardness tested on the product-side surface. Unless otherwise specified, one test shall be conducted for each vertical weld, and one test shall be conducted for each 30 m (100 ft) of circumferential weld. The methods of testing and the acceptance standards shall be agreed upon by the Purchaser and the Manufacturer. 11 07

### • 5.3.5 Thickness

When 6 mm ($^1/_4$ in.) thick material is specified, 0.236 in. thick material may be used in the US Customary rule set with Purchaser approval. Similarly when 5 mm ($^3/_{16}$ in.) thick material is specified, 4.8 mm. thick material may be used in the SI rule set with Purchaser approval. The design calculations shall be based on thickness used. 08

## 5.4 BOTTOM PLATES

• **5.4.1** All bottom plates shall have a corroded thickness of not less than 6 mm (0.236 in.) [49.8 kg/m$^2$ (9.6 lbf/ft$^2$) (see 4.2.1.2)]. Unless otherwise agreed to by the Purchaser, all rectangular and sketch plates (bottom plates on which the shell rests that have one end rectangular) shall have a nominal width of not less than 1800 mm (72 in.). 11

**5.4.2** Bottom plates of sufficient size shall be ordered so that, when trimmed, at least a 50 mm (2 in.) width will project outside the shell or meet requirements given in 5.1.5.7 d whichever is greater. 07

**5.4.3** Bottom plates shall be welded in accordance with 5.1.5.4 or 5.1.5.5.

• **5.4.4** Unless otherwise specified on the Data Sheet, Line 12, tank bottoms requiring sloping shall have a minimum slope of 1:120 upwards toward center of the tank.

• **5.4.5** If specified on the Data Sheet, Line 12, a foundation drip ring shall be provided to prevent ingress of water between the tank bottom and foundation. Unless the Purchaser specifies otherwise, the ring shall meet the following requirements (see Figure 5-5):

07 1. Material shall be carbon steel, 3 mm ($^1/_8$-in.) minimum thickness.

2. All radial joints between sections of the drip rings, as well as between the drip ring and the annular plate or bottom, shall be continuously seal-welded.

3. The drip ring shall extend at least 75 mm (3 in.) beyond the outer periphery of the foundation ringwall and then turn down (up to 90°) at its outer diameter.

11 4. The top and bottom of the drip ring, and the top of the tank bottom edge projection beyond the shell, and a portion of the tank shell shall be coated if specified by the Purchaser.

## 5.5 ANNULAR BOTTOM PLATES

**5.5.1** When the bottom shell course is designed using the allowable stress for materials in Group IV, IVA, V, or VI, butt-welded annular bottom plates shall be used (see 5.1.5.6). When the bottom shell course is of a material in Group IV, IVA, V, or VI and the maximum product stress (see 5.6.2.1) for the first shell course is less than or equal to 160 MPa (23,200 lbf/in.$^2$) or the maximum hydrostatic test stress (see 5.6.2.2) for the first shell course is less than or equal to 171 MPa (24,900 lbf/in.$^2$), lap-welded bottom
08 plates (see 5.1.5.4) may be used in lieu of butt-welded annular bottom plates.

**5.5.2** Annular bottom plates shall have a radial width that provides at least 600 mm (24 in.) between the inside of the shell and any lap-welded joint in the remainder of the bottom. Annular bottom plate projection outside the shell shall meet the requirements of 5.4.2. A greater radial width of annular plate is required when calculated as follows:

In SI units:

$$\frac{215t_b}{(HG)^{0.5}}$$

where

$t_b$ = thickness of the annular plate (see 5.5.3), in mm,

$H$ = maximum design liquid level (see 5.6.3.2), in m,

$G$ = design specific gravity of the liquid to be stored.

11

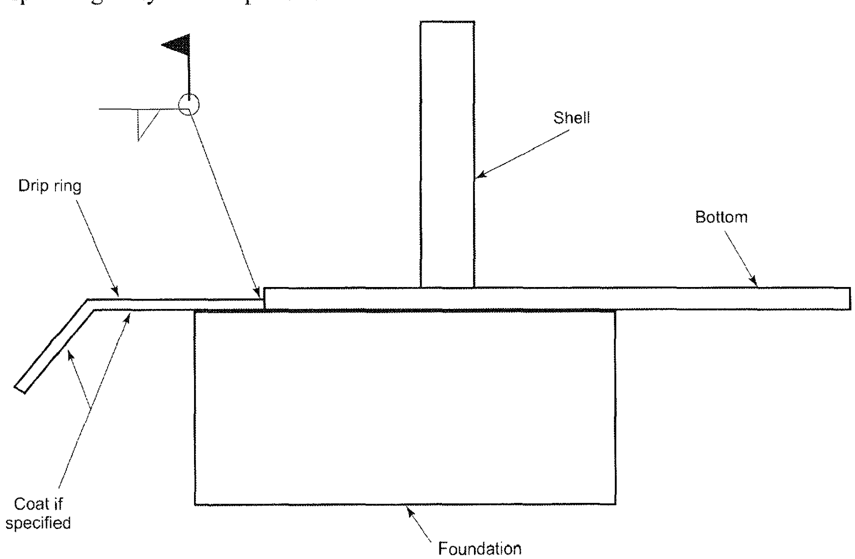



Figure 5-5—Drip Ring (Suggested Detail)

In US Customary units:

$$\frac{390t_b}{(HG)^{0.5}}$$

where

$t_b$ = thickness of the annular plate (see 5.5.3), (in.),

$H$ = maximum design liquid level (see 5.6.3.2), (ft),

$G$ = design specific gravity of the liquid to be stored.

**5.5.3** The thickness of the annular bottom plates shall not be less than the greater thickness determined using Tables 5-1a and 5-1b for product design (plus any specified corrosion allowance) or for hydrostatic test design. Tables 5-1a and 5-1b are 08
applicable for effective product height of $H \times G \leq 23$ m (75 ft). Beyond this height an elastic analysis must be made to determine the annular plate thickness. 07

Table 5-1a—(SI) Annular Bottom-Plate Thicknesses ($t_b$) 08

| Plate Thickness[a] of First Shell Course (mm) | Stress[b] in First Shell Course (MPa) | | | | |
|---|---|---|---|---|---|
| | ≤ 190 | ≤ 210 | ≤ 220 | ≤ 250 | 09 |
| $t \leq 19$ | 6 | 6 | 7 | 9 | |
| $19 < t \leq 25$ | 6 | 7 | 10 | 11 | |
| $25 < t \leq 32$ | 6 | 9 | 12 | 14 | |
| $32 < t \leq 40$ | 8 | 11 | 14 | 17 | |
| $40 < t \leq 45$ | 9 | 13 | 16 | 19 | |

[a]Plate thickness refers to the corroded shell plate thickness for product design and nominal thickness for hydrostatic test design.
[b]The stress to be used is the maximum stress in the first shell course (greater of product or hydrostatic test stress). The stress may be determined using the required thickness divided by the thickness from "a" then multiplied by the applicable allowable stress:
Product Stress = ($t_d$ – $CA$/corroded $t$ ) ($S_d$)
Hydrostatic Test Stress = ($t_t$ /nominal $t$ ) ($S_t$) 11

Note: The thicknesses specified in the table, as well as the width specified in 5.5.2, are based on the foundation providing uniform support under the full width of the annular plate. Unless the foundation is properly compacted, particularly at the inside of a concrete ringwall, settlement will produce additional stresses in the annular plate.

Table 5-1b—(USC) Annular Bottom-Plate Thicknesses ($t_b$)

| Plate Thickness[a] of First Shell Course (in.) | Stress[b] in First Shell Course (lbf/in.$^2$) | | | | |
|---|---|---|---|---|---|
| | ≤ 27,000 | ≤ 30,000 | ≤ 32,000 | ≤ 36,000 | |
| $t \leq 0.75$ | 0.236 | 0.236 | $^9/_{32}$ | $^{11}/_{32}$ | 09 |
| $0.75 < t \leq 1.00$ | 0.236 | $^9/_{32}$ | $^3/_8$ | $^7/_{16}$ | |
| $1.00 < t \leq 1.25$ | 0.236 | $^{11}/_{32}$ | $^{15}/_{32}$ | $^9/_{16}$ | |
| $1.25 < t \leq 1.50$ | $^5/_{16}$ | $^7/_{16}$ | $^9/_{16}$ | $^{11}/_{16}$ | |
| $1.50 < t \leq 1.75$ | $^{11}/_{32}$ | $^1/_2$ | $^5/_8$ | $^3/_4$ | |

[a]Plate thickness refers to the corroded shell plate thickness for product design and nominal thickness for hydrostatic test design.
[b]The stress to be used is the maximum stress in the first shell course (greater of product or hydrostatic test stress). The stress may be determined using the required thickness divided by the thickness from "a" then multiplied by the applicable allowable stress:
Product Stress = ($t_d$ – $CA$/corroded $t$ ) ($S_d$) 11
Hydrostatic Test Stress = ($t_t$ /nominal $t$ ) ($S_t$)

Note: The thicknesses specified in the table, as well as the width specified in 5.5.2, are based on the foundation providing uniform support under the full width of the annular plate. Unless the foundation is properly compacted, particularly at the inside of a concrete ringwall, settlement will produce additional stresses in the annular plate.

**5.5.4** 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 welded in accordance with 5.1.5.6 and 5.1.5.7, Item b.

**5.5.5** In lieu of annular plates, the entire bottom may be butt-welded provided that the requirements for annular plate thickness, welding, materials, and inspection are met for the annular distance specified in 5.5.2.

## 5.6 SHELL DESIGN

### 5.6.1 General

**5.6.1.1** The required shell thickness shall be the greater of the design shell thickness, including any corrosion allowance, or the hydrostatic test shell thickness, but the shell thickness shall not be less than the following:

| | Nominal Tank Diameter | | Nominal Plate Thickness | |
|---|---|---|---|---|
| 07 | (m) | (ft) | (mm) | (in.) |
| 07 | < 15 | < 50 | 5 | 3/16 |
| | 15 to < 36 | 50 to < 120 | 6 | 1/4 |
| | 36 to 60 | 120 to 200 | 8 | 5/16 |
| | > 60 | > 200 | 10 | 3/8 |

Notes:
- ● 1. Unless otherwise specified by the Purchaser, the nominal tank diameter shall be the centerline diameter of the bottom shell-course plates.
- 2. The thicknesses specified are based on erection requirements.
- ● 3. When specified by the Purchaser, plate with a nominal thickness of 6 mm may be substituted for 1/4-in. plate.
- 11 4. For diameters less than 15 m (50 ft) but greater than 3.2 m (10.5 ft), the nominal thickness of the lowest shell course shall not be less than 6 mm (1/4 in.).

● **5.6.1.2** Unless otherwise agreed to by the Purchaser, the shell plates shall have a minimum nominal width of 1800 mm (72 in.). Plates that are to be butt-welded shall be properly squared.

**5.6.1.3** The calculated stress for each shell course shall not be greater than the stress permitted for the particular material used for the course. When the allowable stress for an upper shell course is lower than the allowable stress of the next lower shell course, then either a or b shall be satisfied.

08 a. The lower shell course thickness shall be no less than the thickness required of the upper shell course for product and hydrostatic test loads by 5.6.3 or 5.6.4.

b. The thickness of all shell courses shall be that determined from an elastic analysis per 5.6.5 using final plate thicknesses.

The inside of an upper shell course shall not project beyond the inside surface of the shell course below (except within tolerances provided in 7.2.3.2).

**5.6.1.4** The tank shell shall be checked for stability against buckling from the design wind speed in accordance with 5.9.7. If required for stability, intermediate girders, increased shell-plate thicknesses, or both shall be used.

07 **5.6.1.5** Isolated radial loads on the tank shell, such as those caused by heavy loads on platforms and elevated walkways between tanks, shall be distributed by rolled structural sections, plate ribs, or built-up members.

### 5.6.2 Allowable Stress

11 **5.6.2.1** The maximum allowable product design stress, $S_d$, shall be as shown in Tables 5-2a and 5-2b. The corroded plate thicknesses shall be used in the calculation. The design stress basis, $S_d$, shall be either two-thirds the yield strength or two-fifths the tensile strength, whichever is less.

11 **5.6.2.2** The maximum allowable hydrostatic test stress, $S_t$, shall be as shown in Tables 5-2a and 5-2b. The nominal plate thicknesses shall be used in the calculation. The hydrostatic test basis shall be either three-fourths the yield strength or three-sevenths the tensile strength, whichever is less.

08 **5.6.2.3** Appendix A permits an alternative shell design with a fixed allowable stress of 145 MPa (21,000 lbf/in.$^2$) and a joint efficiency factor of 0.85 or 0.70. This design may only be used for tanks with shell thicknesses less than or equal to 13 mm (1/2 in.).

**5.6.2.4** Structural design stresses shall conform to the allowable working stresses given in 5.10.3.

## Table 5-2a—(SI) Permissible Plate Materials and Allowable Stresses

| Plate Specification | Grade | Nominal Plate Thickness $t$ mm | Minimum Yield Strength Mpa | Minimum Tensile Strength Mpa | Product Design Stress $S_d$ Mpa | Hydrostatic Test Stress $S_t$ Mpa | |
|---|---|---|---|---|---|---|---|
| | | | ASTM Specifications | | | | |
| A 283M | C | | 205 | 380 | 137 | 154 | |
| A 285M | C | | 205 | 380 | 137 | 154 | |
| A 131M | A, B | | 235 | 400 | 157 | 171 | |
| A 36M | — | | 250 | 400 | 160 | 171 | 11 |
| A 131M | EH 36 | | 360 | 490[a] | 196 | 210 | |
| A 573M | 400 | | 220 | 400 | 147 | 165 | |
| A 573M | 450 | | 240 | 450 | 160 | 180 | |
| A 573M | 485 | | 290 | 485[a] | 193 | 208 | |
| A 516M | 380 | | 205 | 380 | 137 | 154 | |
| A 516M | 415 | | 220 | 415 | 147 | 165 | |
| A 516M | 450 | | 240 | 450 | 160 | 180 | |
| A 516M | 485 | | 260 | 485 | 173 | 195 | |
| A 662M | B | | 275 | 450 | 180 | 193 | |
| A 662M | C | | 295 | 485[a] | 194 | 208 | |
| A 537M | 1 | $t \le 65$ | 345 | 485[a] | 194 | 208 | |
| | | $65 < t \le 100$ | 310 | 450[b] | 180 | 193 | |
| A 537M | 2 | $t \le 65$ | 415 | 550[a] | 220 | 236 | |
| | | $65 < t \le 100$ | 380 | 515[b] | 206 | 221 | |
| A 633M | C, D | $t \le 65$ | 345 | 485[a] | 194 | 208 | |
| | | $65 < t \le 100$ | 315 | 450[b] | 180 | 193 | 09 |
| A 678M | A | | 345 | 485[a] | 194 | 208 | |
| A 678M | B | | 415 | 550[a] | 220 | 236 | |
| A 737M | B | | 345 | 485[a] | 194 | 208 | |
| A 841M | Class 1 | | 345 | 485[a] | 194 | 208 | |
| A 841M | Class 2 | | 415 | 550[a] | 220 | 236 | |
| | | | CSA Specifications | | | | |
| G40.21M | 260W | | 260 | 410 | 164 | 176 | |
| G40.21M | 260 WT | | 260 | 410 | 164 | 176 | |
| G40.21M | 300W | | 300 | 450 | 180 | 193 | 11 |
| G40.21M | 300WT | | 300 | 450 | 180 | 193 | |
| G40.21M | 350W | | 350 | 450 | 180 | 193 | |
| G40.21M | 350WT | $t \le 65$ | 350 | 480[a] | 192 | 206 | |
| | | $65 < t \le 100$ | 320 | 480[a] | 192 | 206 | |
| | | | National Standards | | | | |
| | 235 | | 235 | 365 | 137 | 154 | |
| | 250 | | 250 | 400 | 157 | 171 | |
| | 275 | | 275 | 430 | 167 | 184 | |
| | | | ISO Specifications | | | | |
| ISO 630 | E 355C, D | $t \le 16$ | 275 | 410 | 164 | 176 | |
| | | $16 < t \le 40$ | 265 | 410 | 164 | 176 | |
| | E 355, D | $t \le 16$ | 355 | 490[a] | 196 | 210 | |
| | | $16 < t \le 40$ | 345 | 490[a] | 196 | 210 | |
| | | $40 < t \le 50$ | 335 | 490[a] | 196 | 210 | |
| | | | EN Specifications | | | | |
| EN 10025 | S 355J0, J2 | $t \le 16$ | 275 | 410 | 164 | 176 | 11 |
| | | $16 < t \le 1^1/_2$ | 265 | 410 | 164 | 176 | |
| | S355J0, J2, K2 | $t \le 16$ | 355 | 470[a] | 188 | 201 | |
| | | $16 < t \le 40$ | 345 | 470[a] | 188 | 201 | |
| | | $40 < t \le 50$ | 335 | 470[a] | 188 | 201 | |

- [a]By agreement between the Purchaser and the Manufacturer, the tensile strength of ASTM A 537M, Class 2, A 678M, Grade B, and A 841M, Class 2 materials may be increased to 585 MPa minimum and 690 MPa maximum. The tensile strength of the other listed materials may be increased to 515 MPa minimum and 620 MPa maximum. When this is done, the allowable stresses shall be determined as stated in 5.6.2.1 and 5.6.2.2.
- [b]By agreement between the Purchaser and the Manufacturer, the tensile strength of ASTM A 537M, Class 2 materials may be increased to 550 MPa minimum and 690 MPa maximum. The tensile strength of the other listed materials may be increased to 485 MPa minimum and 620 MPa maximum. When this is done, the allowable stresses shall be determined as stated in 5.6.2.1 and 5.6.2.2.

## Table 5-2b— (USC) Permissible Plate Materials and Allowable Stresses

| | Plate Specification | Grade | Nominal Plate Thickness $t$ in. | Minimum Yield Strength psi | Minimum Tensile Strength psi | Product Design Stress $S_d$ psi | Hydrostatic Test Stress $S_t$ psi |
|---|---|---|---|---|---|---|---|
| | **ASTM Specifications** | | | | | | |
| | A 283 | C | | 30,000 | 55,000 | 20,000 | 22,500 |
| | A 285 | C | | 30,000 | 55,000 | 20,000 | 22,500 |
| 11 | A 131 | A, B | | 34,000 | 58,000 | 22,700 | 24,900 |
| | A 36 | — | | 36,000 | 58,000 | 23,200 | 24,900 |
| | A 131 | EH 36 | | 51,000 | 71,000[a] | 28,400 | 30,400 |
| | A 573 | 58 | | 32,000 | 58,000 | 21,300 | 24,000 |
| | A 573 | 65 | | 35,000 | 65,000 | 23,300 | 26,300 |
| | A 573 | 70 | | 42,000 | 70,000[a] | 28,000 | 30,000 |
| | A 516 | 55 | | 30,000 | 55,000 | 20,000 | 22,500 |
| | A 516 | 60 | | 32,000 | 60,000 | 21,300 | 24,000 |
| | A 516 | 65 | | 35,000 | 65,000 | 23,300 | 26,300 |
| | A 516 | 70 | | 38,000 | 70,000 | 25,300 | 28,500 |
| | A 662 | B | | 40,000 | 65,000 | 26,000 | 27,900 |
| | A 662 | C | | 43,000 | 70,000[a] | 28,000 | 30,000 |
| | A 537 | 1 | $t \leq 2\frac{1}{2}$ | 50,000 | 70,000[a] | 28,000 | 30,000 |
| | | | $2\frac{1}{2} < t \leq 4$ | 45,000 | 65,000[b] | 26,000 | 27,900 |
| | A 537 | 2 | $t \leq 2\frac{1}{2}$ | 60,000 | 80,000[a] | 32,000 | 34,300 |
| | | | $2\frac{1}{2} < t \leq 4$ | 55,000 | 75,000[b] | 30,000 | 32,100 |
| | A 633 | C, D | $t \leq 2\frac{1}{2}$ | 50,000 | 70,000[a] | 28,000 | 30,000 |
| | | | $2\frac{1}{2} < t \leq 4$ | 46.000 | 65,000[b] | 26,000 | 27,900 |
| 09 | A 678 | A | | 50,000 | 70,000[a] | 28,000 | 30,000 |
| | A 678 | B | | 60,000 | 80,000[a] | 32,000 | 34,300 |
| | A 737 | B | | 50,000 | 70,000[a] | 28,000 | 30,000 |
| | A 841 | Class 1 | | 50,000 | 70,000[a] | 28,000 | 30,000 |
| | A 841 | Class 2 | | 60,000 | 80,000[a] | 32,000 | 34,300 |
| | **CSA Specifications** | | | | | | |
| | G40.21 | 38W | | 38,000 | 60,000 | 24,000 | 25,700 |
| | G40.21 | 38WT | | 38,000 | 60,000 | 24,000 | 25,700 |
| | G40.21 | 44W | | 44,000 | 65,000 | 26,000 | 27,900 |
| | G40.21 | 44WT | | 44,000 | 65,000 | 26,000 | 27,900 |
| | G40.21 | 50W | | 50,000 | 65,000 | 26,000 | 27,900 |
| | G40.21 | 50WT | $t \leq 2\frac{1}{2}$ | 50,000 | 70,000[a] | 28,000 | 30,000 |
| | | | $2\frac{1}{2} < t \leq 4$ | 46,000 | 70,000[a] | 28,000 | 30,000 |
| | **National Standards** | | | | | | |
| | | 235 | | 34,000 | 52,600 | 20,000 | 22,500 |
| | | 250 | | 36,000 | 58,300 | 22,700 | 25,000 |
| | | 275 | | 40,000 | 62,600 | 24,000 | 26,800 |
| | **ISO Specifications** | | | | | | |
| | ISO 630 | E 355C, D | $t \leq \frac{5}{8}$ | 39,900 | 59,500 | 23,800 | 25,500 |
| | | | $\frac{5}{8} < t \leq 1\frac{1}{2}$ | 38,400 | 59,500 | 23,800 | 25,500 |
| | | E 355C, D | $t \leq \frac{5}{8}$ | 51,500 | 71,000[a] | 28,400 | 30,400 |
| | | | $\frac{5}{8} < t \leq 1\frac{1}{2}$ | 50,000 | 71,000[a] | 28,400 | 30,400 |
| 11 | | | $1\frac{1}{2} < t \leq 2$ | 48,600 | 71,000[a] | 28,400 | 30,400 |
| | **EN Specifications** | | | | | | |
| | EN 10025 | S 355J0, J2 | $t \leq \frac{5}{8}$ | 39,900 | 59,500 | 23,800 | 25,500 |
| | | | $\frac{5}{8} < t \leq 1\frac{1}{2}$ | 38,400 | 59,500 | 23,800 | 25,500 |
| | | S355J0, J2, K2 | $t \leq \frac{5}{8}$ | 51,500 | 68,100[a] | 27,200 | 29,200 |
| | | | $\frac{5}{8} < t \leq 1\frac{1}{2}$ | 50,000 | 68,100[a] | 27,200 | 29,200 |
| | | | $1\frac{1}{2} < t \leq 2$ | 48,600 | 68,100[a] | 27,200 | 29,200 |

• [a]By agreement between the Purchaser and the Manufacturer, the tensile strength of ASTM A 537M, Class 2, A 678M, Grade B, and A 841M, Class 2 materials may be increased to 85,000 psi minimum and 100,000 psi maximum. The tensile strength of the other listed materials may be increased to 75,000 psi minimum and 90,000 psi maximum. When this is done, the allowable stresses shall be determined as stated in 5.6.2.1 and 5.6.2.2.

• [b]By agreement between the Purchaser and the Manufacturer, the tensile strength of ASTM A 537M, Class 2 materials may be increased to 80,000 psi minimum and 100,000 psi maximum. The tensile strength of the other listed materials may be increased to 70,000 psi minimum and 90,000 psi maximum. When this is done, the allowable stresses shall be determined as stated in 5.6.2.1 and 5.6.2.2.

### 5.6.3 Calculation of Thickness by the 1-Foot Method

**5.6.3.1** The 1-foot method calculates the thicknesses required at design points 0.3 m (1 ft) above the bottom of each shell course. Appendix A permits only this design method. This method shall not be used for tanks larger than 61 m (200 ft) in diameter. 08

● **5.6.3.2** The required minimum thickness of shell plates shall be the greater of the values computed by the following formulas:

In SI units:

$$t_d = \frac{4.9D(H-0.3)G}{S_d} + CA$$

$$t_t = \frac{4.9D(H-0.3)}{S_t}$$

where

$t_d$ = design shell thickness, in mm,

$t_t$ = hydrostatic test shell thickness, in mm,

$D$ = nominal tank diameter, in m (see 5.6.1.1, Note 1),

● $H$ = design liquid level, in m,

= height from the bottom of the course under consideration to the top of the shell including the top angle, if any; to the bottom of any overflow that limits the tank filling height; or to any other level specified by the Purchaser, restricted by an internal floating roof, or controlled to allow for seismic wave action,

● $G$ = design specific gravity of the liquid to be stored, as specified by the Purchaser,

● $CA$ = corrosion allowance, in mm, as specified by the Purchaser (see 5.3.2),

$S_d$ = allowable stress for the design condition, in MPa (see 5.6.2.1),

$S_t$ = allowable stress for the hydrostatic test condition, in MPa (see 5.6.2.2).

In US Customary units:

$$t_d = \frac{2.6D(H-1)G}{S_d} + CA$$

$$t_t = \frac{2.6D(H-1)}{S_t}$$

where

$t_d$ = design shell thickness (in.),

$t_t$ = hydrostatic test shell thickness (in.),

$D$ = nominal tank diameter, in ft (see 5.6.1.1, Note 1),

● $H$ = design liquid level, (ft),

= height from the bottom of the course under consideration to the top of the shell including the top angle, if any; to the bottom of any overflow that limits the tank filling height; or to any other level specified by the Purchaser, restricted by an internal floating roof, or controlled to allow for seismic wave action,

● $G$ = design specific gravity of the liquid to be stored, as specified by the Purchaser,

● $CA$ = corrosion allowance, (in.), as specified by the Purchaser (see 5.3.2),

$S_d$ = allowable stress for the design condition, (lbf/in.$^2$) (see 5.6.2.1),

$S_t$ = allowable stress for the hydrostatic test condition, (lbf/in.$^2$) (see 5.6.2.2).

### 5.6.4 Calculation of Thickness by the Variable-Design-Point Method

Note: This procedure normally provides a reduction in shell-course thicknesses and total material weight, but 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."[18]

● **5.6.4.1** Design by the variable-design-point method gives shell thicknesses at design points that result in the calculated stresses being relatively close to the actual circumferential shell stresses. This method may only be used when the Purchaser has not specified that the 1-foot method be used and when the following is true:

In SI units:

$$\frac{L}{H} \leq \frac{1000}{6}$$

where

$L$ = $(500\,Dt)^{0.5}$, in mm,

$D$ = tank diameter, in m,

11 $t$ = bottom-course corroded shell thickness, in mm,

$H$ = maximum design liquid level (see 5.6.3.2), in m.

In US Customary units:

$$\frac{L}{H} \leq 2$$

where

$L$ = $(6\,Dt)^{0.5}$, (in.),

$D$ = tank diameter, (ft),

11 $t$ = bottom-course corroded shell thickness, (in.),

$H$ = maximum design liquid level (see 5.6.3.2), (ft).

**5.6.4.2** The minimum plate thicknesses for both the design condition and the hydrostatic test condition shall be determined as out-
11 lined. Complete, independent calculations shall be made for all of the courses for the design condition and for the hydrostatic test
condition. The required shell thickness for each course shall be the greater of the design shell thickness plus any corrosion allowance
07 or the hydrostatic test shell thickness, but the total shell thickness shall not be less than the shell thickness required by 5.6.1.1, 5.6.1.3,
and 5.6.1.4. When a greater thickness is used for a shell course, the greater thickness may be used for subsequent calculations of the
thicknesses of the shell courses above the course that has the greater thickness, provided the greater thickness is shown as the
required design thickness on the Manufacturer's drawing (see W.3).

**5.6.4.3** To calculate the bottom-course thicknesses, preliminary values $t_{pd}$ and $t_{pt}$ for the design and hydrostatic test conditions shall first be calculated from the formulas in 5.6.3.2.

**5.6.4.4** The bottom-course thicknesses $t_{1d}$ and $t_{1t}$ for the design and hydrostatic test conditions shall be calculated using the following formulas:

In SI units:

$$t_{1d} = \left(1.06 - \frac{0.0696D}{H}\sqrt{\frac{HG}{S_d}}\right)\left(\frac{4.9HDG}{S_d}\right) + CA$$

[18]L.P. Zick and R.V. McGrath, "Design of Large Diameter Cylindrical Shells," *Proceedings*—Division of Refining, American Petroleum Institute, New York, 1968, Volume 48, pp. 1114 – 1140.

In US Customary units:

$$t_{1d} = \left(1.06 - \frac{0.463D}{H}\sqrt{\frac{HG}{S_d}}\right)\left(\frac{2.6HDG}{S_d}\right) + CA$$

Note: For the design condition, $t_{1d}$ need not be greater than $t_{pd}$.

In SI units:

$$t_{1t} = \left(1.06 - \frac{0.0696D}{H}\sqrt{\frac{H}{S_t}}\right)\left(\frac{4.9HD}{S_t}\right)$$

In US Customary units:

$$t_{1t} = \left(1.06 - \frac{0.463D}{H}\sqrt{\frac{H}{S_t}}\right)\left(\frac{2.6HD}{S_t}\right)$$

Note: For the hydrostatic test condition, $t_{1t}$ need not be greater than $t_{pt}$.

**5.6.4.5** To calculate the second-course thicknesses for both the design condition and the hydrostatic test condition, the value of the following ratio shall be calculated for the bottom course:

$$\frac{h_1}{(rt_1)^{0.5}}$$

where

$h_1$ = height of the bottom shell course, in mm (in.),

$r$ = nominal tank radius, in mm (in.),

$t_1$ = calculated corroded thickness of the bottom shell course, in mm (in.), used to calculate $t_2$ (design). The calculated hydrostatic thickness of the bottom shell course shall be used to calculate $t_2$ (hydrostatic test). 11

If the value of the ratio is less than or equal to 1.375:

$$t_2 = t_1$$

If the value of the ratio is greater than or equal to 2.625:

$$t_2 = t_{2a}$$

If the value of the ratio is greater than 1.375 but less than 2.625,:

$$t_2 = t_{2a} + (t_1 - t_{2a})\left[2.1 - \frac{h_1}{1.25(rt_1)^{0.5}}\right]$$

where

$t_2$ = minimum design thickness of the second shell course, in mm (in.),

$t_{2a}$ = corroded thickness of the second shell course, in mm (in.), as calculated for an upper shell course as described in 5.6.4.6 to 5.6.4.8. In calculating second shell course thickness ($t_2$) for design case and hydrostatic test case, applicable values of $t_{2a}$ and $t_1$shall be used. 11

The preceding formula for $t_2$ is based on the same allowable stress being used for the design of the bottom and second courses. For tanks where the value of the ratio is greater than or equal to 2.625, the allowable stress for the second course may be lower than the allowable stress for the bottom course when the methods described in 5.6.4.6 through 5.6.4.8 are used.

**5.6.4.6** To calculate the upper-course thicknesses for both the design condition and the hydrostatic test condition, a preliminary
11 value $t_u$ for the upper-course corroded thickness shall be calculated using the formulas in 5.6.3.2, and then the distance $x$ of the variable design point from the bottom of the course shall be calculated using the lowest value obtained from the following:

In SI units:

$$x_1 = 0.61\,(rt_u)^{0.5} + 320\,CH$$

$$x_2 = 1000\,CH$$

$$x_3 = 1.22\,(rt_u)^{0.5}$$

where

11 $t_u$ = corroded thickness of the upper course at the girth joint, in mm,

$C$ = $[K^{0.5}\,(K-1)]/(1+K^{1.5})$,

$K$ = $t_L / t_u$,

11 $t_L$ = corroded thickness of the lower course at the girth joint, in mm,

• $H$ = design liquid level (see 5.6.3.2), in m.

In US Customary units:

$$x_1 = 0.61\,(rt_u)^{0.5} + 3.84\,CH$$

$$x_2 = 12\,CH$$

$$x_3 = 1.22\,(rt_u)^{0.5}$$

where

11 $t_u$ = corroded thickness of the upper course at the girth joint, (in.),

$C$ = $[K^{0.5}\,(K-1)]/(1+K^{1.5})$,

$K$ = $t_L / t_u$,

11 $t_L$ = corroded thickness of the lower course at the girth joint, (in.),

• $H$ = design liquid level (see 5.6.3.2), (ft).

**5.6.4.7** The minimum thickness $t_x$ for the upper shell courses shall be calculated for both the design condition ($t_{dx}$) and the hydrostatic test condition ($t_{tx}$) using the minimum value of $x$ obtained from 5.6.4.6:

In SI units:

$$t_{dx} = \frac{4.9D\left(H - \frac{x}{1000}\right)G}{S_d} + CA$$

$$t_{tx} = \frac{4.9D\left(H - \frac{x}{1000}\right)}{S_t}$$

In US Customary units:

$$t_{dx} = \frac{2.6D\left(H - \frac{x}{12}\right)G}{S_d} + CA$$

$$t_{tx} = \frac{2.6D\left(H - \frac{x}{12}\right)}{S_t}$$

**5.6.4.8** The steps described in 5.6.4.6 and 5.6.4.7 shall be repeated using the calculated value of $t_x$ as $t_u$ until there is little difference between the calculated values of $t_x$ in succession (repeating the steps twice is normally sufficient). Repeating the steps provides a more exact location of the design point for the course under consideration and, consequently, a more accurate shell thickness.

**5.6.4.9** There are two examples provided in Appendix K. Example #1 are step-by-step calculations illustrating an application of the variable-design-point method to a tank with a diameter of 85 m (280 ft) and a height of 19.2 m (64 ft) to determine shell-plate thicknesses for the first three courses for the hydrostatic test condition only. Example #2 demonstrates the variable-design-point design method in US Customary units for a tank with a diameter of 280 ft and a height of 40 ft with varying corrosion allowances and varying materials for both the design and hydrostatic test conditions. 11

### 5.6.5 Calculation of Thickness by Elastic Analysis

For tanks where *L/H* is greater than 1000/6 (2 in US Customary units), the selection of shell thicknesses shall be based on an elastic analysis that shows the calculated circumferential shell stresses to be below the allowable stresses given in Tables 5-2a and 5-2b. The boundary conditions for the analysis shall assume a fully plastic moment caused by yielding of the plate beneath the shell and zero radial growth. 08

## 5.7 SHELL OPENINGS

### 5.7.1 General

**5.7.1.1** The following requirements for shell openings are intended to restrict the use of appurtenances to those providing for attachment to the shell by welding. See Figure 5-6.

**5.7.1.2** The shell opening designs described in this Standard are required, except for alternative designs allowed in 5.7.1.8. 07

**5.7.1.3** Flush-type cleanout fittings and flush-type shell connections shall conform to the designs specified in 5.7.7 and 5.7.8.

• **5.7.1.4** When a size intermediate to the sizes listed in Tables 5-3a through 5-12b is specified by the Purchaser, the construction details and reinforcements shall conform to the next larger 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. 08

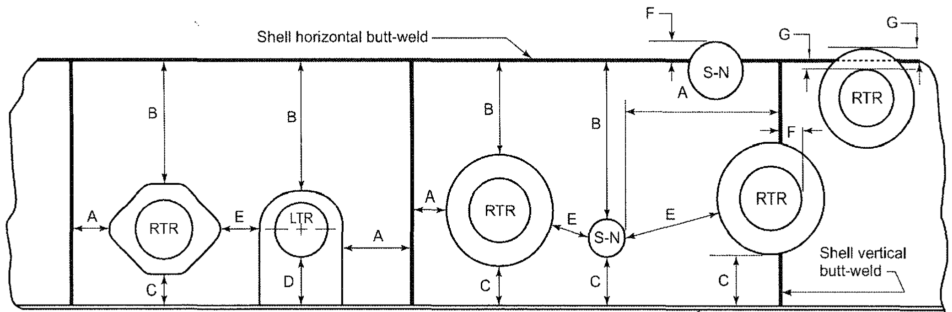
**5.7.1.5** Openings near the bottom of a tank shell will tend to rotate with vertical bending of the shell under hydrostatic loading. Shell openings in this area that have attached piping or other external loads shall be reinforced not only for the static condition but also for any loads imposed on the shell connections by the restraint of the attached piping to the shell rotation. The external loads shall be minimized, or the shell connections shall be relocated outside the rotation area. Appendix P provides a method for evaluating openings that conform to Tables 5-6a and 5-6b. 08

**5.7.1.6** Sheared or oxygen-cut surfaces on manhole necks, nozzle necks, reinforcing plates, and shell-plate openings shall be made uniform and smooth, with the corners rounded except where the surfaces are fully covered by attachment welds.

**5.7.1.7** Shell openings may be reinforced by the use of an insert plate per Figure 5-7B. The insert plate may have the same thickness as an adjacent shell plate or may be thicker to provide reinforcing. A rectangular insert plate shall have rounded corners (except for edges terminating at the tank bottom or at joints between shell courses) with a radius which is greater than or equal to the larger of 150 mm (6 in.) or 6t where t is the thickness of the shell course containing the insert plate. The insert plate may contain multiple shell openings. The thickness and dimensions of insert plate shall provide the reinforcing required per 5.7.2. The weld spacing shall meet requirements of 5.7.3. The periphery of insert plates shall have a 1:4 tapered transition to the thickness of the adjacent shell plates when the insert plate thickness exceeds the adjacent shell thickness by more than 3 mm (1/8 in.). 08

• **5.7.1.8** The shape and dimensions of the shell opening reinforcement, illustrated in Figures 5-7A, 5-7B,and 5-8 and dimensioned in the related tables may be altered as long as the reinforcement meets the area, welding, and weld spacing requirements outlined in 5.7.2 and 5.7.3. For reinforcing plates greater than 1/2 in. thick, with approval of the Purchaser, reinforcement and welding (excluding weld spacing) of shell openings that comply with API Std 620 Section 5 are acceptable. These statements of permissible alternatives of shell opening reinforcement and welding do not apply to flush-type cleanout fittings, flush-type shell connections or similar configurations. 11

**5.7.1.9** The flange facing shall be suitable for the gasket and bolting employed. Gaskets shall be selected to meet the service environment so that the required seating load is compatible with the flange rating and facing, the strength of the flange, and its bolting (see 4.9). 07




08 Note:

RTR = Regular-Type Reinforced Opening (nozzle or manhole) with diamond or circular shape reinforcing plate or insert plate that does not extend to the bottom (see Figure 5-7A and Figure 5-8).

LTR = Low-Type Reinforced Opening (nozzle or manhole) using tombstone type reinforcing plate or insert plate that extends to the bottom [see Figure 5-8, Detail (a) and Detail (b)].

S-N = Shell openings with neither a reinforcing plate nor with a thickened insert plate (i.e., integrally reinforced shell openings; or openings not requiring reinforcing).

| Variables | | Reference | Minimum Dimension Between Weld Toes or Weld Centerline (1)(3) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Shell $t$ | Condition | Paragraph Number | A (2) | B (2) | C (2) | D (3) | E (2) | F (4) | G (4) |
| $t \le 12.5$ mm ($t \le 1/2$ in.) | As welded or PWHT | 5.7.3.2 | 150 mm (6 in.) | 75 mm (3 in.) or $2^1/_2t$ | | | 75 mm (3 in.) or $2^1/_2t$ | | |
| | | 5.7.3.3 | | | 75 mm (3 in.) or $2^1/_2t$ | | | | |
| | | 5.7.3.3 | | | 75 mm (3 in.) for S-N | | | | |
| | | 5.7.3.3 | | | | Table 5-6a and Table 5-6b | | | |
| | | • 5.7.3.4 | | | | | | $8t$ or $1/2\ r$ | |
| | | • 5.7.3.4 | | | | | | | $8t$ |
| $t > 12.5$ mm ($t > 1/2$ in.) | As Welded | 5.7.3.1.a | $8W$ or 250 mm (10 in.) | $8W$ or 250 mm (10 in.) | | | | | |
| | | 5.7.3.1.b | | | | | $8W$ or 150 mm (6 in.) | | |
| | | 5.7.3.3 | | | $8W$ or 250 mm (10 in.) | | | | |
| | | 5.7.3.3 | | | 75 mm (3 in.) for S-N | | | | |
| | | 5.7.3.3 | | | | Table 5-6a and Table 5-6b | | $8t$ or $1/2\ r$ | |
| | | • 5.7.3.4 | | | | | | | $8t$ |
| | | • 5.7.3.4 | | | | | | | |
| $t > 12.5$ mm ($t > 1/2$ in.) | PWHT | 5.7.3.2 | 150 mm (6 in.) | 75 mm (3 in.) or $2^1/_2t$ | | | 75 mm (3 in.) or $2^1/_2t$ | | |
| | | 5.7.3.3 | | | 75 mm (3 in.) or $2^1/_2t$ | | | | |
| | | 5.7.3.3 | | | 75 mm (3 in.) for S-N | | | | |
| | | 5.7.3.3 | | | | Table 5-6a and Table 5-6b | | | |
| | | • 5.7.3.4 | | | | | | $8t$ or $1/2\ r$ | |
| | | • 5.7.3.4 | | | | | | | $8t$ |

08 Notes:

1. If two requirements are given, the minimum spacing is the greater value, except for dimension "F." See Note 4.
2. $t$ = shell nominal thickness. $8W$ = 8 times the largest weld size for reinforcing plate or insert plate periphery weld (fillet or butt-weld) from the toe of the periphery weld to the centerline of the shell butt-weld.
3. $D$ = spacing distance established by minimum elevation for low-type reinforced openings from Tables 5-6a and 5-6b, column 9.
4. Purchaser option to allow shell openings to be located in horizontal or vertical shell butt-welds. See Figure 5-9. $t$ = shell nominal thickness, $r$ = radius of opening. Minimum spacing for dimension $F$ is the lesser of $8t$ or $1/2\ r$.

Figure 5-6—Minimum Weld Requirements for Openings in Shells According to 5.7.3

## Table 5-3a—(SI) Thickness of Shell Manhole Cover Plate and Bolting Flange

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 |
|---|---|---|---|---|---|---|---|---|---|
| Max. Design Liquid Level | Equivalent | Minimum Thickness of Cover Plate[b] ($t_c$) | | | | Minimum Thickness of Bolting Flange After Finishing[b] ($t_f$) | | | |
| m<br>H | Pressure[a]<br>kPa | 500 mm Manhole | 600 mm Manhole | 750 mm Manhole | 900 mm Manhole | 500 mm Manhole | 600 mm Manhole | 750 mm Manhole | 900 mm Manhole |
| 5.2 | 51 | 8 | 10 | 11 | 13 | 6 | 6 | 8 | 10 |
| 6.7 | 66 | 10 | 11 | 13 | 14 | 6 | 8 | 10 | 11 |
| 8.0 | 78 | 10 | 11 | 14 | 16 | 6 | 8 | 11 | 13 |
| 9.9 | 97 | 11 | 13 | 16 | 18 | 8 | 10 | 13 | 14 |
| 11.1 | 109 | 13 | 14 | 16 | 19 | 10 | 11 | 13 | 16 |
| 13.4 | 131 | 13 | 14 | 18 | 21 | 10 | 11 | 14 | 18 |
| 16.1 | 158 | 14 | 16 | 19 | 22 | 11 | 13 | 16 | 19 |
| 18.6 | 182 | 16 | 18 | 21 | 24 | 13 | 14 | 18 | 21 |
| 22.9 | 224 | 18 | 19 | 24 | 25 | 13 | 14 | 18 | 24 |

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[a]Equivalent pressure is based on water loading.
[b]For addition of corrosion allowance, see 5.7.5.2.
[c]Cover Plate and Flange thickness given can be used on Manholes dimensioned to ID or OD.
Note: See Figure 5-7A.

## Table 5-3b—(USC) Thickness of Shell Manhole Cover Plate and Bolting Flange

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 |
|---|---|---|---|---|---|---|---|---|---|
| Max. Design Liquid Level | Equivalent | Minimum Thickness of Cover Plate[b] ($t_c$) | | | | Minimum Thickness of Bolting Flange After Finishing[b] ($t_f$) | | | |
| ft<br>H | Pressure[a]<br>lbf/in.$^2$ | 20 in. Manhole | 24 in. Manhole | 30 in. Manhole | 36 in. Manhole | 20 in. Manhole | 24 in. Manhole | 30 in. Manhole | 36 in. Manhole |
| 17.1 | 7.4 | 5/16 | 3/8 | 7/16 | 1/2 | 1/4 | 1/4 | 5/16 | 3/8 |
| 21.9 | 9.5 | 3/8 | 7/16 | 1/2 | 9/16 | 1/4 | 5/16 | 3/8 | 7/16 |
| 26.1 | 11.3 | 3/8 | 7/16 | 9/16 | 5/8 | 1/4 | 5/16 | 7/16 | 1/2 |
| 32.6 | 14.1 | 7/16 | 1/2 | 5/8 | 11/16 | 5/16 | 3/8 | 1/2 | 9/16 |
| 36.5 | 15.8 | 1/2 | 9/16 | 5/8 | 3/4 | 3/8 | 7/16 | 1/2 | 5/8 |
| 43.9 | 19 | 1/2 | 9/16 | 11/16 | 13/16 | 3/8 | 7/16 | 9/16 | 11/16 |
| 52.9 | 22.9 | 9/16 | 5/8 | 3/4 | 7/8 | 7/16 | 1/2 | 5/8 | 3/4 |
| 61.0 | 26.4 | 5/8 | 11/16 | 13/16 | 15/16 | 1/2 | 9/16 | 11/16 | 13/16 |
| 75.1 | 32.5 | 11/16 | 3/4 | 15/16 | 1 | 1/2 | 9/16 | 11/16 | 15/16 |

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[a]Equivalent pressure is based on water loading.
[b]For addition of corrosion allowance, see 5.7.5.2.
[c]Cover Plate and Flange thickness given can be used on Manholes dimensioned to ID or OD.
Note: See Figure 5-7A.

## Table 5-4a (SI)—Dimensions for Shell Manhole Neck Thickness

| Thickness of Shell and Manhole Reinforcing Plate[a] $t$ and $T$ | Minimum Neck Thickness[b,c] $t_n$ mm | | | |
|---|---|---|---|---|
| | For Manhole Diameter 500 mm | For Manhole Diameter 600 mm | For Manhole Diameter 750 mm | For Manhole Diameter 900 mm |
| 5 | 5 | 5 | 5 | 5 |
| 6 | 6 | 6 | 6 | 6 |
| 8 | 6 | 6 | 8 | 8 |
| 10 | 6 | 6 | 8 | 10 |
| 11 | 6 | 6 | 8 | 10 |
| 12.5 | 6 | 6 | 8 | 10 |
| 14 | 6 | 6 | 8 | 10 |
| 16 | 6 | 6 | 8 | 10 |
| 18 | 6 | 6 | 8 | 10 |
| 19 | 6 | 6 | 8 | 10 |
| 21 | 8 | 6 | 8 | 10 |
| 22 | 10 | 8 | 8 | 10 |
| 24 | 11 | 11 | 11 | 11 |
| 25 | 11 | 11 | 11 | 11 |
| 27 | 11 | 11 | 11 | 11 |
| 28 | 13 | 13 | 13 | 13 |
| 30 | 14 | 14 | 14 | 14 |
| 32 | 16 | 14 | 14 | 14 |
| 33 | 16 | 16 | 16 | 16 |
| 35 | 17 | 16 | 16 | 16 |
| 36 | 17 | 17 | 17 | 17 |
| 38 | 20 | 20 | 20 | 20 |
| 40 | 21 | 21 | 21 | 21 |
| 41 | 21 | 21 | 21 | 21 |
| 43 | 22 | 22 | 22 | 22 |
| 45 | 22 | 22 | 22 | 22 |

[a]If a shell plate thicker than required is used for the product and hydrostatic loading (see 5.6), 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 reinforcing plate 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 5.7.2.
[b]Reinforcement shall be added if the neck thickness is less than that shown in the column. The minimum neck thickness shall be the thickness of the shell plate or the allowable finished thickness of the bolting flange (see Table 5-3a), whichever is thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given. If the neck thickness on a built-up manhole is greater than the required minimum, the manhole reinforcing plate may be decreased accordingly within the limits specified in 5.7.2.
[c]For addition of corrosion allowance, see 5.7.5.2.

## Table 5-4b—(USC) Dimensions for Shell Manhole Neck Thickness

| Thickness of Shell and Manhole Reinforcing Plate[a] $t$ and $T$ | Minimum Neck Thickness[b,c] $t_n$ in. | | | |
|---|---|---|---|---|
| | For Manhole Diameter 20 in. | For Manhole Diameter 24 in. | For Manhole Diameter 30 in. | For Manhole Diameter 36 in. |
| 3/16 | 3/16 | 3/16 | 3/16 | 3/16 |
| 1/4 | 1/4 | 1/4 | 1/4 | 1/4 |
| 5/16 | 1/4 | 1/4 | 5/16 | 5/16 |
| 3/8 | 1/4 | 1/4 | 5/16 | 3/8 |
| 7/16 | 1/4 | 1/4 | 5/16 | 3/8 |
| 1/2 | 1/4 | 1/4 | 5/16 | 3/8 |
| 9/16 | 1/4 | 1/4 | 5/16 | 3/8 |
| 5/8 | 1/4 | 1/4 | 5/16 | 3/8 |
| 11/16 | 1/4 | 1/4 | 5/16 | 3/8 |
| 3/4 | 1/4 | 1/4 | 5/16 | 3/8 |
| 13/16 | 5/16 | 1/4 | 5/16 | 3/8 |
| 7/8 | 3/8 | 5/16 | 5/16 | 3/8 |

### Table 5-4b—(USC) Dimensions for Shell Manhole Neck Thickness (Continued)

| Thickness of Shell and Manhole Reinforcing Plate[a] $t$ and $T$ | Minimum Neck Thickness[b,c] $t_n$ in. | | | | |
|---|---|---|---|---|---|
| | For Manhole Diameter 20 in. | For Manhole Diameter 24 in. | For Manhole Diameter 30 in. | For Manhole Diameter 36 in. | |
| 15/16 | 7/16 | 7/16 | 7/16 | 7/16 | |
| 1 | 7/16 | 7/16 | 7/16 | 7/16 | |
| 1 1/16 | 7/16 | 7/16 | 7/16 | 7/16 | |
| 1 1/8 | 1/2 | 1/2 | 1/2 | 1/2 | |
| 1 3/16 | 9/16 | 9/16 | 9/16 | 9/16 | |
| 1 5/16 | 5/8 | 9/16 | 9/16 | 9/16 | |
| 1 3/8 | 5/8 | 5/8 | 5/8 | 5/8 | |
| 1 3/8 | 11/16 | 5/8 | 5/8 | 5/8 | |
| 1 7/16 | 11/16 | 11/16 | 11/16 | 11/16 | 08 |
| 1 1/2 | 3/4 | 3/4 | 3/4 | 3/4 | |
| 1 9/16 | 13/16 | 13/16 | 13/16 | 13/16 | |
| 1 5/8 | 13/16 | 13/16 | 13/16 | 13/16 | |
| 1 11/16 | 7/8 | 7/8 | 7/8 | 7/8 | |
| 1 3/4 | 7/8 | 7/8 | 7/8 | 7/8 | |

[a]If a shell plate thicker than required is used for the product and hydrostatic loading (see 5.6), 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 reinforcing plate 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 5.7.2.
[b]Reinforcement shall be added if the neck thickness is less than that shown in the column. The minimum neck thickness shall be the thickness of the shell plate or the allowable finished thickness of the bolting flange (see Table 5-3b), whichever is thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given. If the neck thickness on a built-up manhole is greater than the required minimum, the manhole reinforcing plate may be decreased accordingly within the limits specified in 5.7.2.
[c]For addition of corrosion allowance, see 5.7.5.2.

### 5.7.2 Reinforcement and Welding

**5.7.2.1** Openings in tank shells larger than required to accommodate a NPS 2 flanged or threaded nozzle shall be reinforced. The minimum cross-sectional area of the required reinforcement shall not be less than the product of the vertical diameter of the hole cut in the shell and the nominal plate thickness, but when calculations are made for the maximum required thickness considering all design and hydrostatic test load conditions, the required thickness may be used in lieu of the nominal plate thickness. The cross-sectional area of the reinforcement shall be measured vertically, coincident with the diameter of the opening.

•**5.7.2.2** The only shell openings that may utilize welds having less than full penetration through the shell are those that do not require reinforcement and those that utilize a thickened insert plate as shown in Figures 5-7B and 5-8. However, any openings listed in Table 3 of the Data Sheet that are marked "yes" under "Full Penetration on Openings" shall utilize welds that fully penetrate the shell and the reinforcement, if used.

**5.7.2.3** Except for flush-type openings and connections, all effective reinforcements shall be made within a distance above and below the centerline of the shell opening equal to the vertical dimension of the hole in the tank shell plate. Reinforcement may be 07
provided by any one or any combination of the following:

a. The attachment flange of the fitting.

• b. The reinforcing plate. Reinforcing plates for manholes, nozzles, and other attachments shall be of the same nominal composition (i.e., same ASME P-number and Group Number) as the tank part to which they are attached, unless approved otherwise by • the Purchaser.

c. The portion of the neck of the fitting that may be considered as reinforcement according to 5.7.2.4.

d. Excess shell-plate thickness. Reinforcement may be provided by any shell-plate thickness in excess of the thickness required by the governing load condition within a vertical distance above and below the centerline of the hole in the shell equal to the vertical dimension of the hole in the tank shell plate as long as the extra shell-plate thickness is the actual plate thickness used less the required thickness, calculated at the applicable opening, considering all load conditions and the corrosion allowance.

e. The material in the nozzle neck. The strength of the material in the nozzle neck used for reinforcement should preferably be the same as the strength of the tank shell, but lower strength material is permissible as reinforcement as long as the neck material has minimum specified yield and tensile strengths not less than 70% and 80%, respectively, of the shell-plate minimum specified

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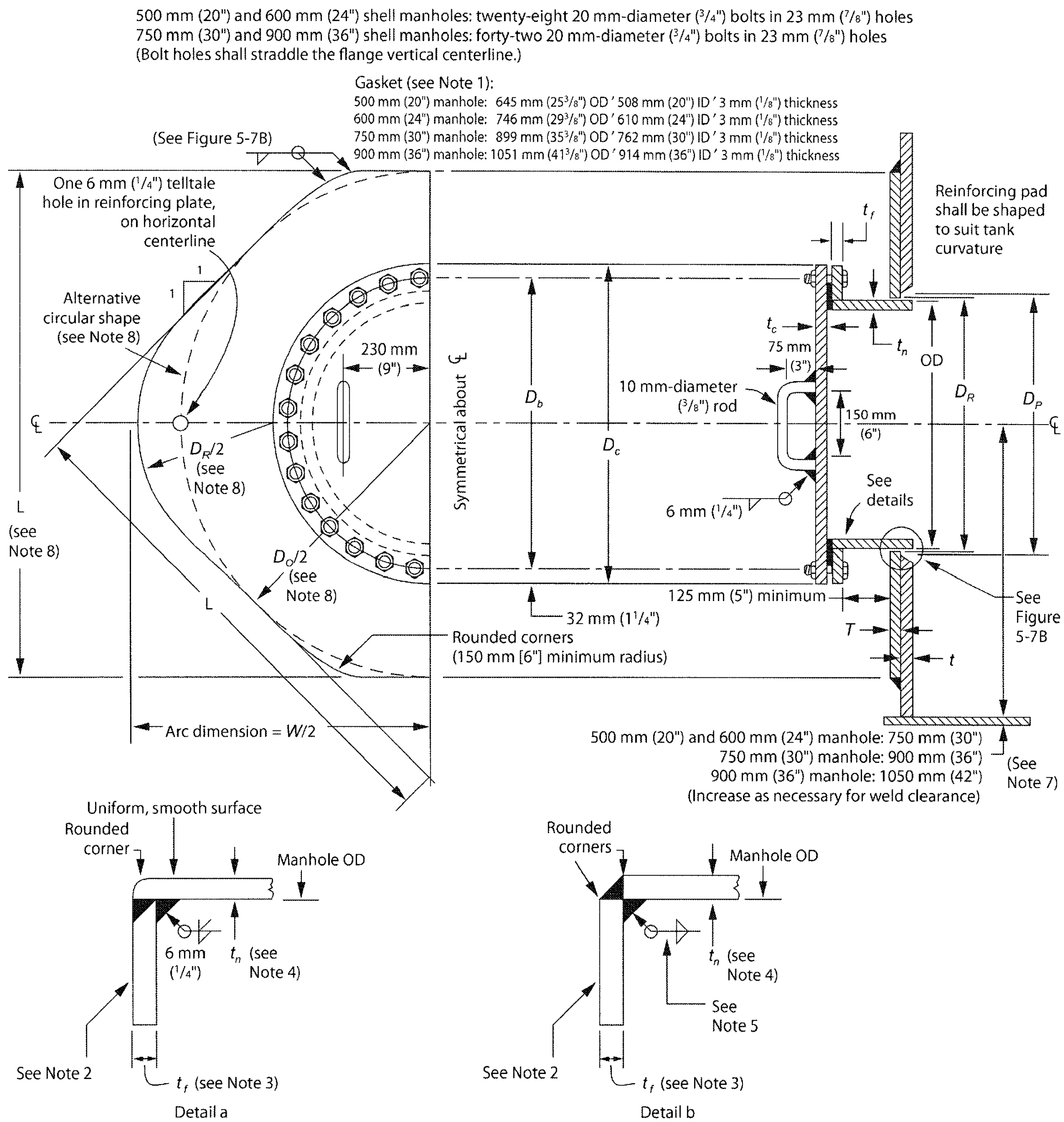
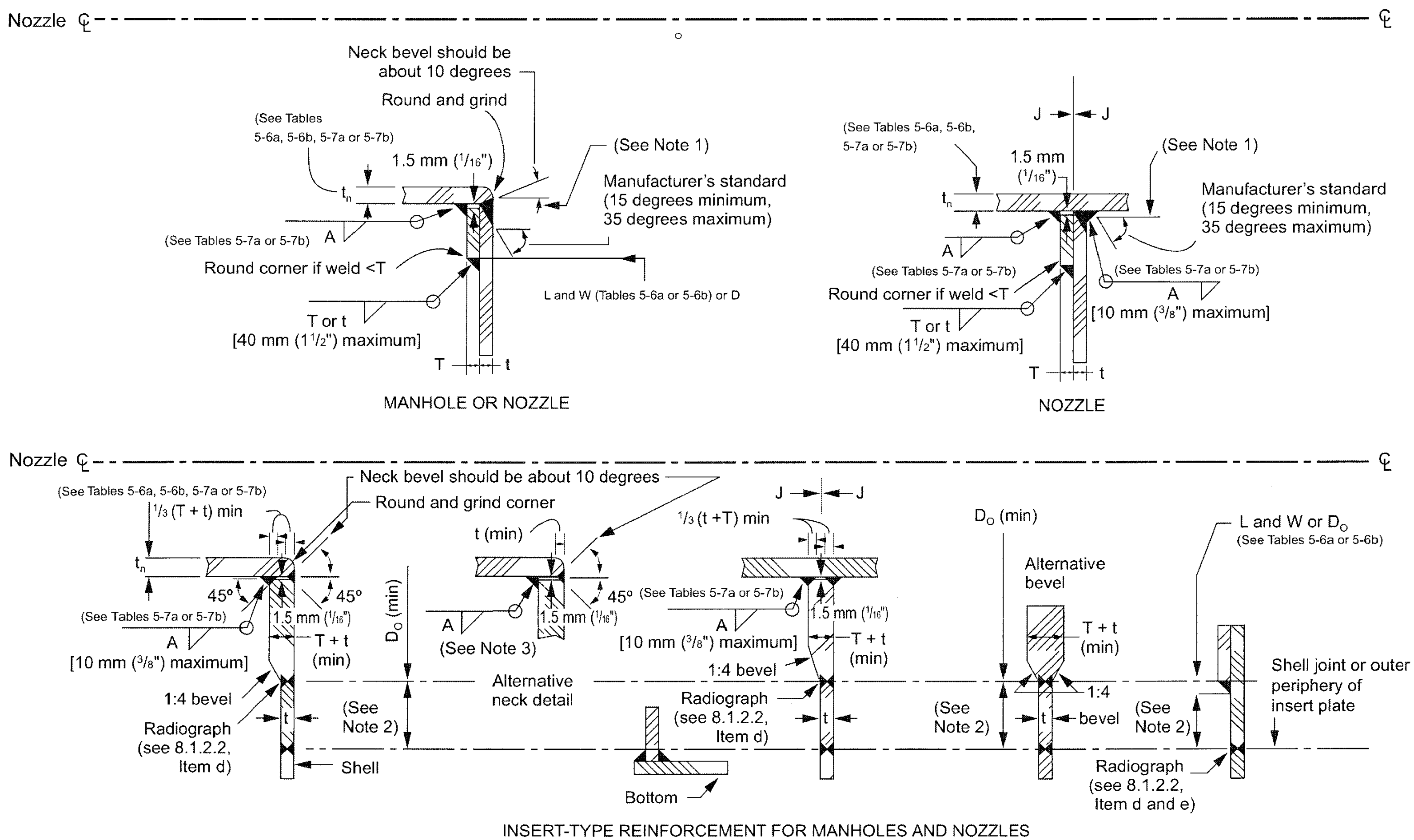



Notes:

1. Gasket material shall be specified by the Purchaser. See 5.7.5.4.
2. The gasketed face shall be machine-finished to provide a minimum gasket-bearing width of 19 mm (3/4 in.).
3. See Tables 5-3a and 5-3b.
4. See Tables 5-4a and 5-4b.
5. The size of the weld shall equal the thickness of the thinner member joined.
6. The shell nozzles shown in Figure 5-8 may be substituted for manholes.
7. ● The minimum centerline elevations allowed by Tables 5-6a and 5-6b and Figure 5-6 may be used when approved by the Purchaser.
8. For dimensions for *OD*, $D_R$, $D_o$, *L*, and *W*, see Tables 5-6a and 5-6b, Columns 2, 4, 5, and 6. For Dimension $D_P$ see Tables 5-7a and 5-7b, Column 3.
9. At the option of the Manufacturer, the manhole ID may be set to the OD dimension listed in Tables 5-6a and 5-6b, Column 2. Reinforcement area and weld spacing must meet 5.7.2 and 5.7.3 requirements respectively.

Figure 5-7A—Shell Manhole




Notes:

1. See Tables 5-7a and 5-7b, Column 3, for the shell cutout, which shall not be less than the outside diameter of the neck plus 13 mm (1/2) in.
2. See 5.7.3 for minimum spacing of welds at opening connections.
3. The weld size shall be either A (from Table 5-7a and 5-7b, based on $t$) or $t_n$ (minimum neck thickness from Tables 5-4a, 5-4b, 5-6a, 5-6b, and 5-7a and 5-7b), whichever is greater.
4. Other permissible insert details are shown in Figure 5-8 of API Std 620. The reinforcement area shall conform to 5.7.2.
5. Dimensions and weld sizes that are not shown are the same as those given in Figure 5-7A and Tables 5-4a – 5-8b.
6. ● Details of welding bevels may vary from those shown if agreed to by the Purchaser.

Figure 5-7B—Details of Shell Manholes and Nozzles

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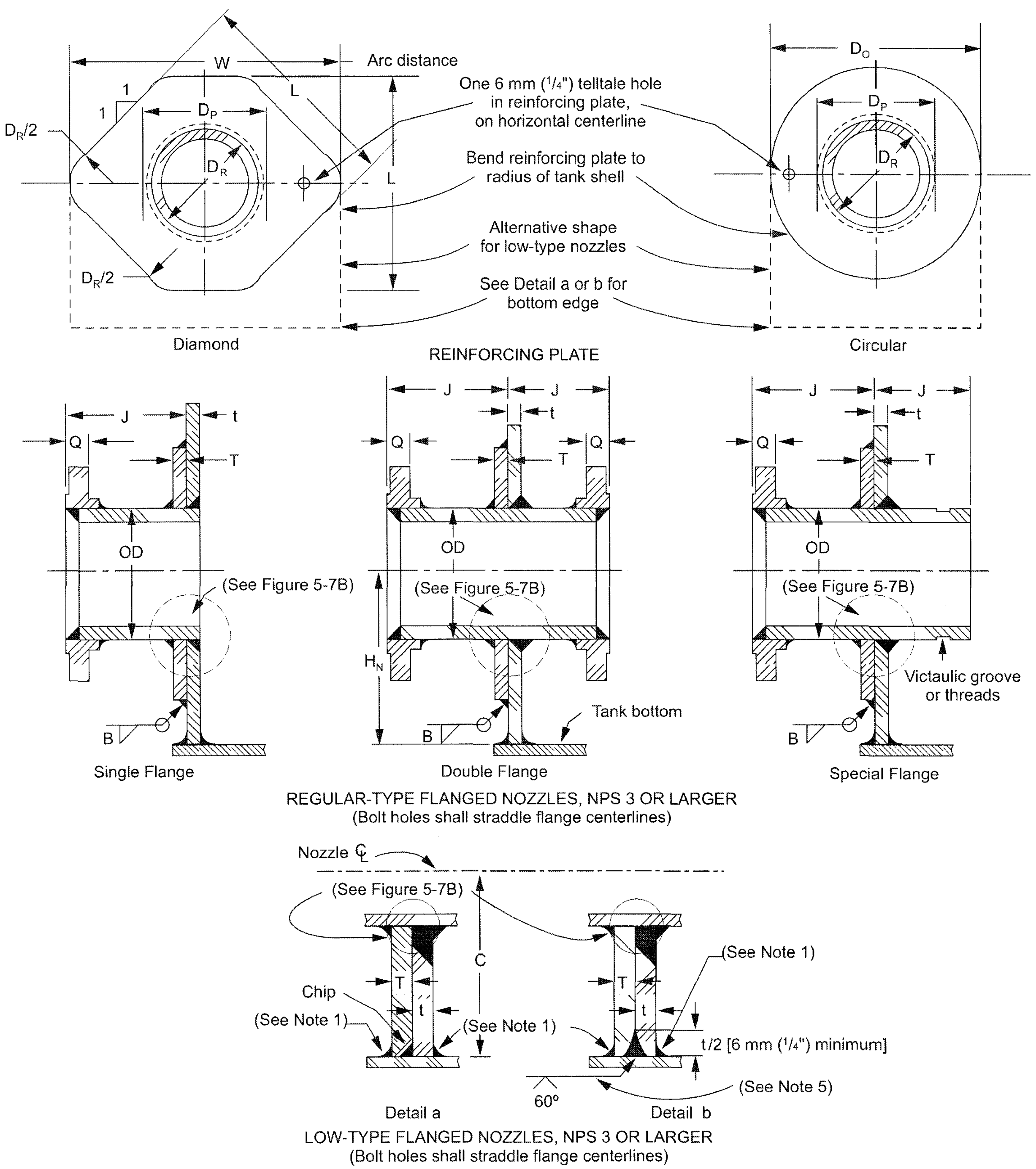
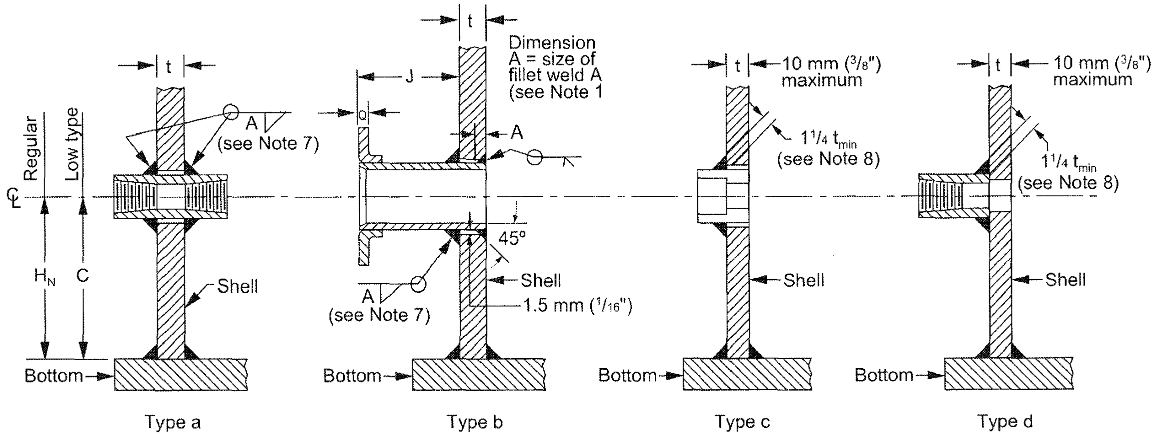



Notes:

1. See 5.1.5.7 for information on the size of welds.
2. See 5.8.9 for information on the couplings used in shell nozzles.
3. Nozzles NPS 3 or larger require reinforcement.
4. Details of welding bevels may vary from those shown if agreed to by the Purchaser.
5. Shop weld not attached to bottom plate.
6. See 5.7.6.2 for information on supplying nozzles flush or with an internal projection.

08 Figure 5-8—Shell Nozzles (See Tables 5-6a, 5-6b, 5-7a, 5-7b, 5-8a and 5-8b)




COUPLINGS AND FLANGED FITTINGS, NPS 3/4 THROUGH NPS 2 (SEE NOTE 9) 09

Notes: (continued)

7. See Tables 5-7a and 5-7b, Column 6. 08
8. $t_{min}$ shall be 19 mm ($^3/_4$ in.) or the thickness of either part joined by the fillet weld, whichever is less.
9. The construction details apply to unreinforced threaded, non-threaded, and flanged nozzles.

Figure 5-8—Shell Nozzles (continued) 08

Table 5-5a—(SI) Dimensions for Bolt Circle Diameter $D_b$ and Cover Plate Diameter $D_c$ for Shell Manholes

| Column 1<br>Manhole Diameter OD<br>mm | Column 2<br>Bolt Circle Diameter $D_b$<br>mm | Column 3<br>Cover Plate Diameter $D_c$<br>mm |
|---|---|---|
| 500 | 667 | 730 |
| 600 | 768 | 832 |
| 750 | 921 | 984 |
| 900 | 1073 | 1137 |

Note: See Figure 5-7A.

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Table 5-5b—(USC) Dimensions for Bolt Circle Diameter $D_b$ and Cover Plate Diameter $D_c$ for Shell Manholes

| Column 1<br>Manhole Diameter OD<br>in. | Column 2<br>Bolt Circle Diameter $D_b$<br>in. | Column 3<br>Cover Plate Diameter $D_c$<br>in. |
|---|---|---|
| 20 | 26$^1/_4$ | 28$^3/_4$ |
| 24 | 30$^1/_4$ | 32$^3/_4$ |
| 30 | 36$^1/_4$ | 38$^3/_4$ |
| 36 | 42$^1/_4$ | 44$^3/_4$ |

Note: See Figure 5-7A.

## Table 5-6a—(SI) Dimensions for Shell Nozzles (mm)

| | Column 1 NPS (Size of Nozzle) | Column 2 Outside Diameter of Pipe OD | Column 3 Nominal Thickness of Flanged Nozzle Pipe Wall[a] $t_n$ | Column 4 Diameter of Hole in Reinforcing Plate $D_R$ | Column 5 Length of Side of Reinforcing Plate[b] or Diameter $L = D_o$ | Column 6 Width of Reinforcing Plate $W$ | Column 7 Minimum Distance from Shell-to-Flange Face $J$ | Column 8 Minimum Distance from Bottom of Tank to Center of Nozzle: Regular Type[d] $H_N$ | Column 9[c] Minimum Distance from Bottom of Tank to Center of Nozzle: Low Type $C$ |
|---|---|---|---|---|---|---|---|---|---|
| 09 | | | | | Flanged Fittings | | | | |
| | 60 | 1524.0 | e | 1528 | 3068 | 3703 | 400 | 1641 | 1534 |
| 11 | 54 | 1371.6 | e | 1375 | 2763 | 3341 | 400 | 1488 | 1382 |
| | 52 | 1320.8 | e | 1324 | 2661 | 3214 | 400 | 1437 | 1331 |
| | 50 | 1270.0 | e | 1274 | 2560 | 3093 | 400 | 1387 | 1280 |
| | 48 | 1219.2 | e | 1222 | 2455 | 2970 | 400 | 1334 | 1230 |
| | 46 | 1168.4 | e | 1172 | 2355 | 2845 | 400 | 1284 | 1180 |
| | 44 | 1117.6 | e | 1121 | 2255 | 2725 | 375 | 1234 | 1125 |
| | 42 | 1066.8 | e | 1070 | 2155 | 2605 | 375 | 1184 | 1075 |
| | 40 | 1016.0 | e | 1019 | 2050 | 2485 | 375 | 1131 | 1025 |
| | 38 | 965.2 | e | 968 | 1950 | 2355 | 350 | 1081 | 975 |
| | 36 | 914.4 | e | 918 | 1850 | 2235 | 350 | 1031 | 925 |
| | 34 | 863.6 | e | 867 | 1745 | 2115 | 325 | 979 | 875 |
| | 32 | 812.8 | e | 816 | 1645 | 1995 | 325 | 929 | 820 |
| | 30 | 762.0 | e | 765 | 1545 | 1865 | 300 | 879 | 770 |
| | 28 | 711.2 | e | 714 | 1440 | 1745 | 300 | 826 | 720 |
| | 26 | 660.4 | e | 664 | 1340 | 1625 | 300 | 776 | 670 |
| | 24 | 609.6 | 12.7 | 613 | 1255 | 1525 | 300 | 734 | 630 |
| | 22 | 558.8 | 12.7 | 562 | 1155 | 1405 | 275 | 684 | 580 |
| | 20 | 508.0 | 12.7 | 511 | 1055 | 1285 | 275 | 634 | 525 |
| | 18 | 457.2 | 12.7 | 460 | 950 | 1160 | 250 | 581 | 475 |
| | 16 | 406.4 | 12.7 | 410 | 850 | 1035 | 250 | 531 | 425 |
| | 14 | 355.6 | 12.7 | 359 | 750 | 915 | 250 | 481 | 375 |
| | 12 | 323.8 | 12.7 | 327 | 685 | 840 | 225 | 449 | 345 |
| 09 | 10 | 273.0 | 12.7 | 276 | 585 | 720 | 225 | 399 | 290 |
| | 8 | 219.1 | 12.7 | 222 | 485 | 590 | 200 | 349 | 240 |
| | 6 | 168.3 | 10.97 | 171 | 400 | 495 | 200 | 306 | 200 |
| | 4 | 114.3 | 8.56 | 117 | 305 | 385 | 175 | 259 | 150 |
| | 3 | 88.9 | 7.62 | 92 | 265 | 345 | 175 | 239 | 135 |
| | 2[f] | 60.3 | 5.54 | 63 | — | — | 150 | 175 | h |
| | 1 1/2[f] | 48.3 | 5.08 | 51 | — | — | 150 | 150 | h |
| | 1[f] | 33.4 | 6.35 | — | — | — | 150 | 150 | h |
| | 3/4[f] | 26.7 | 5.54 | — | — | — | 150 | 150 | h |
| | | | | | Threaded and Socket-Welded Couplings | | | | |
| | 3[g] | 108.0 | Coupling | 111.1 | 285 | 360 | — | 245 | 145 |
| | 2[f] | 76.2 | Coupling | 79.4 | — | — | — | 175 | h |
| | 1 1/2[f] | 63.5 | Coupling | 66.7 | — | — | — | 150 | h |
| | 1[f] | 44.5 | Coupling | 47.6 | — | — | — | 150 | h |
| | 3/4[f] | 35.0 | Coupling | 38.1 | — | — | — | 150 | h |

[a]For extra-strong pipe, see ASTM A 53M or A 106M for other wall thicknesses; however, piping material must conform to 4.5.
[b]The width of the shell plate shall be sufficient to contain the reinforcing plate and to provide clearance from the girth joint of the shell course.
● [c]Low type reinforced nozzles shall not be located lower than the minimum distance shown in Column 9. The minimum distance from the bottom shown in Column 9 complies with spacing rules of 5.7.3 and Figure 5-6.
[d]Regular type reinforced nozzles shall not be located lower than the minimum distance $H_N$ shown in Column 8 when shell thickness is equal to or less than 12.5 mm. Greater distances may be required for shells thicker than 12.5 mm to meet the minimum weld spacing of 5.7.3 and Figure 5-6.
[e]See Table 5-7a, Column 2.
[f]Flanged nozzles and couplings in pipe sizes NPS 2 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 specified in Table 5-7a, Column 6. Reinforcing plates may be used if the construction details comply with reinforced nozzle details.
[g]A coupling in an NPS 3 requires reinforcement.
[h]See 5.7.3 and Figure 5-6.
Note: See Figure 5-8.

## Table 5-6b—(USC) Dimensions for Shell Nozzles (in.)

| Column 1<br>NPS (Size of Nozzle) | Column 2<br>Outside Diameter of Pipe OD | Column 3<br>Nominal Thickness of Flanged Nozzle Pipe Wall[a] $t_n$ | Column 4<br>Diameter of Hole in Reinforcing Plate $D_R$ | Column 5<br>Length of Side of Reinforcing Plate[b] or Diameter $L = D_o$ | Column 6<br>Width of Reinforcing Plate $W$ | Column 7<br>Minimum Distance from Shell-to-Flange Face $J$ | Column 8<br>Minimum Distance from Bottom of Tank to Center of Nozzle: Regular Type[d] $H_N$ | Column 9[c]<br>Minimum Distance from Bottom of Tank to Center of Nozzle: Low Type $C$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 09 |
| **Flanged Fittings** | | | | | | | | | |
| 60 | 60 | e | $60^{1}/_{8}$ | $120^{3}/_{4}$ | $145^{3}/_{4}$ | 16 | $64^{5}/_{8}$ | $60^{3}/_{8}$ | |
| 54 | 54 | e | $54^{1}/_{8}$ | $108^{3}/_{4}$ | $131^{1}/_{2}$ | 16 | $58^{5}/_{8}$ | $54^{3}/_{8}$ | |
| 52 | 52 | e | $52^{1}/_{8}$ | $104^{3}/_{4}$ | $126^{1}/_{2}$ | 16 | $56^{5}/_{8}$ | $52^{3}/_{8}$ | 11 |
| 50 | 50 | e | $50^{1}/_{8}$ | $100^{3}/_{4}$ | $121^{3}/_{4}$ | 16 | $54^{5}/_{8}$ | $50^{3}/_{8}$ | |
| 48 | 48 | e | $48^{1}/_{8}$ | $96^{3}/_{4}$ | 117 | 16 | $52^{5}/_{8}$ | $48^{3}/_{8}$ | |
| 46 | 46 | e | $46^{1}/_{8}$ | $92^{3}/_{4}$ | 112 | 16 | $50^{5}/_{8}$ | $46^{3}/_{8}$ | |
| 44 | 44 | e | $44^{1}/_{8}$ | $88^{3}/_{4}$ | $107^{1}/_{4}$ | 15 | $48^{5}/_{8}$ | $44^{3}/_{8}$ | |
| 42 | 42 | e | $42^{1}/_{8}$ | $84^{3}/_{4}$ | $102^{1}/_{2}$ | 15 | $46^{5}/_{8}$ | $42^{3}/_{8}$ | |
| 40 | 40 | e | $40^{1}/_{8}$ | $80^{3}/_{4}$ | $97^{3}/_{4}$ | 15 | $44^{5}/_{8}$ | $40^{3}/_{8}$ | |
| 38 | 38 | e | $38^{1}/_{8}$ | $76^{3}/_{4}$ | $92^{3}/_{4}$ | 14 | $42^{5}/_{8}$ | $38^{3}/_{8}$ | |
| 36 | 36 | e | $36^{1}/_{8}$ | $72^{3}/_{4}$ | 88 | 14 | $40^{5}/_{8}$ | $36^{3}/_{8}$ | |
| 34 | 34 | e | $34^{1}/_{8}$ | $68^{3}/_{4}$ | $83^{1}/_{4}$ | 13 | $38^{5}/_{8}$ | $34^{3}/_{8}$ | |
| 32 | 32 | e | $32^{1}/_{8}$ | $64^{3}/_{4}$ | $78^{1}/_{2}$ | 13 | $36^{5}/_{8}$ | $32^{3}/_{8}$ | |
| 30 | 30 | e | $30^{1}/_{8}$ | $60^{3}/_{4}$ | $73^{1}/_{2}$ | 12 | $34^{5}/_{8}$ | $30^{3}/_{8}$ | |
| 28 | 28 | e | $28^{1}/_{8}$ | $56^{3}/_{4}$ | $68^{3}/_{4}$ | 12 | $32^{5}/_{8}$ | $28^{3}/_{8}$ | |
| 26 | 26 | e | $26^{1}/_{8}$ | $52^{3}/_{4}$ | 64 | 12 | $30^{5}/_{8}$ | $26^{3}/_{8}$ | |
| 24 | 24 | 0.50 | $24^{1}/_{8}$ | $49^{1}/_{2}$ | 60 | 12 | 29 | $24^{3}/_{4}$ | |
| 22 | 22 | 0.50 | $22^{1}/_{8}$ | $45^{1}/_{2}$ | $55^{1}/_{4}$ | 11 | 27 | $22^{3}/_{4}$ | |
| 20 | 20 | 0.50 | $20^{1}/_{8}$ | $41^{1}/_{2}$ | $50^{1}/_{2}$ | 11 | 25 | $20^{3}/_{4}$ | |
| 18 | 18 | 0.50 | $18^{1}/_{8}$ | $37^{1}/_{2}$ | $45^{3}/_{4}$ | 10 | 23 | $18^{3}/_{4}$ | |
| 16 | 16 | 0.50 | $16^{1}/_{8}$ | $33^{1}/_{2}$ | $40^{3}/_{4}$ | 10 | 21 | $16^{3}/_{4}$ | |
| 14 | 14 | 0.50 | $14^{1}/_{8}$ | $29^{1}/_{2}$ | 36 | 10 | 19 | $14^{3}/_{4}$ | |
| 12 | $12^{3}/_{4}$ | 0.50 | $12^{7}/_{8}$ | 27 | 33 | 9 | $17^{3}/_{4}$ | $13^{1}/_{2}$ | |
| 10 | $10^{3}/_{4}$ | 0.50 | $10^{7}/_{8}$ | 23 | $28^{1}/_{4}$ | 9 | $15^{3}/_{4}$ | $11^{1}/_{2}$ | |
| 8 | $8^{5}/_{8}$ | 0.50 | $8^{3}/_{4}$ | 19 | $23^{1}/_{4}$ | 8 | $13^{3}/_{4}$ | $9^{1}/_{2}$ | |
| 6 | $6^{5}/_{8}$ | 0.432 | $6^{3}/_{4}$ | $15^{3}/_{4}$ | $19^{1}/_{2}$ | 8 | $12^{1}/_{8}$ | $7^{7}/_{8}$ | |
| 4 | $4^{1}/_{2}$ | 0.337 | $4^{5}/_{8}$ | 12 | $15^{1}/_{4}$ | 7 | $10^{1}/_{4}$ | 6 | |
| 3 | $3^{1}/_{2}$ | 0.300 | $3^{5}/_{8}$ | $10^{1}/_{2}$ | $13^{1}/_{2}$ | 7 | $9^{1}/_{2}$ | $5^{1}/_{4}$ | 09 |
| 2[f] | $2^{3}/_{8}$ | 0.218 | $2^{1}/_{2}$ | — | — | 6 | 7 | h | |
| $1^{1}/_{2}$[f] | 1.90 | 0.200 | 2 | — | — | 6 | 6 | h | |
| 1[f] | 1.315 | 0.250 | — | — | — | 6 | 6 | h | |
| $^{3}/_{4}$[f] | 1.05 | 0.218 | — | — | — | 6 | 6 | h | |
| **Threaded and Socket-Welded Couplings** | | | | | | | | | |
| 3[g] | 4.250 | Coupling | $4^{3}/_{8}$ | $11^{1}/_{4}$ | $14^{1}/_{4}$ | — | $9^{5}/_{8}$ | $5^{5}/_{8}$ | |
| 2[f] | 3.000 | Coupling | $3^{1}/_{8}$ | — | — | — | 7 | h | |
| $1^{1}/_{2}$[f] | 2.500 | Coupling | $2^{5}/_{8}$ | — | — | — | 6 | h | |
| 1[f] | 1.750 | Coupling | $1^{7}/_{8}$ | — | — | — | 6 | h | |
| $^{3}/_{4}$[f] | 1.375 | Coupling | $1^{1}/_{2}$ | — | — | — | 5 | h | |

[a]For extra-strong pipe, see ASTM A 53 or A 106 for other wall thicknesses; however, piping material must conform to 4.5.

[b]The width of the shell plate shall be sufficient to contain the reinforcing plate and to provide clearance from the girth joint of the shell course.

● [c]Low type reinforced nozzles shall not be located lower than the minimum distance shown in Column 9. The minimum distance from the bottom shown in Column 9 complies with spacing rules of 5.7.3 and Figure 5-6.

[d]Regular type reinforced nozzles shall not be located lower than the minimum distance $H_N$ shown in Column 8 when shell thickness is equal to or less than $^{1}/_{2}$ in. Greater distances may be required for shells thicker than $^{1}/_{2}$ in. to meet the minimum weld spacing of 5.7.3 and Figure 5-6.

[e]See Table 5-7b, Column 2.

[f]Flanged nozzles and couplings in pipe sizes NPS 2 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 specified in Table 5-7b, Column 6. Reinforcing plates may be used if the construction details comply with reinforced nozzle details.

[g]A coupling in an NPS 3 requires reinforcement.

[h]See 5.7.3 and Figure 5-6.

Note: See Figure 5-8.

## Table 5-7a—(SI) Dimensions for Shell Nozzles: Pipe, Plate, and Welding Schedules (mm)

| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
|---|---|---|---|---|---|---|
| | | | | | Size of Fillet Weld *A* | |
| | Thickness of Shell and Reinforcing Plate[a] *t* and *T* | Minimum Pipe Wall Thickness of Flanged Nozzles[b] $t_n$ | Maximum Diameter of Hole in Shell Plate ($D_p$) Equals Outside Diameter of Pipe Plus | Size of Fillet Weld *B* | Nozzles Larger Than NPS 2 | NPS $^3/_4$ to 2 Nozzles |
| | 5 | 12.7 | 16 | 5 | 6 | 6 |
| | 6 | 12.7 | 16 | 6 | 6 | 6 |
| | 8 | 12.7 | 16 | 8 | 6 | 6 |
| | 10 | 12.7 | 16 | 10 | 6 | 6 |
| | 11 | 12.7 | 16 | 11 | 6 | 6 |
| | 13 | 12.7 | 16 | 13 | 6 | 8 |
| | 14 | 12.7 | 20 | 14 | 6 | 8 |
| | 16 | 12.7 | 20 | 16 | 8 | 8 |
| | 17 | 12.7 | 20 | 18 | 8 | 8 |
| | 20 | 12.7 | 20 | 20 | 8 | 8 |
| | 21 | 12.7 | 20 | 21 | 10 | 8 |
| | 22 | 12.7 | 20 | 22 | 10 | 8 |
| 08 | 24 | 12.7 | 20 | 24 | 10 | 8 |
| | 25 | 12.7 | 20 | 25 | 11 | 8 |
| | 27 | 14 | 20 | 27 | 11 | 8 |
| | 28 | 14 | 20 | 28 | 11 | 8 |
| | 30 | 16 | 20 | 30 | 13 | 8 |
| | 32 | 16 | 20 | 32 | 13 | 8 |
| | 33 | 18 | 20 | 33 | 13 | 8 |
| | 35 | 18 | 20 | 35 | 14 | 8 |
| | 36 | 20 | 20 | 36 | 14 | 8 |
| | 38 | 20 | 20 | 38 | 14 | 8 |
| | 40 | 21 | 20 | 40 | 14 | 8 |
| | 41 | 21 | 20 | 40 | 16 | 8 |
| | 43 | 22 | 20 | 40 | 16 | 8 |
| | 45 | 22 | 20 | 40 | 16 | 8 |

[a]If a shell plate thicker than required is used for the product and hydrostatic loading (see 5.6), 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 nozzle reinforcing plate 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 5.7.2.

11 [b]This column applies to flanged nozzles NPS 26 and larger. See 4.5 for piping materials.

[c]Note: See Figure 5-8.

Table 5-7b—(USC) Dimensions for Shell Nozzles: Pipe, Plate, and Welding Schedules (in.)

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
|---|---|---|---|---|---|
| | | | | Size of Fillet Weld $A$ | |
| Thickness of Shell and Reinforcing Plate[a] $t$ and $T$ | Minimum Pipe Wall Thickness of Flanged Nozzles[b] $t_n$ | Maximum Diameter of Hole in Shell Plate ($D_p$) Equals Outside Diameter of Pipe Plus | Size of Fillet Weld $B$ | Nozzles Larger Than NPS 2 | NPS 3/4 to 2 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 | 3/4 | 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 | 3/4 | 13/16 | 3/8 | 5/16 |
| 7/8 | 1/2 | 3/4 | 7/8 | 3/8 | 5/16 |
| 15/16 | 1/2 | 3/4 | 15/16 | 3/8 | 5/16 |
| 1 | 1/2 | 3/4 | 1 | 7/16 | 5/16 |
| 1 1/16 | 9/16 | 3/4 | 1 1/16 | 7/16 | 5/16 |
| 1 1/8 | 9/16 | 3/4 | 1 1/8 | 7/16 | 5/16 |
| 1 3/16 | 5/8 | 3/4 | 1 3/16 | 1/2 | 5/16 |
| 1 1/4 | 5/8 | 3/4 | 1 1/4 | 1/2 | 5/16 |
| 1 5/16 | 11/16 | 3/4 | 1 5/16 | 1/2 | 5/16 |
| 1 3/8 | 11/16 | 3/4 | 1 3/8 | 9/16 | 5/16 |
| 1 7/16 | 3/4 | 3/4 | 1 7/16 | 9/16 | 5/16 |
| 1 1/2 | 3/4 | 3/4 | 1 1/2 | 9/16 | 5/16 |
| 1 9/16 | 13/16 | 3/4 | 1 1/2 | 9/16 | 5/16 |
| 1 5/8 | 13/16 | 3/4 | 1 1/2 | 5/8 | 5/16 |
| 1 11/16 | 7/8 | 3/4 | 1 1/2 | 5/8 | 5/16 |
| 1 3/4 | 7/8 | 3/4 | 1 1/2 | 5/8 | 5/16 |

08

[a]If a shell plate thicker than required is used for the product and hydrostatic loading (see 5.6), 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 nozzle reinforcing plate 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 5.7.2.

[b]This column applies to flanged nozzles NPS 26 and larger. See 4.5 for piping materials.

11

[c]Note: See Figure 5-8.

## Table 5-8a—(SI) Dimensions for Shell Nozzle Flanges (mm)

| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 | Column 11 | Column 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Diameter of Bore | | Minimum Diameter of Hub at Point of Weld | |
| 08 | NPS (Size of Nozzle) | Minimum Thickness of Flange[d] $Q$ | Outside Diameter of Flange $A$ | Diameter of Raised Face $D$ | Diameter of Bolt Circle $C$ | Number of Holes | Diameter of Holes | Diameter of Bolts | Slip-On Type: Outside Diameter of Pipe Plus $B$ | Welding Neck Type[a] $B_1$ | Slip-On Type[b] $E$ | Welding-Neck Type[c] $E_1$ |
| | 60 | 79.4 | 1854 | 1676 | 1759 | 52 | 48 | 45 | 6.4 | a | b | c |
| | 54 | 76.2 | 1683 | 1511 | 1594 | 44 | 48 | 45 | 6.4 | a | b | c |
| 11 | 52 | 73 | 1626 | 1461 | 1537 | 44 | 48 | 45 | 6.4 | a | b | c |
| | 50 | 70 | 1569 | 1410 | 1480 | 44 | 48 | 45 | 6.4 | a | b | c |
| | 48 | 70 | 1510 | 1360 | 1426 | 44 | 42 | 40 | 6.4 | a | b | c |
| | 46 | 68 | 1460 | 1295 | 1365 | 40 | 42 | 40 | 6.4 | a | b | c |
| | 44 | 67 | 1405 | 1245 | 1315 | 40 | 42 | 40 | 6.4 | a | b | c |
| | 42 | 67 | 1345 | 1195 | 1257 | 36 | 42 | 40 | 6.4 | a | b | c |
| | 40 | 65 | 1290 | 1125 | 1200 | 36 | 42 | 40 | 6.4 | a | b | c |
| | 38 | 60 | 1240 | 1075 | 1150 | 32 | 42 | 40 | 6.4 | a | b | c |
| | 36 | 60 | 1170 | 1020 | 1036 | 32 | 42 | 40 | 6.4 | a | b | c |
| | 34 | 59 | 1110 | 960 | 1029 | 32 | 42 | 40 | 6.4 | a | b | c |
| | 32 | 57 | 1060 | 910 | 978 | 28 | 42 | 40 | 6.4 | a | b | c |
| | 30 | 54 | 985 | 855 | 914 | 28 | 33 | 30 | 6.4 | a | b | c |
| 08 | 28 | 52 | 925 | 795 | 864 | 28 | 33 | 30 | 6.4 | a | b | c |
| | 26 | 50 | 870 | 745 | 806 | 24 | 33 | 30 | 6.4 | a | b | c |
| | 24 | 48 | 815 | 690 | 750 | 20 | 33 | 30 | 4.8 | a | b | c |
| | 22 | 46 | 750 | 640 | 692 | 20 | 33 | 30 | 4.8 | a | b | c |
| | 20 | 43 | 700 | 585 | 635 | 20 | 30 | 27 | 4.8 | a | b | c |
| | 18 | 40 | 635 | 535 | 577 | 16 | 30 | 27 | 4.8 | a | b | c |
| | 16 | 36 | 595 | 470 | 540 | 16 | 27 | 24 | 4.8 | a | b | c |
| | 14 | 35 | 535 | 415 | 476 | 12 | 27 | 24 | 4.8 | a | b | c |
| | 12 | 32 | 485 | 380 | 432 | 12 | 25 | 22 | 3.2 | a | b | c |
| | 10 | 30 | 405 | 325 | 362 | 12 | 25 | 22 | 3.2 | a | b | c |
| | 8 | 28 | 345 | 270 | 298 | 8 | 23 | 20 | 3.2 | a | b | c |
| | 6 | 25 | 280 | 216 | 241 | 8 | 23 | 20 | 2.4 | a | b | c |
| | 4 | 24 | 230 | 157 | 190 | 8 | 19 | 16 | 1.6 | a | b | c |
| | 3 | 24 | 190 | 127 | 152 | 4 | 19 | 16 | 1.6 | a | b | c |
| | 2 | 20 | 150 | 92 | 121 | 4 | 19 | 16 | 1.6 | a | b | c |
| | $1^1/_2$ | 17 | 125 | 73 | 98 | 4 | 16 | 12 | 1.6 | a | b | c |

[a]$B_1$ = inside diameter of pipe.

[b]$E$ = outside diameter of pipe + $2t_n$.

[c]$E_1$ = outside diameter of pipe.

● [d]Corrosion allowance, if specified, need not be added to flange and cover thicknesses complying with ASME B16.5 Class 150, ASME B16.1 Class 125, and ASME B16.47 flanges.

Note: See Figure 5-8. The facing dimensions for slip-on and welding-neck flanges in NPS $1^1/_2$ through 20 and NPS 24 are identical to those specified in ASME B16.5 for Class 150 steel flanges. The facing dimensions for flanges in NPS 30, 36, 42, 48, 50, 52, 54, and 60 are in agreement with ASME B16.1 for Class 125

11 cast iron flanges. The dimensions for large flanges may conform to Series B of ASME B16.47.

## Table 5-8b—(USC) Dimensions for Shell Nozzle Flanges (in.)

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 | Column 11 | Column 12 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Diameter of Bore | | Minimum Diameter of Hub at Point of Weld | | |
| NPS (Size of Nozzle) | Minimum Thickness of Flange[d] $Q$ | Outside Diameter of Flange $A$ | Diameter of Raised Face $D$ | Diameter of Bolt Circle $C$ | Number of Holes | Diameter of Holes | Diameter of Bolts | Slip-On Type: Outside Diameter of Pipe Plus $B$ | Welding Neck Type[a] $B_1$ | Slip-On Type[b] $E$ | Welding-Neck Type[c] $E_1$ | 08 |
| 60 | 3 1/8 | 73 | 66 | 69 1/4 | 52 | 17/8 | 1 3/4 | 0.25 | a | b | c | |
| 54 | 3 | 66 1/4 | 59 1/2 | 62 3/4 | 44 | 17/8 | 1 3/4 | 0.25 | a | b | c | |
| 52 | 2 7/8 | 64 | 57 1/2 | 60 1/2 | 44 | 17/8 | 1 3/4 | 0.25 | a | b | c | 11 |
| 50 | 2 3/4 | 61 3/4 | 55 1/2 | 58 1/4 | 44 | 17/8 | 1 3/4 | 0.25 | a | b | c | |
| 48 | 2 3/4 | 59 1/2 | 53 1/2 | 56 | 44 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 46 | 2 11/16 | 57 1/2 | 51 | 53 3/4 | 40 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 44 | 2 5/8 | 55 1/4 | 49 | 51 3/4 | 40 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 42 | 2 5/8 | 53 | 47 | 49 1/2 | 36 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 40 | 2 1/2 | 50 3/4 | 44 1/4 | 47 1/4 | 36 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 38 | 2 3/8 | 48 3/4 | 42 1/4 | 45 1/4 | 32 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 36 | 2 3/8 | 46 | 40 1/4 | 42 3/4 | 32 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 34 | 2 5/16 | 43 3/4 | 37 3/4 | 40 1/2 | 32 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 32 | 2 1/4 | 41 3/4 | 35 3/4 | 38 1/2 | 28 | 1 5/8 | 1 1/2 | 0.25 | a | b | c | |
| 30 | 2 1/8 | 38 3/4 | 33 3/4 | 36 | 28 | 1 3/8 | 1 1/4 | 0.25 | a | b | c | |
| 28 | 2 1/16 | 36 1/2 | 31 1/4 | 34 | 28 | 1 3/8 | 1 1/4 | 0.25 | a | b | c | 08 |
| 26 | 2 | 34 1/4 | 29 1/4 | 31 3/4 | 24 | 1 3/8 | 1 1/4 | 0.25 | a | b | c | |
| 24 | 1 7/8 | 32 | 27 1/4 | 29 1/2 | 20 | 1 3/8 | 1 1/4 | 0.19 | a | b | c | |
| 22 | 1 13/16 | 29 1/2 | 25 1/4 | 27 1/4 | 20 | 1 3/8 | 1 1/4 | 0.19 | a | b | c | |
| 20 | 1 11/16 | 27 1/2 | 23 | 25 | 20 | 1 1/4 | 1 1/8 | 0.19 | a | b | c | |
| 18 | 1 9/16 | 25 | 21 | 22 3/4 | 16 | 1 1/4 | 1 1/8 | 0.19 | a | b | c | |
| 16 | 1 7/16 | 23 1/2 | 18 1/2 | 21 1/4 | 16 | 1 1/8 | 1 | 0.19 | a | b | c | |
| 14 | 1 3/8 | 21 | 16 1/4 | 18 3/4 | 12 | 1 1/8 | 1 | 0.19 | a | b | c | |
| 12 | 1 1/4 | 19 | 15 | 17 | 12 | 1 | 7/8 | 0.13 | a | b | c | |
| 10 | 1 3/16 | 16 | 12 3/4 | 14 1/4 | 12 | 1 | 7/8 | 0.13 | a | b | c | |
| 8 | 1 1/8 | 13 1/2 | 10 5/8 | 11 3/4 | 8 | 7/8 | 3/4 | 0.10 | a | b | c | |
| 6 | 1 | 11 | 8 1/2 | 9 1/2 | 8 | 7/8 | 3/4 | 0.10 | a | b | c | |
| 4 | 15/16 | 9 | 6 3/16 | 7 1/2 | 8 | 3/4 | 5/8 | 0.06 | a | b | c | |
| 3 | 15/16 | 7 1/2 | 5 | 6 | 4 | 3/4 | 5/8 | 0.06 | a | b | c | |
| 2 | 3/4 | 6 | 3 5/8 | 4 3/4 | 4 | 3/4 | 5/8 | 0.07 | a | b | c | |
| 1 1/2 | 11/16 | 5 | 2 7/8 | 3 7/8 | 4 | 5/8 | 1/2 | 0.07 | a | b | c | |

[a] $B_1$ = inside diameter of pipe.

[b] $E$ = outside diameter of pipe + $2t_n$.

[c] $E_1$ = outside diameter of pipe.

● [d] Corrosion allowance, if specified, need not be added to flange and cover thicknesses complying with ASME B16.5 Class 150, ASME B16.1 Class 125, and ASME B16.47 flanges.

Note: See Figure 5-8. The facing dimensions for slip-on and welding-neck flanges in NPS 1 1/2 through 20 and NPS 24 are identical to those specified in ASME B16.5 for Class 150 steel flanges. The facing dimensions for flanges in NPS 30, 36, 42, 48, 50, 52, 54, and 60 are in agreement with ASME B16.1 for Class 125 cast iron flanges. The dimensions for large flanges may conform to Series B of ASME B16.47. 11

### Table 5-9a—(SI) Dimensions for Flush-Type Cleanout Fittings (mm)

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| Column 1<br>Height of Opening<br>*h* | Column 2<br>Width of Opening<br>*b* | Column 3<br>Arc Width of Shell Reinforcing Plate<br>*W* | Column 4<br>Upper Corner Radius of Opening<br>$r_1$ | Column 5<br>Upper Corner Radius of Shell Reinforcing Plate<br>$r_2$ | Column 6<br>Edge Distance of Bolts<br>*e* | Column 7<br>Flange Width[a] (Except at Bottom)<br>$f_3$ | Column 8<br>Bottom Flange Width<br>$f_2$ | Column 9<br>Special Bolt Spacing[b]<br>*g* | Column 10<br>Number of Bolts | Column 11<br>Diameter of Bolts |
|---|---|---|---|---|---|---|---|---|---|---|
| 203 | 406 | 1170 | 100 | 360 | 32 | 102 | 89 | 83 | 22 | 20 |
| 610 | 610 | 1830 | 300 | 740 | 38 | 102 | 95 | 89 | 36 | 20 |
| 914 | 1219 | 2700 | 610 | 1040 | 38 | 114 | 121 | 108 | 46 | 24 |
| 1219[c] | 1219 | 3200 | 610 | 1310 | 38 | 114 | 127 | 114 | 52 | 24 |

[a]For neck thicknesses greater than 40 mm, increase $f_3$ as necessary to provide a 1.5 mm clearance between the required neck-to-flange weld and the head of the bolt.
[b]Refers to spacing at the lower corners of the cleanout-fitting flange.
● [c]Only for Group I, II, III, or IIIA shell materials (see 5.7.7.2).
Note: See Figure 5-12.

### Table 5-9b—(USC) Dimensions for Flush-Type Cleanout Fittings (in.)

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11

| Column 1<br>Height of Opening<br>*h* | Column 2<br>Width of Opening<br>*b* | Column 3<br>Arc Width of Shell Reinforcing Plate<br>*W* | Column 4<br>Upper Corner Radius of Opening<br>$r_1$ | Column 5<br>Upper Corner Radius of Shell Reinforcing Plate<br>$r_2$ | Column 6<br>Edge Distance of Bolts<br>*e* | Column 7<br>Flange Width[a] (Except at Bottom)<br>$f_3$ | Column 8<br>Bottom Flange Width<br>$f_2$ | Column 9<br>Special Bolt Spacing[b]<br>*g* | Column 10<br>Number of Bolts | Column 11<br>Diameter of Bolts |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 16 | 46 | 4 | 14 | $1\frac{1}{4}$ | 4 | $3\frac{1}{2}$ | $3\frac{1}{4}$ | 22 | $\frac{3}{4}$ |
| 24 | 24 | 72 | 12 | 29 | $1\frac{1}{2}$ | 4 | $3\frac{3}{4}$ | $3\frac{1}{2}$ | 36 | $\frac{3}{4}$ |
| 36 | 48 | 106 | 24 | 41 | $1\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | $4\frac{1}{4}$ | 46 | 1 |
| 48[c] | 48 | 125 | 24 | $51\frac{1}{2}$ | $1\frac{1}{2}$ | $4\frac{1}{2}$ | 5 | $4\frac{1}{2}$ | 52 | 1 |

[a]For neck thicknesses greater than $1\frac{9}{16}$ in., increase $f_3$ as necessary to provide a $\frac{1}{16}$ in. clearance between the required neck-to-flange weld and the head of the bolt.
[b]Refers to spacing at the lower corners of the cleanout-fitting flange.
● [c]Only for Group I, II, III, or IIIA shell materials (see 5.7.7.2).
Note: See Figure 5-12.

yield and tensile strengths. When the material strength is greater than or equal to the 70% and 80% minimum values, the area in the neck available for reinforcement shall be reduced by the ratio of the allowable stress in the neck, using the governing stress factors, to the allowable stress in the attached shell plate. No credit may be taken for the additional strength of any reinforcing material that has a higher allowable stress than that of the shell plate. Neck material that has a yield or tensile strength less than the 70% or 80% minimum values may be used, provided that no neck area is considered as effective reinforcement.

07 **5.7.2.4** The following portions of the neck of a fitting may be considered part of the area of reinforcement, except where prohibited by 5.7.2.3, Item e:

a. The portion extending outward from the outside surface of the tank shell plate to 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.

b. The portion lying within the shell-plate thickness.

c. The portion extending inward from the inside surface of the tank shell plate to the distance specified in Item a.

**5.7.2.5** The aggregate strength of the weld attaching a fitting to the shell plate, an intervening reinforcing plate, or both shall at least equal the proportion of the forces passing through the entire reinforcement that is calculated to pass through the fitting.

07

**5.7.2.6** The aggregate strength of the welds attaching any intervening reinforcing plate to the shell plate shall at least equal the proportion of the forces passing through the entire reinforcement that is calculated to pass through the reinforcing plate.

Table 5-10a—(SI) Minimum Thickness of Cover Plate, Bolting Flange, and Bottom Reinforcing Plate for Flush-Type Cleanout Fittings (mm)[f]

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 |
|---|---|---|---|---|---|---|---|---|---|
| | | Size of Opening $h \times b$ (Height × Width) | | | | | | | |
| | | 200 × 400 | | 600 × 600 | | 900 × 1200 | | 1200 × 1200 | |
| Maximum Design Liquid Level m $H$ | Equivalent Pressure[a] kPa | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[b] $t_b$ | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[c] $t_b$ | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[d] $t_b$ | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[e] $t_b$ |
| 6.1 | 60 | 10 | 13 | 10 | 13 | 16 | 21 | 16 | 22 |
| 10.4 | 101 | 10 | 13 | 13 | 13 | 19 | 25 | 21 | 28 |
| 12.5 | 123 | 10 | 13 | 13 | 14 | 22 | 28 | 22 | 30 |
| 16.1 | 159 | 10 | 13 | 14 | 16 | 24 | 32 | 25 | 33 |
| 18.3 | 179 | 11 | 13 | 16 | 18 | 25 | 33 | 28 | 35 |
| 19.5 | 191 | 11 | 13 | 16 | 18 | 27 | 35 | 28 | 36 |
| 21.9 | 215 | 11 | 13 | 18 | 19 | 28 | 36 | 30 | 40 |

08

[a]Equivalent pressure is based on water loading.
[b]Maximum of 25 mm.
[c]Maximum of 28 mm.
[d]Maximum of 40mm.
[e]Maximum of 45 mm.
[f]See 5.7.7.7 when corrosion allowance is specified.
Note: See Figure 5-12. 11

Table 5-10b—(USC) Minimum Thickness of Cover Plate, Bolting Flange, and Bottom Reinforcing Plate for Flush-Type Cleanout Fittings (in.)[f]

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 |
|---|---|---|---|---|---|---|---|---|---|
| | | Size of Opening $h \times b$ (Height × Width) | | | | | | | |
| | | 8 × 16 | | 24 × 24 | | 36 × 48 | | 48 × 48 | |
| Maximum Design Liquid Level ft $H$ | Equivalent Pressure[a] psi | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[b] $t_b$ | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[c] $t_b$ | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[d] $t_b$ | Thickness of Bolting Flange and Cover Plate $t_c$ | Thickness of Bottom Reinforcing Plate[e] $t_b$ |
| 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 |
| 64 | 27.8 | 7/16 | 1/2 | 5/8 | 11/16 | 1 1/16 | 1 3/8 | 1 1/8 | 1 7/16 |
| 72 | 31.2 | 7/16 | 1/2 | 11/16 | 3/4 | 1 1/8 | 1 7/16 | 1 3/16 | 1 1/2 |

08

[a]Equivalent pressure is based on water loading.
[b]Maximum of 1 in.
[c]Maximum of 1 1/8 in.
[d]Maximum of 1 1/2 in.
[e]Maximum of 1 3/4 in.
[f]See 5.7.7.7 when corrosion allowance is specified. 11
Note: See Figure 5-12.

**5.7.2.7** The attachment weld to the shell along the outer periphery of a reinforcing plate or proprietary connection that lap welds to the shell shall be considered effective only for the parts lying outside the area bounded by vertical lines drawn tangent to the shell opening; however, the outer peripheral weld shall be applied completely around the reinforcement. See 5.7.2.8 for allowable stresses. All of the inner peripheral weld shall be considered effective. The strength of the (07) effective attachment weld shall be considered as the weld's shear resistance at the stress value given for fillet welds in 5.7.2.8. The size of the outer peripheral weld shall be equal to the thickness of the shell plate or reinforcing plate, whichever is thinner, but shall not be greater than 40 mm (1 1/2 in.). When low-type nozzles are used with a reinforcing plate that (08) extends to the tank bottom (see Figure 5-8), the size of the portion of the peripheral weld that attaches the reinforcing plate to the bottom plate shall conform to 5.1.5.7. The inner peripheral weld shall be large enough to sustain the remainder (07) of the loading.

Table 5-11a—(SI) Thicknesses and Heights of Shell Reinforcing Plates for Flush-Type Cleanout Fittings (mm)

| Thickness of Lowest Shell Course $t$, $t_d$[a] mm | Maximum Design Liquid Level[c] $H$ m | Height of Shell Reinforcing Plate for Size of Opening $h \times b$ (Height × Width) mm | | | |
|---|---|---|---|---|---|
| | | 200 × 400 | 600 × 600 | 900 × 1200 | 1200 × 1200[b] |
| All | < 22 | 350 | 915 | 1372 | 1830 |

Notes:
[a]Dimensions $t_d$ and $L$ may be varied within the limits defined in 5.7.7.
[b]1200 × 1200 flush-type cleanout fittings are not permitted for tanks with greater than 38 mm lowest shell course thickness.
[c]See 5.6.3.2.

09 Table 5-11b—(USC) Thicknesses and Heights of Shell Reinforcing Plates for Flush-Type Cleanout Fittings (in.)

| Thickness of Lowest Shell Course $t$, $t_d$[a] in. | Maximum Design Liquid Level[c] $H$ ft | Height of Shell Reinforcing Plate for Size of Opening $h \times b$ (Height × Width) in. | | | |
|---|---|---|---|---|---|
| | | 8 × 16 | 24 × 24 | 36 × 48 | 48 × 48[b] |
| All | < 72 | 14 | 36 | 54 | 72 |

Notes:
[a]Dimensions $t_d$ and $L$ may be varied within the limits defined in 5.7.7.
[b]48 × 48 flush-type cleanout fittings are not permitted for tanks with greater than $1^1/_2$ in. lowest shell course thickness.
[c]See 5.6.3.2.

**5.7.2.8** The reinforcement and welding shall be configured to provide the required strength for the forces covered in 5.7.2.5 and 5.7.2.6.

07 The allowable stresses for the attachment elements are:

a. For outer reinforcing plate-to-shell and inner reinforcing plate-to-nozzle neck fillet welds: $S_d \times 0.60$.

b. For tension across groove welds: $S_d \times 0.875 \times 0.70$

c. For shear in the nozzle neck: $S_d \times 0.80 \times 0.875$

where

$S_d$ = the maximum allowable design stress (the lesser value of the base materials joined) permitted by 5.6.2.1 for carbon
08 steel, or by Tables S-2a and S-2b for stainless steel.

Stress in fillet welds shall be considered as shear on the throat of the weld. The throat of the fillet shall be assumed to be 0.707
07 times the length of the shorter leg. Tension stress in the groove weld shall be considered to act over the effective weld depth.

**5.7.2.9** When two or more openings are located so that the outer edges (toes) of their normal reinforcing-plate fillet welds are closer than eight times the size of the larger of the fillet welds, with a minimum of 150 mm (6 in.), they shall be treated and reinforced as follows:

a. All such openings shall be included in a single reinforcing plate that shall be proportioned for the largest opening in the group.

b. If the normal reinforcing plates for the smaller openings in the group, considered separately, fall within the area limits of the solid portion of the normal plate for the largest opening, the smaller openings may be included in the normal plate for the largest opening without an increase in the size of the plate, provided that if any opening intersects the vertical centerline of another opening, the total width of the final reinforcing plate along the vertical centerline of either opening is not less than the sum of the widths of the normal plates for the openings involved.

c. If the normal reinforcing plates for the smaller openings in the group, considered separately, do not fall within the area limits of the solid portion of the normal plate for the largest opening, the group reinforcing-plate size and shape shall include the outer limits of the normal reinforcing plates for all the openings in the group. A change in size from the outer limits of the normal plate for the largest opening to the outer limits of that for the smaller opening farthest from the largest opening shall be accomplished by uniform straight taper unless the normal plate for any intermediate opening would extend beyond these limits, in which case uniform straight tapers shall join the outer limits of the several normal plates. The provisions of Item b with respect to openings on the same or adjacent vertical centerlines also apply in this case.

**5.7.2.10** Reinforcing plates for shell openings, or each segment of the plates if they are not made in one piece, shall be provided with a 6 mm ($^{1}/_{4}$ in.) diameter telltale hole. Such holes shall be located on the horizontal centerline and shall be open to the 07
atmosphere.

### 5.7.3 Spacing of Welds around Connections

See Figure 5-6 for spacing requirements listed in 5.7.3.1 through 5.7.3.4.

Note 1: Additional weld spacing requirements exist in this Standard. Other paragraphs and tables dealing with nozzles and manholes may increase the minimum spacing.

Note 2: Whenever stress relief or thermal stress relief is used in this Standard, it shall mean post-weld heat treatment.

**5.7.3.1** For non-stress-relieved welds on shell plates over 13 mm ($^{1}/_{2}$ in.) thick, the minimum spacing between penetration con- 08
nections and adjacent shell-plate joints shall be governed by the following:

a. The outer edge or toe of fillet around a penetration, around the periphery of a thickened insert plate, or around the periphery of a reinforcing plate shall be spaced at least the greater of eight times the weld size or 250 mm (10 in.) (dimension A or B in Figure 08
5-6) from the centerline of any butt-welded shell joints.

b. The welds around the periphery of a thickened insert plate, around a reinforcing insert plate, or around a reinforcing plate shall be spaced at least the greater of eight times the larger weld size or 150 mm (6 in.) (dimension E in Figure 5-6) from each other. 08

**5.7.3.2** Where stress-relieving of the periphery weld has been performed prior to welding of the adjacent shell joint or where a non-stress-relieved weld is on a shell plate less than or equal to 13 mm ($^{1}/_{2}$ in.) thick, the spacing may be reduced to 150 mm (6 in.) (dimension A in Fig. 5-6) from vertical joints or to the greater of 75 mm (3 in.) or 2$^{1}/_{2}$ times the shell thickness (dimension B in Fig. 5-6) from horizontal joints. The spacing between the welds around the periphery of a thickened insert plate or around a reinforcing plate shall be the greater of 75 mm (3 in.) or 2$^{1}/_{2}$ times the shell thickness (dimension E in Figure 5-6). 08

**5.7.3.3** The rules in 5.7.3.1 and 5.7.3.2 shall also apply to the bottom-to-shell joint (dimension C in Figure 5-6) unless, as an alternative, the insert plate or reinforcing plate extends to the bottom-to-shell joint and intersects it at approximately 90 degrees (dimension D in Figure 5-6). A minimum distance of 75 mm (3 in.) shall be maintained between the toe of a weld 08
around a nonreinforced penetration (see 5.7.2.1) and the toe of the shell-to-bottom weld.

• **5.7.3.4** Nozzles and manholes should not be placed in shell weld seams and reinforcing pads for nozzles and manholes should not overlap plate seams (i.e., Figure 5-9, Details a, c, and e should be avoided). If there is no other feasible option and the Purchaser accepts the design, circular shell openings and reinforcing plates (if used) may be located in a horizontal or vertical butt-welded shell joint provided that the minimum spacing dimensions are met and a radiographic examination of the 07
welded shell joint is conducted. The welded shell joint shall be fully radiographed for a length equal to three times the diameter of the opening, but the weld seam being removed need not be radiographed. Radiographic examination shall be in accordance with 8.1.3 through 8.1.8.

### 5.7.4 Thermal Stress Relief

**5.7.4.1** All flush-type cleanout fittings and flush-type shell connections shall be thermally stress-relieved as an assembly prior to installation in the tank shell or after installation into the tank shell if the entire tank is stress-relieved. The stress relief shall be carried out within a temperature range of 600°C – 650°C (1100°F – 1200°F) (see 5.7.4.3 for quenched and tempered materials) for 1 hour per 25 mm (1 in.) of shell thickness. The assembly shall include the bottom reinforcing plate (or annular plate) and the flange-to-neck weld.

**5.7.4.2** When the shell material is Group I, II, III, or IIIA, all opening connections NPS 12 or larger in nominal diameter in a shell plate or thickened insert plate more than 25 mm (1 in.) thick shall be prefabricated into the shell plate or thickened insert plate, and the prefabricated assembly shall be thermally stress-relieved within a temperature range of 600°C – 650°C (1100°F – 1200°F) for 1 hour per 25 mm (1 in.) of thickness prior to installation. The stress-relieving

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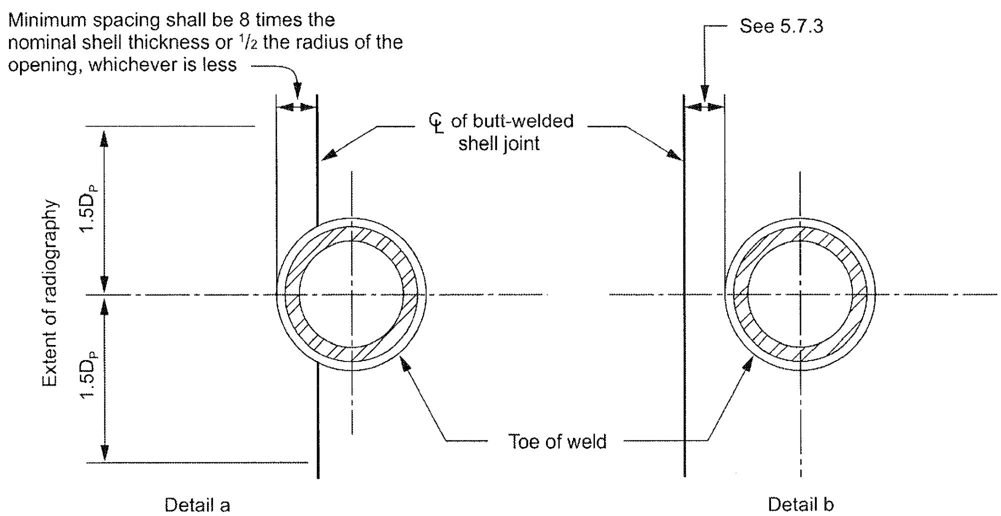
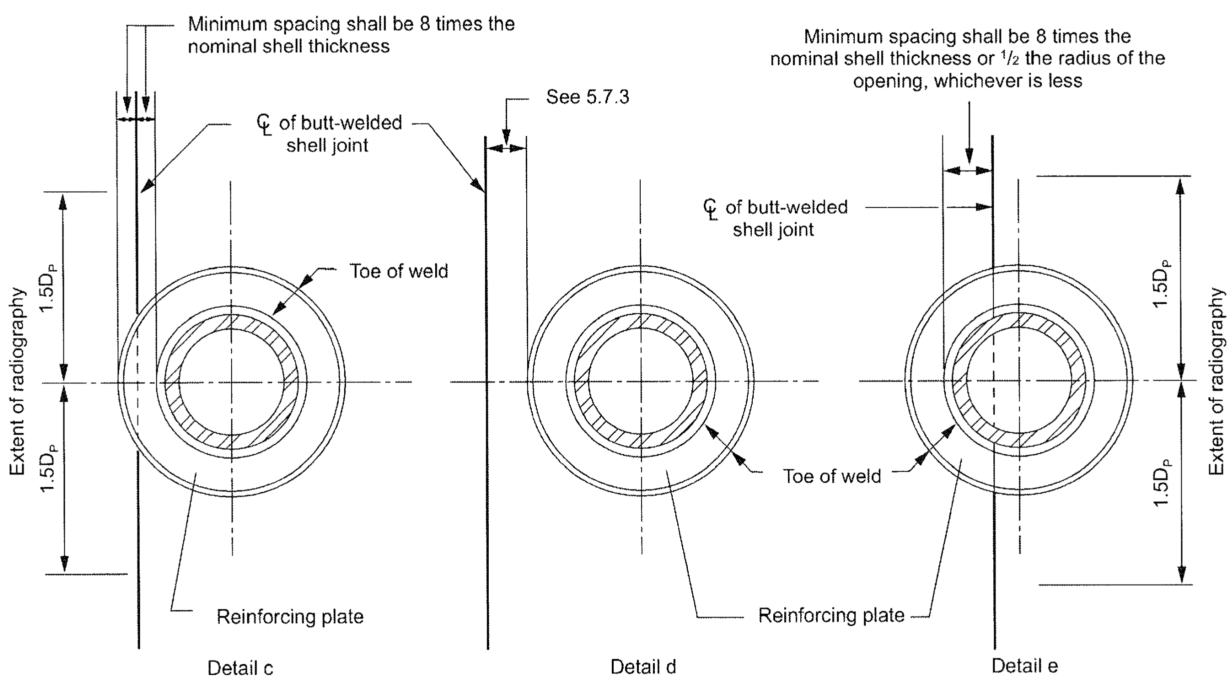



PENETRATION WITHOUT REINFORCING PLATE




PENETRATION WITH REINFORCING PLATE

Note: $D_p$ = diameter of opening.

Figure 5-9—Minimum Spacing of Welds and Extent of Related Radiographic Examination requirements need not include the flange-to-neck welds or other nozzle-neck and manhole-neck attachments, provided the following conditions are fulfilled:

a. The welds are outside the reinforcement (see 5.7.2.4). 07

b. The throat dimension of a fillet weld in a slip-on flange does not exceed 16 mm ($^{5}/_{8}$ in.), or the butt joint of a welding-neck flange does not exceed 19 mm ($^{3}/_{4}$ in.). If the material is preheated to a minimum temperature of 90°C (200°F) during welding, the weld limits of 16 mm ($^{5}/_{8}$ in.) and 19 mm ($^{3}/_{4}$ in.) may be increased to 32 mm and 40 mm ($1^{1}/_{4}$ in. and $1^{1}/_{2}$ in.), 08 respectively.

**5.7.4.3** When the shell material is Group IV, IVA, V, or VI, all opening connections requiring reinforcement in a shell plate or thickened insert plate more than 13 mm ($^{1}/_{2}$ in.) thick shall be prefabricated into the shell plate or thickened insert plate, and the 08 prefabricated assembly shall be thermally stress relieved within a temperature range of 600°C – 650°C (1100°F – 1200°F) for 1 hour per 25 mm (1 in.) of thickness prior to installation.

When connections are installed in quenched and tempered material, the maximum thermal stress-relieving temperature shall not exceed the tempering temperature for the materials in the prefabricated stress-relieving assembly. The stress-relieving requirements do not apply to the weld to the bottom annular plate, but they do apply to flush-type cleanout openings when the bottom reinforcing plate is an annular-plate section. The stress-relieving requirements need not include the flange-to-neck welds or other nozzle-neck and manhole-neck attachments, provided the conditions of 5.7.4.2 are fulfilled.

**5.7.4.4** Examination after stress relief shall be in accordance with 7.2.3.6 or 7.2.3.7.

• **5.7.4.5** When it is impractical to stress relieve at a minimum temperature of 600°C (1100°F), it is permissible, subject to the Purchaser's agreement, to carry out the stress-relieving operation at lower temperatures for longer periods of time in accordance with the tabulation below. The lower temperature/longer time PWHT may not provide material toughness and residual stresses 07 equivalent to that using the higher temperature/shorter time PWHT; therefore, a review by a knowledgeable metallurgist and possible verification by mill testing of heat-treated coupons and/or testing of welded plates shall be considered. See Line 23 of the Data Sheet for any Purchaser-specified requirements applicable to this heat-treatment option.

| Minimum Stress-Relieving Temperature | | Holding Time (hours per 25 mm [1 in.] of thickness) | See Note |
|---|---|---|---|
| (°C) | (°F) | | |
| 600 | 1100 | 1 | 1 |
| 570 | 1050 | 2 | 1 |
| 540 | 1000 | 4 | 1 |
| 510 | 950 | 10 | 1, 2 |
| 480 (min.) | 900 (min.) | 20 | 1, 2 |

Notes:
1. For intermediate temperatures, the time of heating shall be determined by straight line interpolation.
2. Stress relieving at these temperatures is not permitted for A 537 Class 2 material.

**5.7.4.6** When used in stress-relieved assemblies, the material of quenched and tempered steels A 537, Cl 2 and A 678, Grade B, and of TMCP steel A 841 shall be represented by test specimens that have been subjected to the same heat treatment as that used for the stress relieved assembly.

### 5.7.5 Shell Manholes

**5.7.5.1** Shell manholes shall conform to Figures 5-7A and 5-7B and Tables 5-3a through 5-5b (or Tables 5-6a through 5-8b), 08 but other shapes are permitted by 5.7.1.8. Manhole reinforcing plates or each segment of the plates if they are not made in one piece shall be provided with a 6 mm ($^{1}/_{4}$ in.) diameter telltale hole (for detection of leakage through the interior welds). Each hole shall be located on the horizontal centerline and shall be open to the atmosphere.

• **5.7.5.2** Manholes shall be of built-up welded construction. The dimensions are listed in Tables 5-3a through 5-5b. The dimensions are based on the minimum neck thicknesses listed in Tables 5-4a and 5-4b. When corrosion allowance is specified to be applied to shell manholes, corrosion allowance is to be added to the minimum neck, cover plate, and bolting flange thicknesses of Tables 5-3a, 08 5-3b, 5-4a and 5-4b.

**5.7.5.3** The maximum diameter $D_p$ of a shell cutout shall be as listed in Column 3 of Tables 5-7a and 5-7b. Dimensions for
08 required reinforcing plates are listed in Tables 5-6a and 5-6b.

**5.7.5.4** The gasket materials shall meet service requirements based on the product stored, maximum design temperature, and fire resistance. Gasket dimensions, when used in conjunction with thin-plate flanges described in Figure 5-7A, have proven effec-
07 tive when used with soft gaskets, such as non-asbestos fiber with suitable binder. When using hard gaskets, such as solid metal, corrugated metal, metal-jacketed, and spiral-wound metal, the gasket dimensions, manhole flange, and manhole cover shall be designed per API Std 620, Sections 3.20 and 3.21. See 4.9 for additional requirements.

**5.7.5.5** In lieu of using Figure 5-7A or design per API Std 620, forged flanges and forged blind flanges may be furnished per 4.6.

### 5.7.6 Shell Nozzles and Flanges

• **5.7.6.1.a** Unless otherwise specified, shell nozzle flanges, excluding manholes, in sizes NPS $1^1/_2$ through NPS 20 and NPS 24 shall meet the requirements of ASME B16.5. For sizes larger than NPS 24 but not greater than NPS 60, flanges shall meet the requirements of ASME B16.47, Series A or Series B. Series A and Series B flanges are not compatible in all sizes and must be carefully selected to match the mating flange. If diameters, materials of construction, and flange styles of ASME B16.47 are unavailable, fabricated flanges with drilling template (bolt circle diameter, number of holes,
07 and hole diameter) matching Series A or Series B shall be used. These fabricated flanges shall be designed in accordance with the ASME *Boiler and Pressure Vessel Code,* Section VIII, Division 1, Section UG-34 and Appendix 2. The allowable stresses for design shall be a matter of agreement between the Purchaser and the Manufacturer. Bolt holes shall straddle the vertical centerline of the flange.

• **5.7.6.1.b** Shell nozzles (and flanges, if specified by the Purchaser as an alternate to a. above) shall conform to Figures 5-7B, 5-
08 8, and 5-10 and Tables 5-6a through 5-8b, but other shapes are permitted by 5.7.1.8. An alternative connection design is permissible for the nozzle end that is not welded to the shell, if it provides equivalent strength, toughness, leak tightness, and utility and if the Purchaser agrees to its use in writing.

07

• **5.7.6.2** Unless shell nozzles are specified to be flush on the inside of the tank shell by the Purchaser, shell nozzles without internal piping in a tank without a floating roof may be supplied flush or with an internal projection at the option of the Manufacturer. In floating roof tanks, shell nozzles without internal piping within operating range of the floating roof shall be supplied flush on the inside of the tank shell unless agreed otherwise between the Manufacturer and the Purchaser.

• **5.7.6.3** The details and dimensions specified in this Standard are for nozzles installed with their axes perpendicular to the shell plate. A nozzle may be installed at an angle other than 90 degrees to the shell plate in a horizontal plane, provided the width of the reinforcing plate ($W$ or $D_o$ in Figure 5-8 and Tables 5-6a and 5-6b) is increased by the amount that the horizontal chord of the
08 opening cut in the shell plate ($D_p$ in Figure 5-8 and Tables 5-7a and 5-7b) increases as the opening is changed from circular to elliptical for the angular installation. In addition, nozzles not larger than NPS 3—for the insertion of thermometer wells, for sampling connections, or for other purposes not involving the attachment of extended piping—may be installed at an angle of 15
07 degrees or less off perpendicular in a vertical plane without modification of the nozzle reinforcing plate.

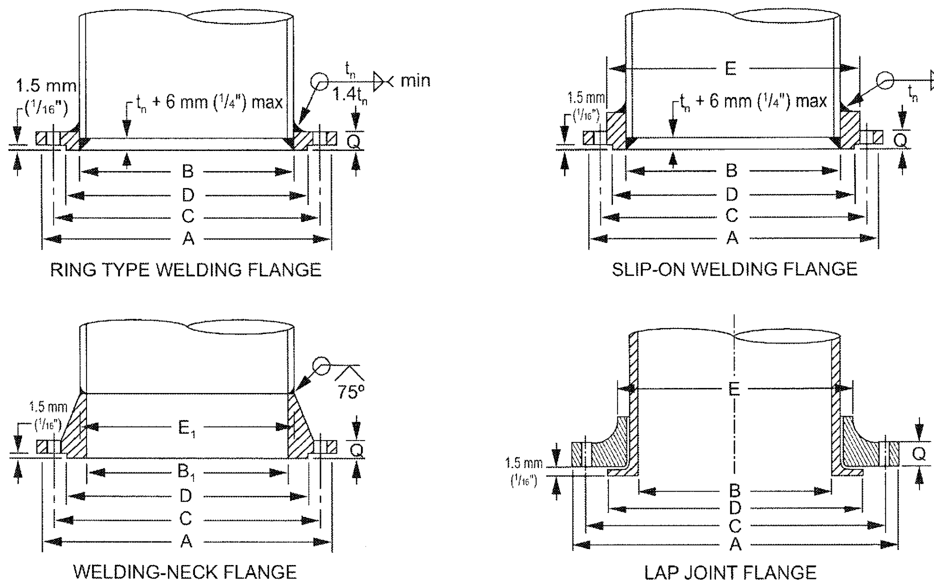
11 **5.7.6.4** The minimum nominal thickness of nozzle necks to be used shall be equal to the required thickness as identified by the
08 term $t_n$ in Tables 5-6a and 5-6b, Column 3.

### 5.7.7 Flush-Type Cleanout Fittings

• **5.7.7.1** Flush-type cleanout fittings shall conform to the requirements of 5.7.7.2 through 5.7.7.12 and to the details and dimensions
08 shown in Figures 5-12 and 5-13 and Tables 5-9a through 5-11b. When a size intermediate to the sizes given in Tables 5-9a through 5-11b is specified by the Purchaser, the construction details and reinforcements shall conform to the next larger 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.

11 **5.7.7.2** The opening shall be rectangular, but the upper corners of the opening shall have a radius ($r_1$) as shown in Tables 5-9a and 5-9b. When the shell material is Group I, II, III, or IIIA, the width or height of the clear opening shall not exceed 1200 mm (48 in.); when the shell material is Group IV, IVA, V, or VI, the height shall not exceed 900 mm (36 in.).

**5.7.7.3** 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 as described in 5.7.4 (regardless of the thickness or strength of the material).




Note: The $t_n$ designated for weld thickness is the nominal pipe wall thickness (see Tables 5-6a, 5-6b, 5-7a and 5-7b). 11

Figure 5-10—Shell Nozzle Flanges (See Tables 5-8a and 5-8b)

Vertical axis in SI units:

$$\left[\frac{(H+8.8)D+71.5}{1.408h}\right]\left[\frac{123t}{4.9D(H-0.3)}\right]^{0.5}$$

Vertical axis in US Customary units:

$$\left[\frac{(H+29)D+770}{385h}\right]\left[\frac{17{,}850t}{2.6D(H-1)}\right]^{0.5}$$

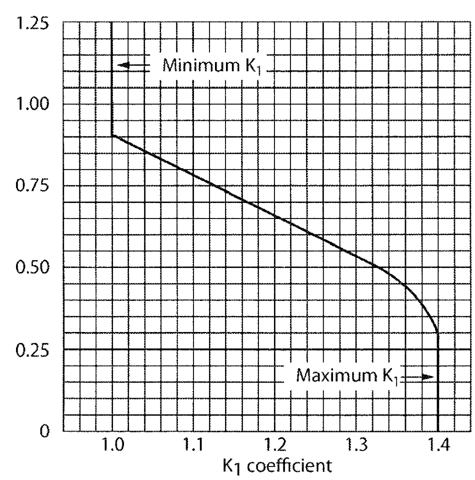



Figure 5-11—Area Coefficient for Determining Minimum Reinforcement of Flush-Type Cleanout Fittings

**5.7.7.4** The required cross-sectional area of the reinforcement over the top of the opening shall be calculated for Design Condition as well as Hydrostatic Test Condition as follows: 08

$$A_{cs} \geq \frac{K_1 h t}{2}$$

where

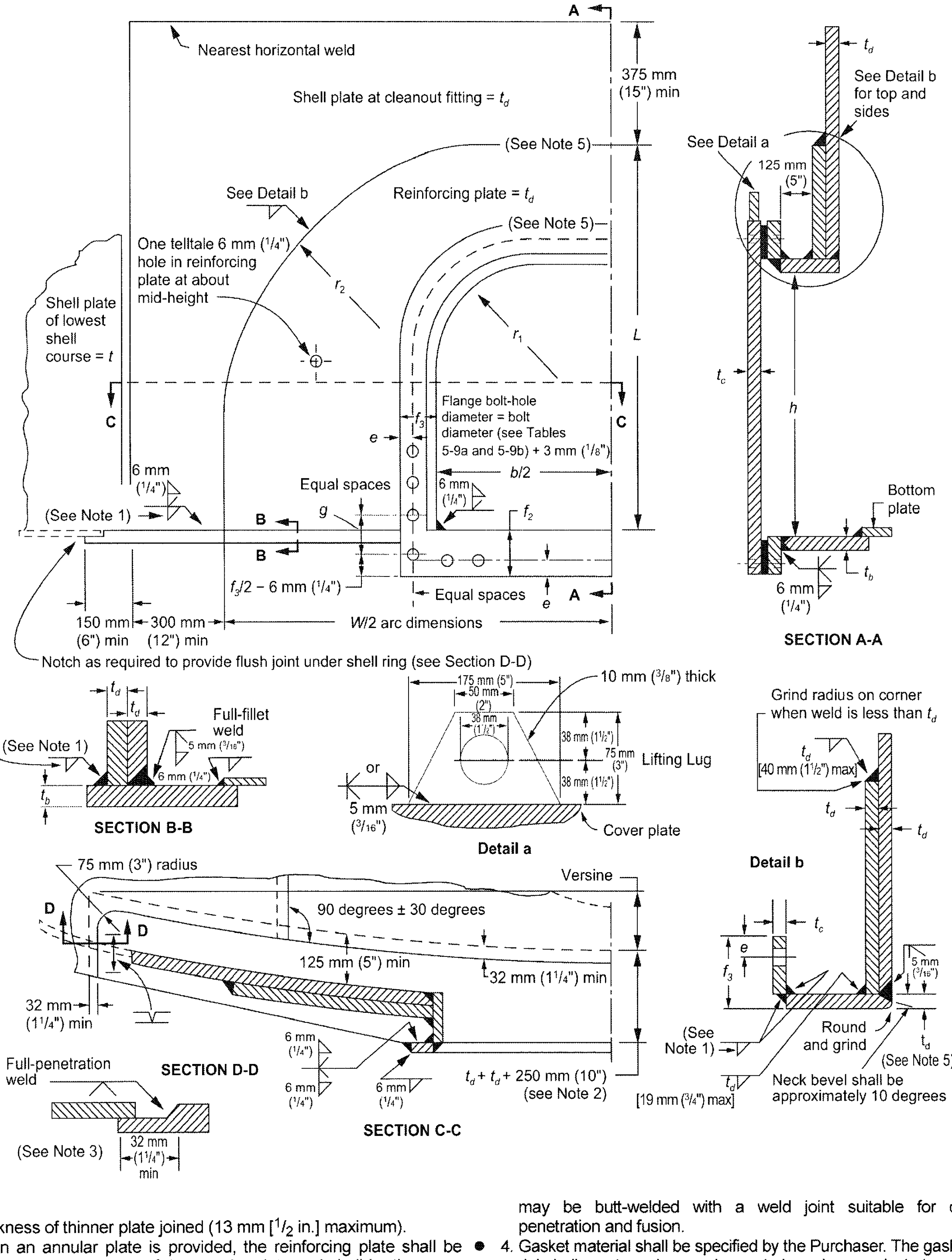
$A_{cs}$ = required cross-sectional area of the reinforcement over the top of the opening, in mm$^2$ (in.$^2$), 08

$K_1$ = area coefficient from Figure 5-11,

$h$ = vertical height of clear opening, in mm (in.),

$t$ = calculated thickness of the lowest shell course, in mm (in.), required by the formulas of 5.6.3, 5.6.4, or A.4.1 (with joint efficiency E = 1.0), including corrosion allowance, where applicable. 08

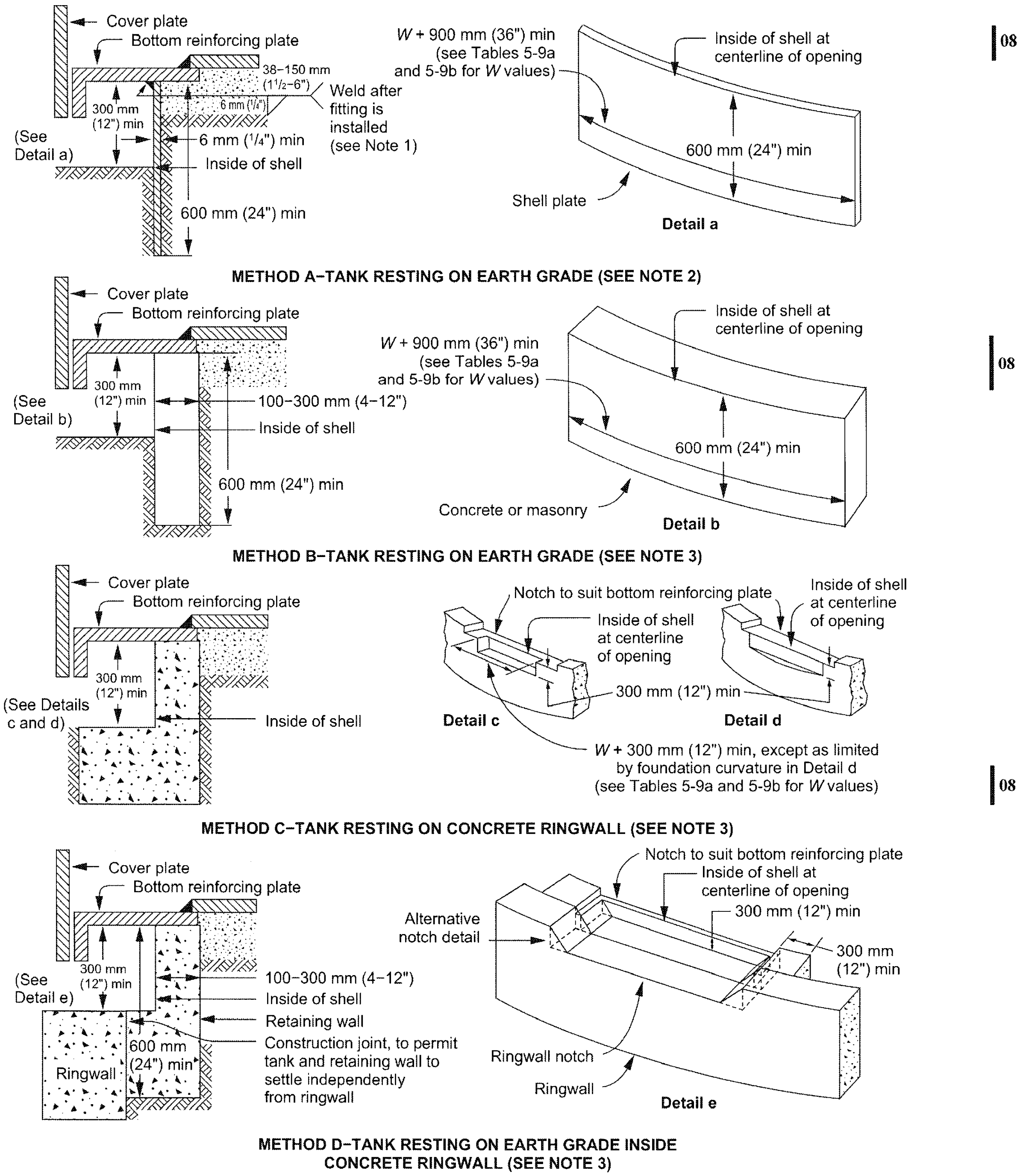
08




Notes:

1. Thickness of thinner plate joined (13 mm [1/2 in.] maximum).
2. When an annular plate is provided, the reinforcing plate shall be regarded as a segment of the annular plate and shall be the same width as the annular plate.
3. When the difference between the thickness of the annular ring and that of the bottom reinforcing plate is less than 6 mm (1/4 in.), the radial joint between the annular ring and the bottom reinforcing plate may be butt-welded with a weld joint suitable for complete penetration and fusion.
4. ● Gasket material shall be specified by the Purchaser. The gasket material shall meet service requirements based on product stored, design metal temperature, maximum design temperature and fire resistance.
5. The thickness ($t_d$) of the shell plate at the cleanout opening, the reinforcing plate, and the neck plate, shall be equal to or greater than the thickness ($t$) of the shell plate of the lowest shell course.

08 Figure 5-12—Flush-Type Cleanout Fittings (See Tables 5-9a, 5-9b, 5-10a, 5-10b, 5-11a and 5-11b)




Notes:

1. This weld is not required if the earth is stabilized with portland cement at a ratio of not more than 1:12 or if the earth fill is replaced with concrete for a lateral distance and depth of at least 300 mm (12 in.).
2. When Method A is used, before the bottom plate is attached to the bottom reinforcing plate, (a) a sand cushion shall be placed flush with the top of the bottom reinforcing plate, and (b) the earth fill and sand cushion shall be thoroughly compacted.
3. When Method B, C, or D is used, before the bottom plate is attached to the bottom reinforcing plate, (a) a sand cushion shall be placed flush with the top of the bottom reinforcing plate, (b) the earth fill and sand cushion shall be thoroughly compacted, and (c) grout shall be placed under the reinforcing plate (if needed) to ensure a firm bearing.

Figure 5-13—Flush-Type Cleanout-Fitting Supports (See 5.7.7)

**5.7.7.5** The nominal thickness of the shell plate in the flush-type cleanout fitting assembly shall be at least as thick as the adjacent
11 shell plate nominal thickness in the lowest shell course. The nominal thickness of the shell reinforcing plate and the neck plate shall be, as a minimum, the thickness of the shell plate in the cleanout-opening assembly.

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, in the case of small openings, $L - h$ shall not be less than 150 mm (6 in.). Where this exception results in an $L$ that is greater than $1.5h$, only the portion of the reinforcement that is within the height of $1.5h$ shall be considered effective. The reinforcement required may be provided by any one or any combination of the following:

a. The shell reinforcing plate.

b. Any thickness of the shell plate in the flush-type cleanout fitting assembly that is greater than the required thickness of lowest
11 shell course, as determined by 5.6.3, 5.6.4 or A.4.1 (with joint efficiency E = 1.0).

c. The portion of the neck plate having a length equal to the nominal thickness of the reinforcing plate.

08 Reinforcing area provided shall be adequate for Design Conditions as well as Hydrostatic test Conditions.

**5.7.7.6** The minimum width of the tank-bottom reinforcing plate at the centerline of the opening shall be 250 mm (10 in.) plus the combined nominal thickness of the shell plate in the cleanout-opening assembly and the shell reinforcing plate.
11 The nominal thickness of the bottom reinforcing plate shall be not less than that determined by the following equation:

In SI units:

11 $$t_b = \frac{h^2}{360{,}000} + \frac{b}{170}\sqrt{HG} + CA$$

where

$t_b$ = minimum thickness of the bottom reinforcing plate, in mm,

$h$ = vertical height of clear opening, in mm,

$b$ = horizontal width of clear opening, in mm,

$H$ = maximum design liquid level (see 5.6.3.2), in m,

$G$ = specific gravity, not less than 1.0.

In US Customary units:

11 $$t_b = \frac{h^2}{14{,}000} + \frac{b}{310}\sqrt{HG} + CA$$

where

$t_b$ = minimum thickness of the bottom reinforcing plate, (in.),

$h$ = vertical height of clear opening, (in.),

$b$ = horizontal width of clear opening, (in.),

$H$ = maximum design liquid level (see 5.6.3.2), (ft),

$G$ = specific gravity, not less than 1.0.

**5.7.7.7** The dimensions of the cover plate, bolting flange, bolting, and bottom-reinforcing plate shall conform to Tables 5-9a, 5-9b,
11 5-10a and 5-10b. When corrosion allowance is specified, it is to be added to the cover plate, bolting flange thicknesses, and bottom-reinforcing plate.

**5.7.7.8** All materials in the flush-type cleanout fitting assembly shall conform to the requirements in Section 4. The shell plate containing the cleanout assembly, the shell reinforcing plate, the neck plate, and the bottom reinforcing plate shall meet the impact test requirements of 4.2.9 and Figure 4-1 for the respective thickness involved at the design metal temperature for the tank. The notch toughness of the bolting flange and the cover plate shall be based on the governing thickness as defined in 4.5.5.3 using
08 Tables 4-3a, 4-3b, and Figure 4-1. Additionally, the yield strength and the tensile strength of the shell plate at the flush-type cleanout fitting, the shell reinforcing plate, and the neck plate shall be equal to, or greater than, the yield strength and the tensile strength of the adjacent lowest shell course plate material.

**5.7.7.9** The dimensions and details of the cleanout-opening assemblies covered by this section are based on internal hydrostatic loading with no external-piping loading.

**5.7.7.10** When a flush-type cleanout fitting is installed on a tank that is 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:

a. Install a vertical steel bulkhead plate under the tank, along the contour of the tank shell, symmetrical with the opening, as shown in Figure 5-13, Method A.
b. Install a concrete or masonry retaining wall under the tank with the wall's outer face conforming to the contour of the tank shell as shown in Figure 5-13, Method B.

**5.7.7.11** When a flush-type cleanout fitting is installed on a tank that is resting on a ringwall, a notch with the dimensions shown in Figure 5-13, Method C, shall be provided to accommodate the cleanout fitting.

**5.7.7.12** When a flush-type cleanout fitting is installed on a tank that is 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 Figure 5-13, Method D.

### 5.7.8 Flush-Type Shell Connections

• **5.7.8.1** Tanks may have flush-type connections at the lower edge of the shell. Each connection may be made flush with the flat bottom under the following conditions (see Figure 5-14):

a. The shell uplift from the internal design and test pressures (see Appendix F) and wind and earthquake loads (see Appendix E) shall be counteracted so that no uplift will occur at the cylindrical-shell/flat-bottom junction.
b. The vertical or meridional membrane stress in the cylindrical shell at the top of the opening for the flush-type connection shall not exceed one-tenth of the circumferential design stress in the lowest shell course containing the opening.
c. The maximum width, $b$, of the flush-type connection opening in the cylindrical shell shall not exceed 900 mm (36 in.).
d. The maximum height, $h$, of the opening in the cylindrical shell shall not exceed 300 mm (12 in.).
e. The thickness, $t_a$, of the bottom-transition plate in the assembly shall be 13 mm ($^1/_2$ in.) minimum or, when specified, the same as the thickness of the tank annular plate. 08

**5.7.8.2** The details of the connection shall conform to those shown in Figure 5-14, and the dimensions of the connection shall conform to Tables 5-12a and 5-12b and to the requirements of 5.7.8.3 through 5.7.8.11. 08

**5.7.8.3** The reinforced connection shall be completely preassembled into a shell plate. The completed assembly, including the shell plate containing the connection, shall be thermally stress-relieved at a temperature of 600°C – 650°C (1100°F – 1200°F) for 1 hour per 25 mm (1 in.) of shell-plate thickness, $t_d$ (see 5.7.4.1 and 5.7.4.2).

**5.7.8.4** The reinforcement for a flush-type shell connection shall meet the following requirements:

a. The cross-sectional area of the reinforcement over the top of the connection shall not be less than $K_1ht/2$ (see 5.7.7.4).
b. The nominal thickness of the shell plate, $t_d$, for the flush-connection assembly shall be at least as thick as the adjacent shell plate nominal thickness, $t$, in the lowest shell course. 11
c. The nominal thickness of the shell reinforcing plate shall be, as a minimum, the nominal thickness of the shell plate in the flush-connection assembly.
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, in the case of small openings, $L - h$ shall not be less than 150 mm (6 in.). Where this exception results in an $L$ that is greater than $1.5h$, only the portion of the reinforcement that is within the height of $1.5h$ shall be considered effective.
e. The required reinforcement may be provided by any one or any combination of the following:
1. the shell reinforcing plate;
2. any thickness of the shell plate in the flush-type shell connection assembly that is greater than the required thickness of lowest shell course, as determined by 5.6.3, 5.6.4, or A.4.1 (with joint efficiency E = 1.0); and 08
3. the portion of the neck plate having a length equal to the thickness of the reinforcing plate.

Reinforcing area provided shall be adequate for Design Conditions as well as Hydrostatic Test Conditions.
f. The width of the tank-bottom reinforcing plate at the centerline of the opening shall be 250 mm (10 in.) plus the combined nominal thickness of the shell plate in the flush-connection assembly and the shell reinforcing plate. The thickness of the bottom reinforcing plate shall be calculated by the following equation (see 5.7.6): 11

### Table 5-12a—(SI) Dimensions for Flush-Type Shell Connections (mm)

| Class 150 Nominal Height of Flange Size | Height of Opening $h$ | Width of Opening $b$ | Arc Width of Shell Reinforcing Plate $W$ | Upper Corner Radius of Opening $r_1$ | Lower Corner Radius of Shell Reinforcing Plate $r_2$ |
|---|---|---|---|---|---|
| 8 | 200 | 200 | 950 | OD of 8 NPS[a] | 350 |
| 12 | 300 | 300 | 1300 | OD of 12 NPS[a] | 450 |
| 16 | 300 | 500 | 1600 | 150 | 450 |
| 18 | 300 | 550 | 1650 | 150 | 450 |
| 20 | 300 | 625 | 1725 | 150 | 450 |
| 24 | 300 | 900 | 2225 | 150 | 450 |

[a]For circular openings, this value will be $^1/_2$ of the ID based on the nozzle neck specified.
08 Note: See Figure 5-14.

### Table 5-12b—(USC) Dimensions for Flush-Type Shell Connections (in.)

| Class 150 Nominal Height of Flange Size | Height of Opening $h$ | Width of Opening $b$ | Arc Width of Shell Reinforcing Plate $W$ | Upper Corner Radius of Opening $r_1$ | Lower Corner Radius of Shell Reinforcing Plate $r_2$ |
|---|---|---|---|---|---|
| 8 | $8^5/_8$ | $8^5/_8$ | 38 | 4[a] | 14 |
| 12 | $12^3/_4$ | $12^3/_4$ | 52 | 4[a] | 18 |
| 16 | 12 | 20 | 64 | 6 | 18 |
| 18 | 12 | 22 | 66 | 6 | 18 |
| 20 | 12 | 25 | 69 | 6 | 18 |
| 24 | 12 | 36 | 89 | 6 | 18 |

[a]For circular openings, this value will be $^1/_2$ of the ID based on the nozzle neck specified.
Note: See Figure 5-14.

In SI units:

11

$$t_b = \frac{h^2}{360{,}000} + \frac{b}{170}\sqrt{HG} + CA$$

where

$t_b$ = minimum thickness of the bottom reinforcing plate, in mm,

$h$ = vertical height of clear opening, in mm,

$b$ = horizontal width of clear opening, in mm,

$H$ = maximum design liquid level (see 5.6.3.2), in m,

$G$ = specific gravity, not less than 1.0.

In US Customary units:

11

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

where

08 $t_b$ = minimum thickness of the bottom reinforcing plate, (in.),

$h$ = vertical height of clear opening, (in.),

$b$ = horizontal width of clear opening, (in.),

$H$ = maximum design liquid level (see 5.6.3.2), (ft),

$G$ = specific gravity, not less than 1.0.

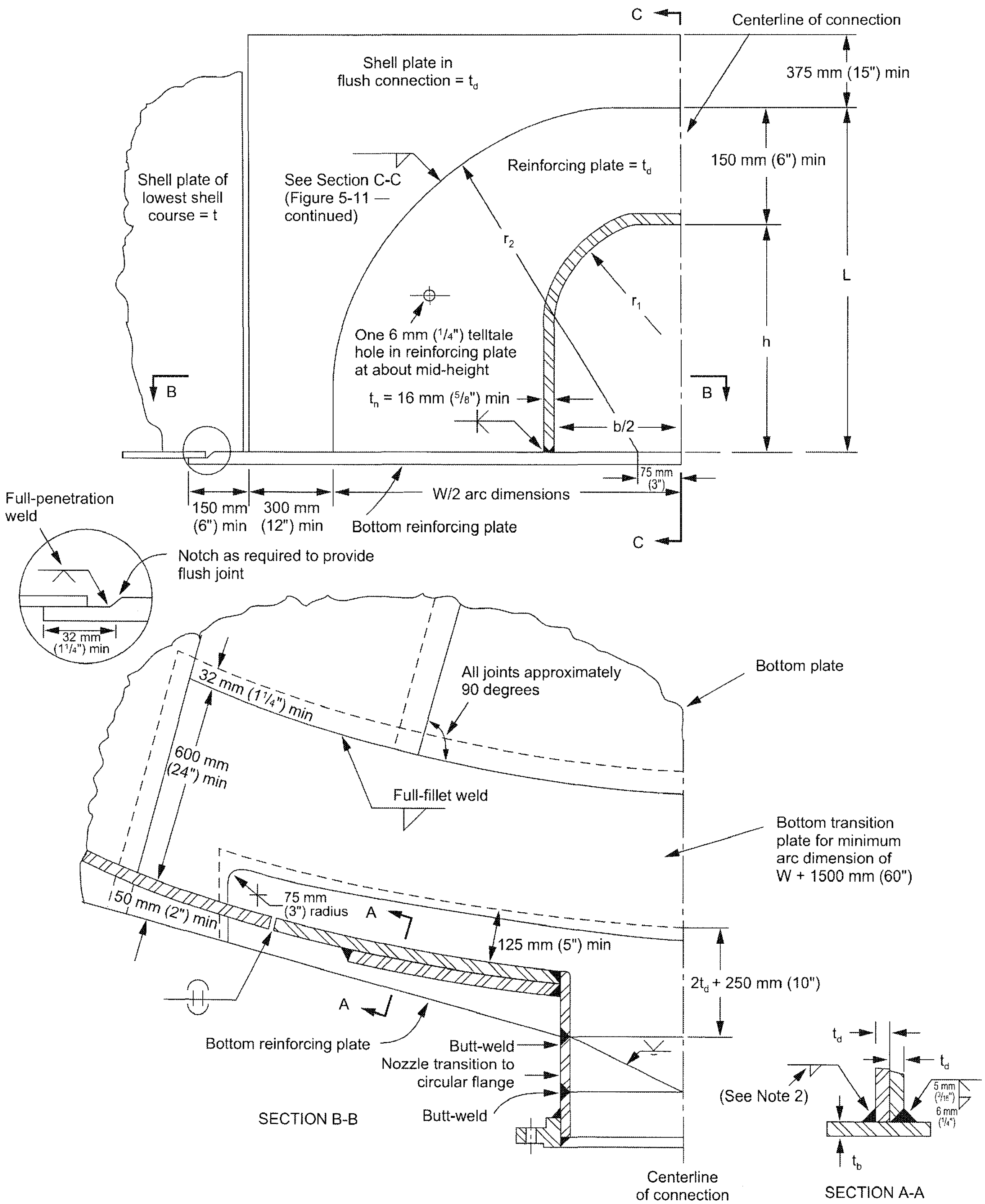



Figure 5-14—Flush-Type Shell Connection

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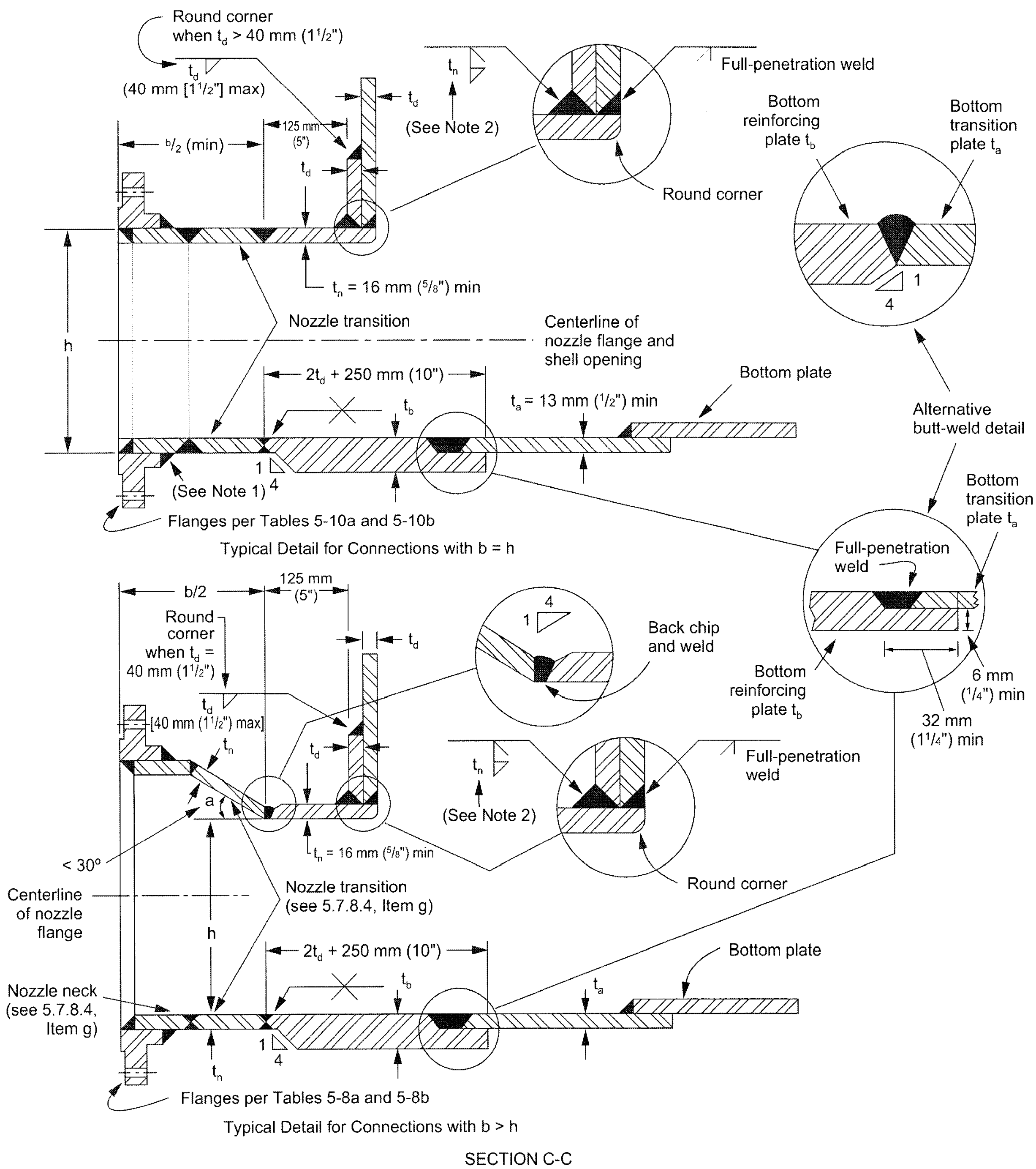


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Note 1: Flange weld sizes shall be the smaller of the available hub material for $t_n$

Note 2: Thickness of thinner plate joined 13 mm (1/2 in.) maximum.

Figure 5-14—Flush-Type Shell Connection (continued)

The minimum value of $t_b$ shall be:

16 mm ($^5/_8$ in.) for $HG \leq 14.4$ m (48 ft)

17 mm ($^{11}/_{16}$ in.) for 14.4 m (48 ft) < $HG \leq 16.8$ m (56 ft)

19 mm ($^3/_4$ in.) for 16.8 m (56 ft) < $HG \leq 19.2$ m (64 ft)

g. The corroded thickness of the nozzle neck and transition piece, $t_n$, shall be not less than 16 mm ($^5/_8$ in.). External loads applied 11
to the connection may require $t_n$ to be greater than 16 mm ($^5/_8$ in.).

**5.7.8.5** All materials in the flush-type shell connection assembly shall conform to the requirements in Section 4. The material of the shell plate in the connection assembly, the shell reinforcing plate, the nozzle neck attached to the shell, the transition piece, and the bottom reinforcing plate shall conform to 4.2.9 and Figure 4-1 for the respective thickness involved at the design metal temperature for the tank. The notch toughness of the bolting flange and the nozzle neck attached to the bolting flange shall be based on the governing thickness as defined in 4.5.5.3 and used in Figure 4-1. Additionally, the yield strength and the tensile strength of the shell plate at the flush-type shell connection and the shell reinforcing plate shall be equal to, or greater than, the yield strength and the tensile strength of the adjacent lowest shell course plate material.

**5.7.8.6** The nozzle transition between the flush connection in the shell and the circular pipe flange shall be designed in a manner consistent with the requirements of this Standard. Where this Standard does not cover all details of design and construction, the Manufacturer shall provide details of design and construction that will be as safe as the details provided by this Standard.

**5.7.8.7** Where anchoring devices are required by Appendices E and F to resist shell uplift, the devices shall be spaced so that they will be located immediately adjacent to each side of the reinforcing plates around the opening.

**5.7.8.8** Adequate provision shall be made for free movement of connected piping to minimize thrusts and moments applied to the shell connection. Allowance shall be made for the rotation of the shell connection caused by the restraint of the tank bottom-to-shell expansion from stress and temperature as well as for the thermal and elastic movement of the piping. Rotation of the shell connection is shown in Figure 5-15.

**5.7.8.9** The foundation in the area of a flush-type connection shall be prepared to support the bottom reinforcing plate of the connection. The foundation for a tank resting on a concrete ringwall shall provide uniform support for both the bottom reinforcing plate and the remaining bottom plate under the tank shell. Different methods of supporting the bottom reinforcing plate under a flush-type connection are shown in Figure 5-13.

**5.7.8.10** Flush-type connections may be installed using a common reinforcing pad; however, when this construction is employed, the minimum distance between nozzle centerlines shall not be less than $1.5[b_1 + b_2 + 65$ mm ($2^1/_2$ in.)], where $b_1$ and $b_2$ are the widths of adjacent openings, or 600 mm (24 in.), whichever is greater. The width of each opening, $b$, shall be obtained
from Tables 5-12a and 5-12b for the respective nominal flange size. Adjacent shell flush-type connections that do not share a 08
common reinforcing plate shall have at least a 900 mm (36 in.) clearance between the ends of their reinforcing plates.

**5.7.8.11** All longitudinal butt-welds in the nozzle neck and transition piece, if any, and the first circumferential butt-weld in the neck closest to the shell, excluding neck-to-flange weld, shall receive 100% radiographic examination (see 8.1). The nozzle-to-tank-shell and reinforcing plate welds and the shell-to-bottom reinforcing plate welds shall be examined for their complete length by magnetic particle examination (see 8.2). The magnetic particle examination shall be performed on the root pass, on every
13 mm ($^1/_2$ in.) of deposited weld metal while the welds are made, and on the completed welds. The completed welds shall also 08
be visually examined. The examination of the completed welds shall be performed after stress-relieving but before hydrostatic testing (see 8.2 and 8.5 for the appropriate inspection and repair criteria).

## 5.8 SHELL ATTACHMENTS AND TANK APPURTENANCES

### 5.8.1 Shell Attachments

**5.8.1.1** Shell attachments shall be made, inspected, and removed in conformance with Section 7.

a. Permanent attachments are items welded to the shell that will remain while the tank is in its intended service. These include items such as wind girders, stairs, gauging systems, davits, walkways, tank anchors, supports for internal items such as heating coils and other piping supports, ladders, floating roof supports welded to the shell, exterior piping supports, grounding clips, insu-

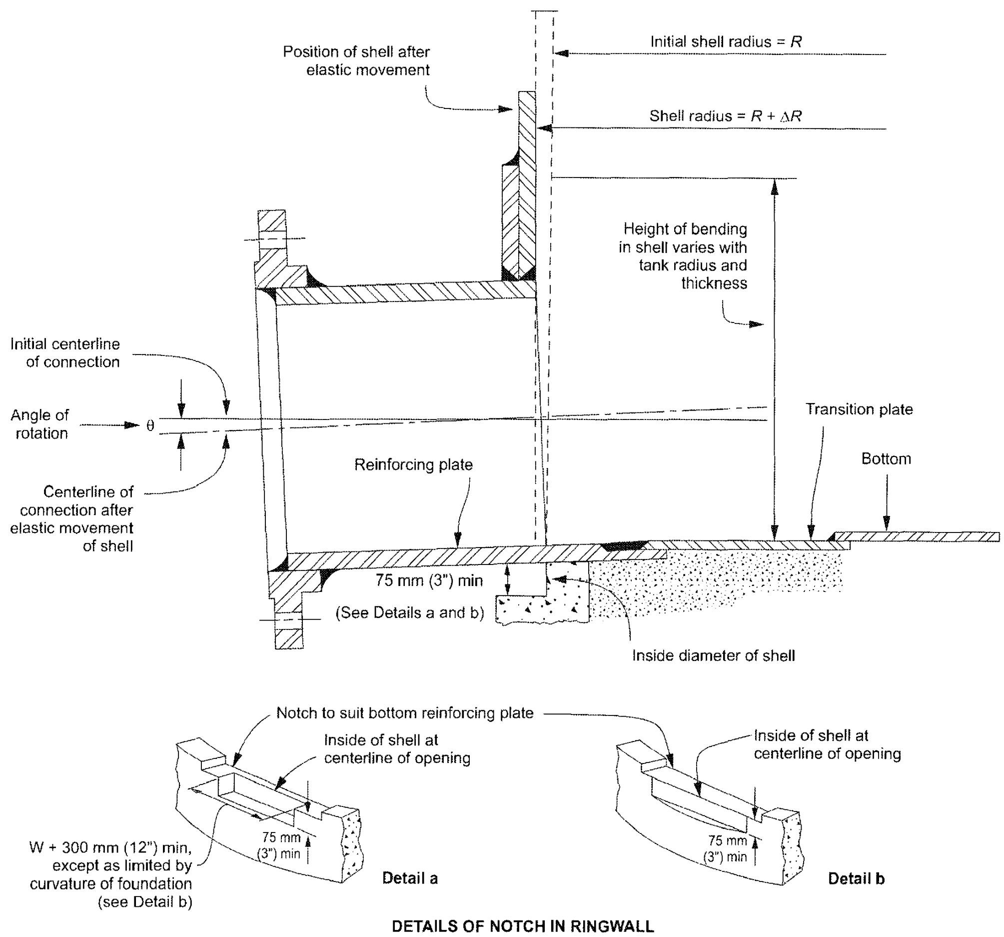



Figure 5-15—Rotation of Shell Connection

lation rings, and electrical conduit and fixtures. Items installed above the maximum liquid level of the tank are not permanent attachments.

b. Temporary attachments are items welded to the shell that will be removed prior to the tank being commissioned into its intended service. These include items such as alignment clips, fitting equipment, stabilizers, and lifting lugs.

**5.8.1.2** When attachments are made to shell courses of material in Group IV, IVA, V, or VI, the movement of the shell (particularly the movement of the bottom course) under hydrostatic loading shall be considered, and the attachments shall meet the following requirements:

a. Permanent attachments may be welded directly to the shell with fillet welds having a maximum leg dimension of 13 mm ($^1/_2$ in.). The edge of any permanent attachment welds shall be at least 75 mm (3 in.) from the horizontal joints of the shell and at least 150 mm (6 in.) from the vertical joints, insert-plate joints, or reinforcing-plate fillet welds. Permanent attachment welds may cross shell horizontal or vertical butt welds providing the welds are continuous within these limits and the angle of incidence between the two welds is greater than or equal to 45 degrees. Additionally, any splice weld in the permanent attachment shall be located a minimum of 150 mm (6 in.) from any shell weld unless the splice weld is kept from intersecting the shell weld by acceptable modifications to the attachment.

b. The welding and inspection of permanent attachments to these shell courses shall conform to 7.2.3.5.

c. Temporary attachments to shell courses shall preferably be made 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 shell courses shall be removed, and any resulting damage shall be repaired and ground to a smooth profile.

### • 5.8.2 Bottom Connections

Connections to the tank bottom are permitted subject to agreement between the Purchaser and the Manufacturer with respect to details that provide strength, tightness, and utility equal to the details of shell connections specified in this Standard.

### 5.8.3 Cover Plates

**5.8.3.1** Unreinforced openings less than or equal to NPS 2 pipe size are permissible in flat cover plates without increasing the cover plate thickness if the edges of the openings are not closer to the center of the cover plate than one-fourth the height or diameter of the opening. Requirements for openings NPS 2 pipe size and smaller that do not satisfy the location requirement and for larger reinforced openings are given in 5.8.3.2 through 5.8.3.4.

**5.8.3.2** Reinforced openings in the cover plates of shell manholes and flush-type clean outs shall be limited to one-half the diameter of the manhole or one-half the least dimension of the flush-type clean out opening but shall not exceed NPS 12 pipe size. 09 The reinforcement added to an opening may be a reinforcing plate or an increased thickness of the cover plate, but in either case, the reinforcement shall provide an added reinforcing area no less than the cutout area of the opening in the cover plate.

A cover plate with a nozzle attachment for product-mixing equipment shall have a thickness at least 1.4 times greater than the thickness required by Tables 5-3a and 5-3b. The added thickness (or pad plate) for replacement of the opening cutout in the cover plate shall be based on Tables 5-3a and 5-3b. The 40% increase in thickness within a radius of one diameter of the opening may be 08 included as part of the area of replacement required. The mixer-nozzle attachment to the cover plate shall be a full-penetration weld. The manhole bolting-flange thickness shall not be less than 1.4 times the thickness required by Tables 5-3a and 5-3b. The 08 manhole nozzle neck shall be designed to support the mixer forces with a minimum thickness not less than the requirements of Tables 5-4a and 5-4b without comparison to the increased bolting-flange thickness noted in this section. 08

**5.8.3.3** When cover plates (or blind flanges) are required for shell nozzles, the minimum thickness shall be that given for flanges in Tables 5-8a and 5-8b. Reinforced openings in the cover plates (or blind flanges) of shell nozzles shall be limited to one-half the diameter of the nozzle. 08 The reinforcement added to an opening may be an added pad plate or an increased thickness of the cover plate, but in either case, the reinforcement shall provide an added reinforcing area no less than 50% of the cutout area of the opening in the cover plate. Mixer nozzles may be attached to cover plates.

**5.8.3.4** Openings in the cover plates of flush-type cleanout fittings shall be located on the vertical centerline of the cover plate and shall be in accordance with 5.8.3.1 and 5.8.3.2. Adequate provisions should be made for free movement of connected piping 09 to minimize thrusts and moments on the cover plate to 2225 N (500 lbs) and 60 N-m (500 ft-lbs). Analysis or load leak test may be used to accept greater loads or moments.

**5.8.3.5** Shell manhole covers shall have two handles. Those covers weighing more than 34 kg (75 lb) shall be equipped with either a hinge or davit to facilitate the handling of the manhole cover plate. The davit support arm shall not be welded directly to 07 the shell without a reinforcing plate.

### 5.8.4 Roof Manholes

Roof manholes shall conform to Figure 5-16 and Tables 5-13a and 5-13b. The effects of loads (other than normal personnel access) applied at the roof manhole and supporting roof structure shall be considered. Examples of such loads may include fall protection anchorage, hoisting, or personnel retrieval. 08 The roof structure and plate around the manhole shall be reinforced as necessary.

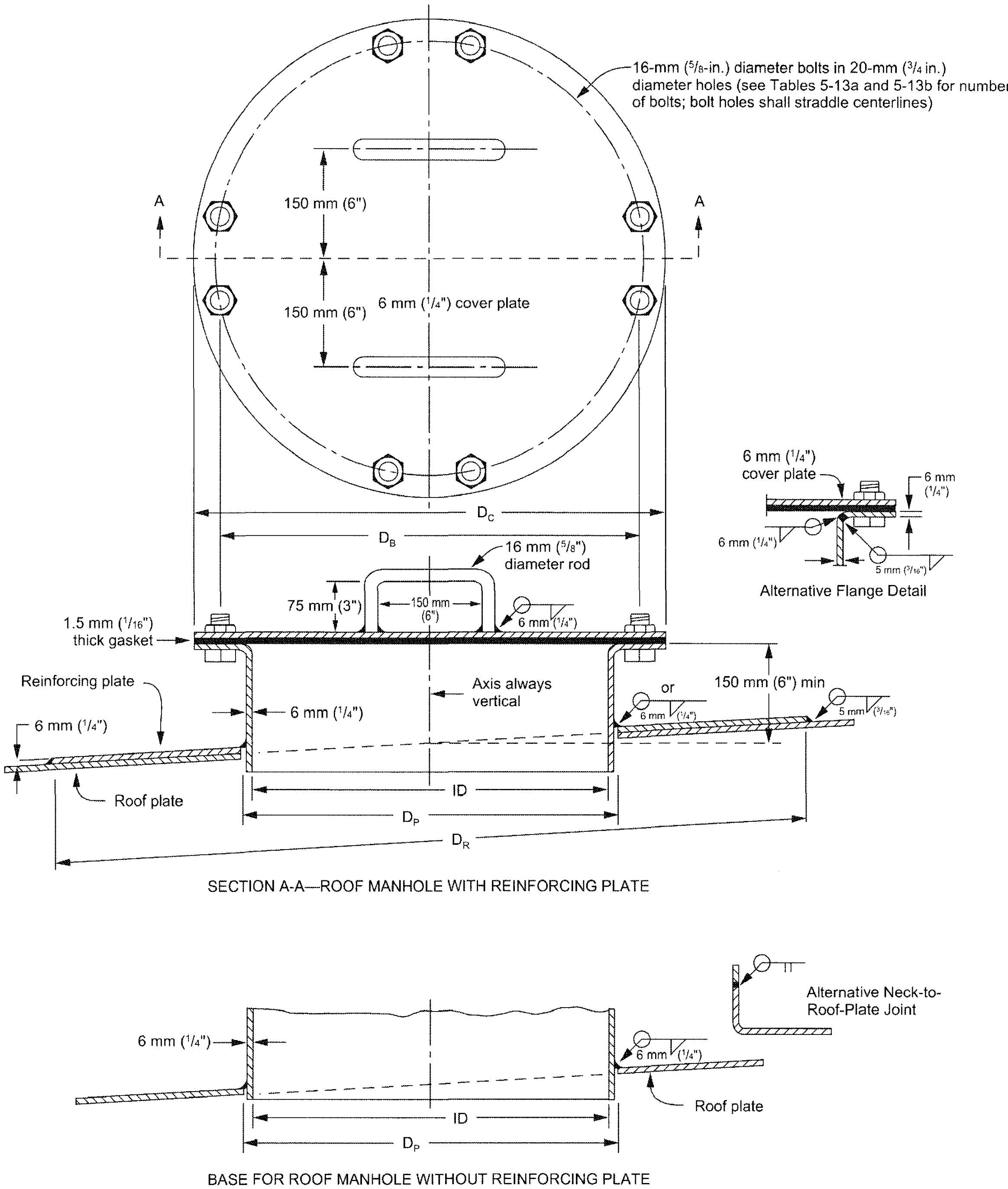
### 5.8.5 Roof Venting

**5.8.5.1** Tanks designed in accordance with this Standard and having a fixed roof shall be vented for both normal conditions (resulting from operational requirements, including maximum filling and emptying rates, and atmospheric temperature changes) and emergency conditions (resulting from exposure to an external fire). Tanks with both a fixed roof and a floating roof satisfy these requirements when they comply with the circulation venting requirements of Appendix H. All other tanks designed in accordance with this Standard and having a fixed roof shall meet the venting requirements of 5.8.5.2 and 5.8.5.3. 07

**5.8.5.2** Normal venting shall be adequate to prevent internal or external pressure from exceeding the corresponding tank design pressures and shall meet the requirements specified in API Std 2000 for normal venting.

• **5.8.5.3** Emergency venting requirements are satisfied if the tank is equipped with a weak roof-to-shell attachment (frangible joint) in accordance with 5.10.2.6, or if the tank is equipped with pressure relief devices meeting the requirements specified in API Std

08




08

Figure 5-16—Roof Manholes (See Tables 5-13a and 5-13b)

Table 5-13a—(SI) Dimensions for Roof Manholes (mm)

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Diameter of Gasket | | | |
| Size of Manhole | Diameter of Neck $ID^a$ | Diameter of Cover Plate $D_C$ | Diameter of Bolt Circle $D_B$ | Number of Bolts | Inside | Outside | Diameter of Hole in Roof Plate or Reinforcing Plate $D_P$ | Outside Diameter of Reinforcing Plate $D_R$ |
| 500 | 500 | 660 | 597 | 16 | 500 | 660 | 524 | 1050 |
| 600 | 600 | 762 | 699 | 20 | 600 | 762 | 625 | 1150 |

[a]Pipe may be used for neck, providing the minimum nominal wall thickness is 6 mm ($ID$ and $D_p$ shall be adjusted accordingly.)
Note: See Figure 5-18.

Table 5-13b—(USC) Dimensions for Roof Manholes (in.) 08

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Diameter of Gasket | | | |
| Size of Manhole | Diameter of Neck $ID^a$ | Diameter of Cover Plate $D_C$ | Diameter of Bolt Circle $D_B$ | Number of Bolts | Inside | Outside | Diameter of Hole in Roof Plate or Reinforcing Plate $D_P$ | Outside Diameter of Reinforcing Plate $D_R$ |
| 20 | 20 | 26 | $23^1/_2$ | 16 | 20 | 26 | $20^5/_8$ | 42 |
| 24 | 24 | 30 | $27^1/_2$ | 20 | 24 | 30 | $24^5/_8$ | 46 |

[a]Pipe may be used for neck, providing the minimum nominal wall thickness is $^1/_4$ in. ($ID$ and $D_p$ shall be adjusted accordingly.)
Note: See Figure 5-18.

2000 for emergency venting. When pressure relief devices are used to satisfy the emergency venting requirements, they shall achieve the flow rates specified in API Std 2000 without exceeding the following limits on internal pressure:

a. For unanchored tanks, the pressure relief devices shall be adequate to prevent internal pressure from exceeding the tank design pressure as determined in F.4.1 (subject to the limitations in F.4.2 and F.4.3, as applicable). In calculating limitations per F.4.2, use $M = 0$.

b. For anchored tanks, except those designed to F.1.3, the pressure relief devices shall be adequate to prevent internal pressure from exceeding the tank design pressure as determined in F.4.1 (subject to the limitations in F.4.3, as applicable).

c. For tanks designed to F.1.3 (anchored tanks), the pressure relief devices shall be adequate to prevent internal pressure from exceeding the design pressure specified by the Purchaser. 07

• **5.8.5.4** The filling and emptying rates are specified on the Data Sheet, Line 7. See the Data Sheet, Table 3 for venting devices, which shall be specified by the Purchaser and verified by the Manufacturer.

**5.8.5.5** Corrosion-resistant coarse-mesh bird screens (13 mm [$^1/_2$ in.] nominal openings) shall protect all free vents.

**5.8.5.6** Flanged roof nozzles shall conform to Figure 5-19 and Tables 5-14a and 5-14b. Slip-on flanges and weld neck flanges 08
shall conform to the requirements of ASME B16.5 for Class 150 plate-ring flanges shall conform to all of the dimensional requirements for slip-on welding flanges with the exception that it is acceptable to omit the extended hub on the back of the slip-on or weld neck flanges. Raised face flanges shall be provided for nozzles with attached piping. 07
Flat face flanges shall be provided for roof nozzles used for the mounting of tank accessories.

**5.8.5.7** Threaded roof nozzles shall conform to Figure 5-20 and Tables 5-15a and 5-15b. 08

### 5.8.6 Rectangular Roof Openings

**5.8.6.1** Rectangular roof openings shall conform to Figures 5-17 and 5-18 and/or this section. The effects of loads (other than normal personnel access) applied at the roof opening and supporting roof structure shall be considered. Examples of such loads may include fall protection anchorage, hoisting, or personnel retrieval. The roof structure and plate around the opening shall be reinforced as necessary. 08

## Table 5-14a—(SI) Dimensions for Flanged Roof Nozzles (mm)

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|
| Nozzle NPS | Outside Diameter of Pipe Neck | Diameter of Hole in Roof Plate or Reinforcing Plate $D_P$ | Minimum Height of Nozzle $H_R$ | Outside Diameter of Reinforcing Plate[a] $D_R$ |
| $1\frac{1}{2}$ | 48.3 | 50 | 150 | 125 |
| 2 | 60.3 | 65 | 150 | 175 |
| 3 | 88.9 | 92 | 150 | 225 |
| 4 | 114.3 | 120 | 150 | 275 |
| 6 | 168.3 | 170 | 150 | 375 |
| 8 | 219.1 | 225 | 150 | 450 |
| 10 | 273.0 | 280 | 200 | 550 |
| 12 | 323.8 | 330 | 200 | 600 |

[a]Reinforcing plates are not required on nozzles NPS 6 or smaller but may be used if desired.
Note: See Figure 5-19.

11 ## Table 5-14b—(USC) Dimensions for Flanged Roof Nozzles (in.)

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|
| Nozzle NPS | Outside Diameter of Pipe Neck | Diameter of Hole in Roof Plate or Reinforcing Plate $D_P$ | Minimum Height of Nozzle $H_R$ | Outside Diameter of Reinforcing Plate[a] $D_R$ |
| $1\frac{1}{2}$ | 1.900 | 2 | 6 | 5 |
| 2 | $2\frac{3}{8}$ | $2\frac{1}{2}$ | 6 | 7 |
| 3 | $3\frac{1}{2}$ | $3\frac{5}{8}$ | 6 | 9 |
| 4 | $4\frac{1}{2}$ | $4\frac{5}{8}$ | 6 | 11 |
| 6 | $6\frac{5}{8}$ | $6\frac{3}{4}$ | 6 | 15 |
| 8 | $8\frac{5}{8}$ | $8\frac{7}{8}$ | 6 | 18 |
| 10 | $10\frac{3}{4}$ | 11 | 8 | 22 |
| 12 | $12\frac{3}{4}$ | 13 | 8 | 24 |

[a]Reinforcing plates are not required on nozzles NPS 6 or smaller but may be used if desired.
Note: See Figure 5-19.

**5.8.6.2** The cover plate thickness and/or structural support shall be designed to limit maximum fiber stresses in accordance with this Standard, however, cover plate thickness shall not be less than 5 mm ($^3/_{16}$ in.). In addition to other expected design loads, consider a 112 kg (250 lb) person standing in the center of the installed/closed cover. The designer shall consider wind in the design of hinged openings and how removed covers will be handled without damage (adequate rigidity).

**5.8.6.3** Rectangular openings, other than shown in Figures 5-17 and 5-18, and openings larger than indicated shall be designed by an engineer experienced in tank design in accordance with this Standard. Hinged covers prescribed in Figure 5-18 may not be used on roofs designed to contain internal pressure. Flanged covers prescribed in Figure 5-17 may not be used on tanks with internal pressures (acting across the cross sectional area of the tank roof) that exceed the weight of the roof plates. This section applies only to fixed steel roofs.

### • 5.8.7 Water Drawoff Sumps

08 Water drawoff sumps shall be as specified in Figure 5-21 and Tables 5-16a and 5-16b) unless otherwise specified by the Purchaser.

Table 5-15a—(SI) Dimensions for Threaded Roof Nozzles (mm)

| Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|
| Nozzle NPS | Coupling NPS | Diameter of Hole in Roof Plate or Reinforcing Plate $D_P$ | Outside Diameter of Reinforcing Plate[a] $D_R$ |
| 3/4 | 3/4 | 36 | 100 |
| 1 | 1 | 44 | 110 |
| 1 1/2 | 1 1/2 | 60 | 125 |
| 2 | 2 | 76 | 175 |
| 3 | 3 | 105 | 225 |
| 4 | 4 | 135 | 275 |
| 6 | 6 | 192 | 375 |
| 8 | 8 | 250 | 450 |
| 10 | 10 | 305 | 550 |
| 12 | 12 | 360 | 600 |

[a]Reinforcing plates are not required on nozzles NPS 6 or smaller but may be used if desired.
Note: See Figure 5-20.

Table 5-15b—(USC) Dimensions for Threaded Roof Nozzles (in.) 08

| Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|
| Nozzle NPS | Coupling NPS | Diameter of Hole in Roof Plate or Reinforcing Plate $D_P$ | Outside Diameter of Reinforcing Plate[a] $D_R$ |
| 3/4 | 3/4 | 1 7/16 | 4 |
| 1 | 1 | 1 23/32 | 4 1/2 |
| 1 1/2 | 1 1/2 | 2 11/32 | 5 |
| 2 | 2 | 3 | 7 |
| 3 | 3 | 4 1/8 | 9 |
| 4 | 4 | 5 11/32 | 11 |
| 6 | 6 | 7 17/32 | 15 |
| 8 | 8 | 9 7/8 | 18 |
| 10 | 10 | 12 | 22 |
| 12 | 12 | 14 1/4 | 24 |

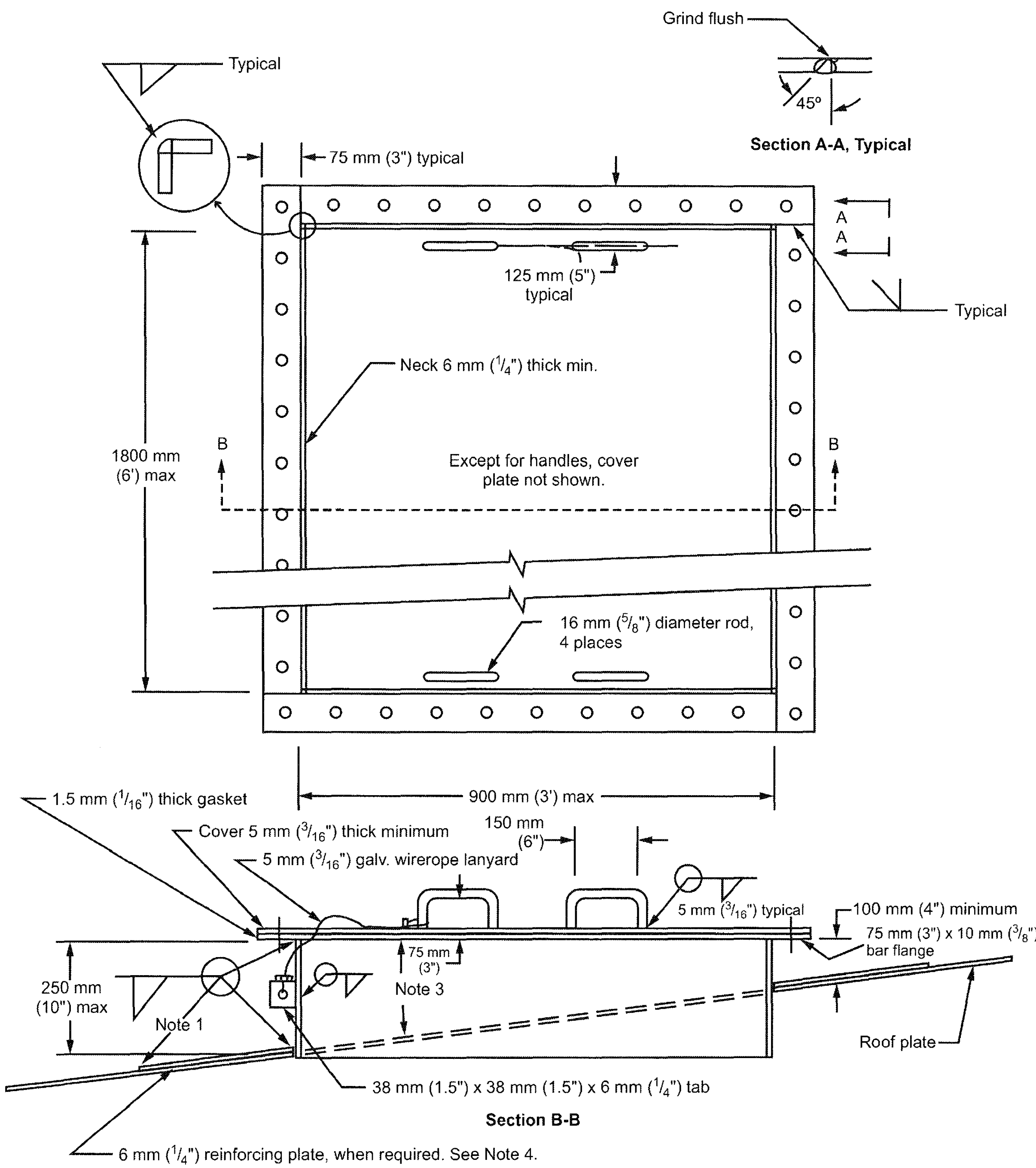
[a]Reinforcing plates are not required on nozzles NPS 6 or smaller but may be used if desired.
Note: See Figure 5-20.

### 5.8.8 Scaffold-Cable Support

The scaffold-cable support shall conform to Figure 5-22. Where seams or other attachments are located at the center of the tank roof, the scaffold support shall be located as close as possible to the center.

### 5.8.9 Threaded Connections

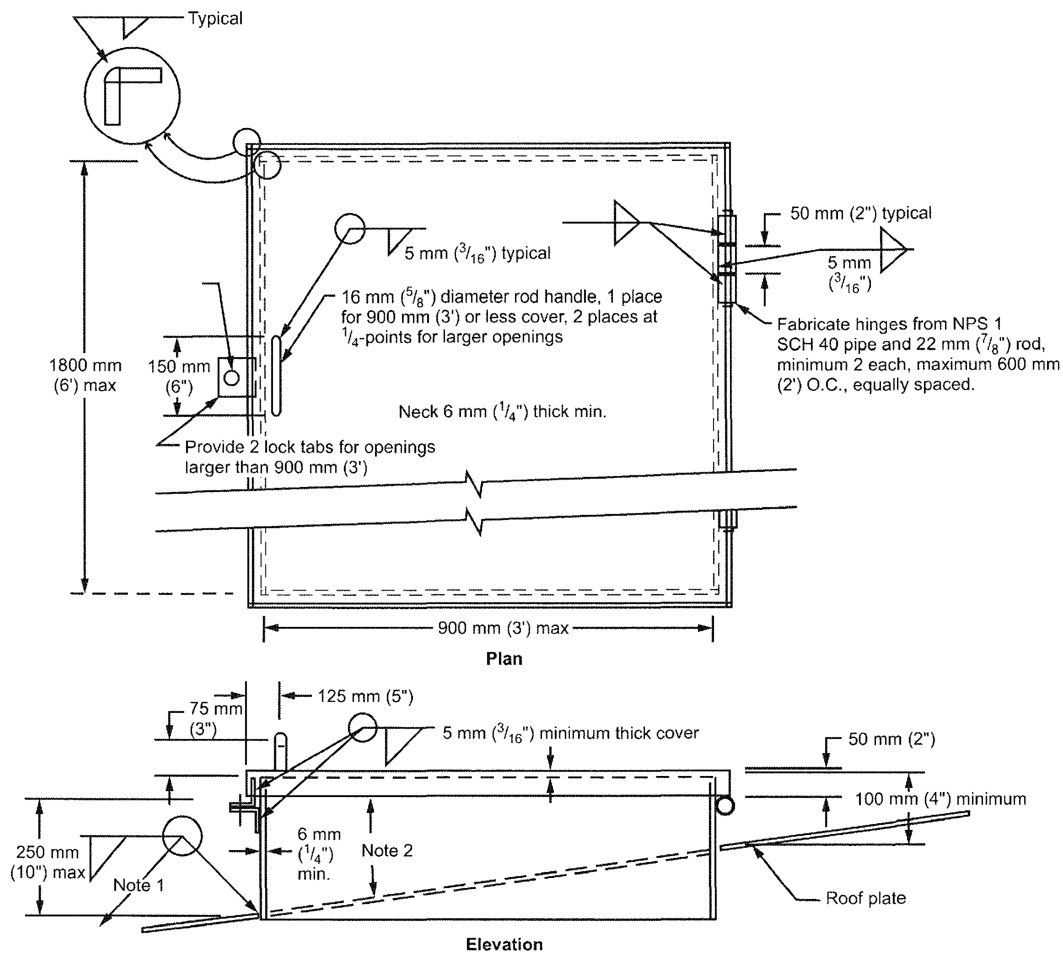
Threaded piping connections shall be female and tapered. The threads shall conform to the requirements of ASME B1.20.1 for tapered pipe threads.




Notes:

1. Weld size shall be the smaller of the plate thicknesses being joined.
2. Cover may be either parallel to roof or horizontal. Opening may be oriented as desired.
3. Bolts shall be 16-mm (5/8-in.) diameter in 20-mm (3/4-in.) holes, which shall be equally spaced and shall not exceed 125-mm (5 in.) on center.
4. When required, provide 6-mm (1/4-in.) reinforcing plate. Width at least 1/2 smallest opening dimension. Round outside corners with 75 mm (3 in.) radius, minimum. Seams shall be square groove butt-welded.

Figure 5-17—Rectangular Roof Openings with Flanged Covers




Notes:
1. Weld size shall be the smaller of the plate thicknesses being joined.
2. Cover may be either parallel to roof or horizontal. Opening may be oriented as desired.
3. Reinforcement, when required, shall be as shown in Figure 5-19.
4. Not for use on roofs designed to contain internal pressure.

Figure 5-18—Rectangular Roof Openings with Hinged Cover

### 5.8.10 Platforms, Walkways, and Stairways

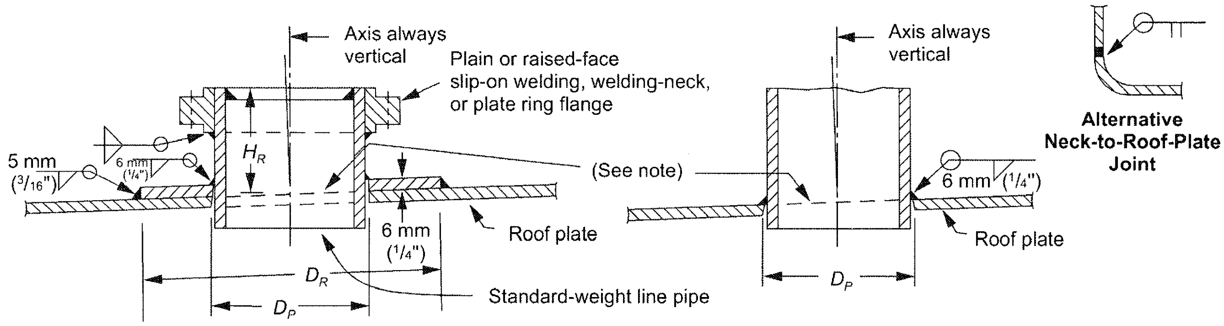
a. Platforms, walkways, and stairways shall be in accordance with Tables 5-17, 5-18, 5-19a, and 5-19b, and OSHA 29 *CFR* 1910, Subpart D, or equivalent national safety standard and the requirements herein, except as noted herein. 08

b. For examples of acceptable details, see Process Industry Practices standard details PIP STF05501, PIP STF05520, and PIP STF05521 (see www.pip.org).

c. Unless declined on the Data Sheet, Line 24, a roof edge landing or gauger's platform shall be provided at the top of all tanks. 07

### 5.8.11 Other Appurtenances and Attachments

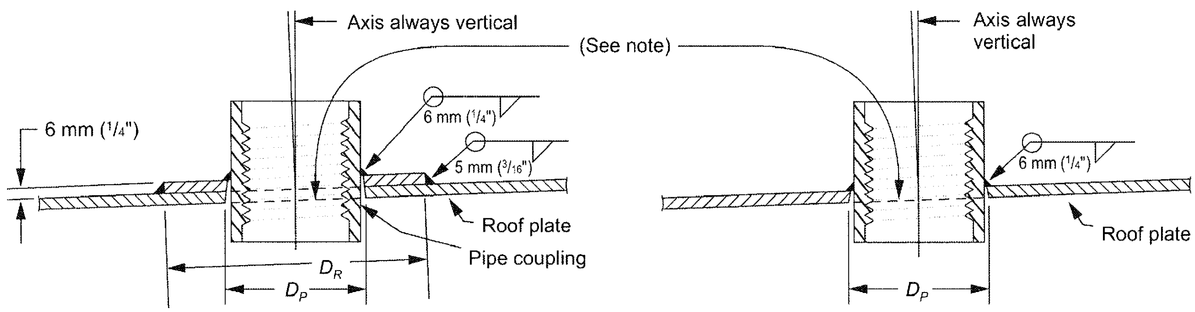
**5.8.11.1** Floating suction lines shall be provided when specified on the Data Sheet, Table 4. Floating suction lines using rigid articulated (having one or more swing joints) pipe shall be designed to travel in a vertical plane and prevent damage to the floating




NOZZLE WITH REINFORCING PLATE BASE FOR NOZZLE WITHOUT REINFORCING PLATE

Note: When the roof nozzle is used for venting, the neck shall be trimmed flush with the roofline.

08 Figure 5-19—Flanged Roof Nozzles (See Tables 5-14a and 5-14b)




NOZZLE WITH REINFORCING PLATE NOZZLE WITHOUT REINFORCING PLATE

Note: See 5.8.9 for requirements for threaded connections. When the roof nozzle is used for venting, the neck shall be trimmed flush with the roofline.

08 Figure 5-20—Threaded Roof Nozzles (See Tables 5-15a and 5-15b)

roof and the suction line through its design range of travel. These lines shall be designed so that the vertical plane is as close as possible to, and in no case greater than 10 degrees off, a radial line from the tank centerline to the nozzle. Adjustments shall be made to clear internal structures.

• **5.8.11.2** Inlet diffusers shall be provided if requested in the Other Tank Appurtenances section of the Data Sheet, Table 4. (See API RP 2003 and Appendix H for additional information.)

• **5.8.11.3** If required by the Purchaser, grounding lugs shall be provided in the quantity specified on the Data Sheet, Table 4, and
07 comply with Figure 5-23. The lugs shall be equally spaced around the base of the tank. Provide a minimum of four lugs. The suggested maximum lug spacing is 30 m (100 ft).

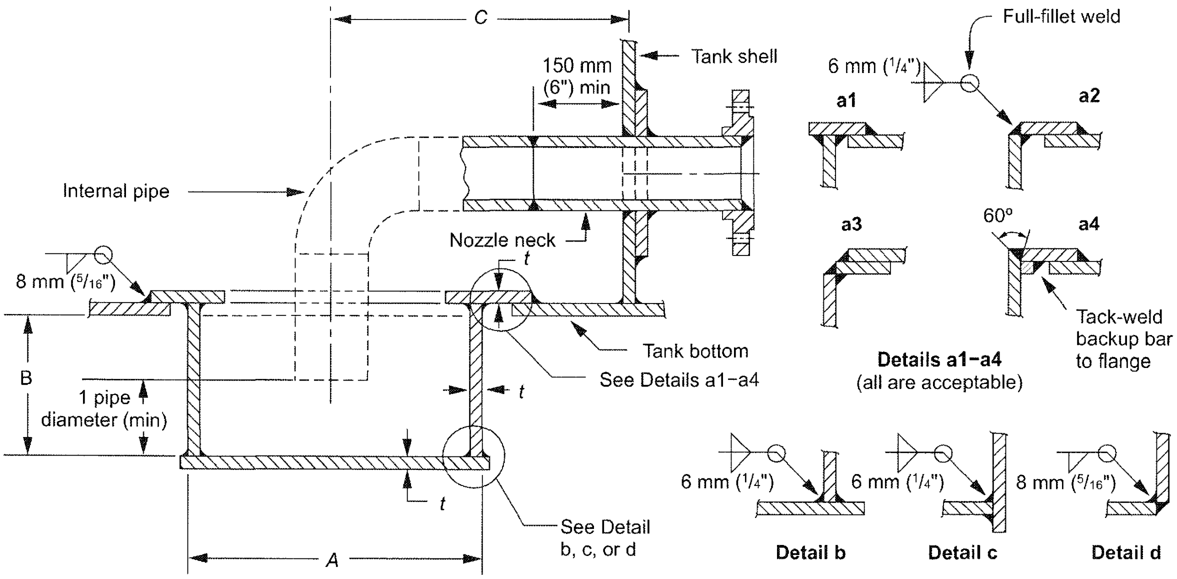
Note: Tanks that rest directly on a foundation of soil, asphalt or concrete are inherently grounded for purposes of dissipation of electrostatic charges. The addition of grounding rods or similar devices will not reduce the hazard associated with electrostatic charges in the stored product. API RP 2003 and NFPA-780 contain additional information about tank grounding issues as well as comments about lightning protection.

**5.8.11.4** All non-circular miscellaneous pads shall have rounded corners with a minimum radius of 50 mm (2 in.). Pads that must cover shell seams shall be provided with a 6 mm ($^1/_4$ in.) telltale hole (see 5.7.3.4).

## 5.9 TOP AND INTERMEDIATE STIFFENING RINGS

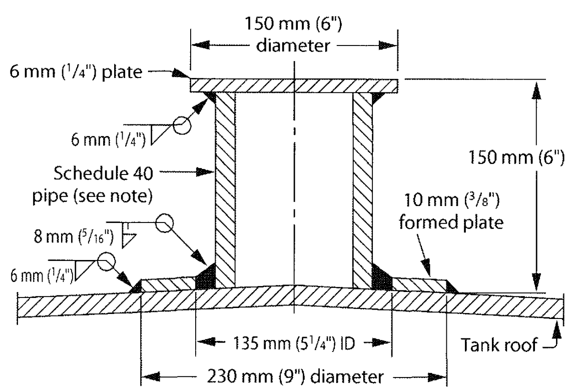
### 5.9.1 General

An open-top tank shall be provided with stiffening rings to maintain roundness when the tank is subjected to wind loads. The stiffening rings shall be located at or near the top of the top course, preferably on the outside of the tank shell. This design for rings




Note: The erection procedure shall include the following steps: (a) a hole shall be cut in the bottom plate or a sump shall be placed in the foundation before bottom placement; (b) a neat excavation shall be made to conform to the shape of the drawoff sump, the sump shall be put in place, and the foundation shall be compacted around the sump after placement; and (c) the sump shall be welded to the bottom.

Figure 5-21—Drawoff Sump (See Tables 5-16a and 5-16b) 08




Note: NPS 4 Schedule 40 pipe (wall thickness = 6.02 mm [0.237 in.]; outside diameter = 114.3 mm [4.5 in.]).

Figure 5-22—Scaffold Cable Support

used as wind girders also applies to floating-roof tanks covered in Appendix C. The top angle and the wind girders shall conform, in material and size, to the requirements of this Standard.

### 5.9.2 Types of Stiffening Rings

Stiffening rings may be made of structural sections, formed plate sections, sections built up by welding, or combinations of such types of sections assembled by welding. The outer periphery of stiffening rings may be circular or polygonal (see Figure 5-24).

### 5.9.3 Restrictions on Stiffening Rings

**5.9.3.1** The minimum size of angle for use alone or as a component in a built-up stiffening ring shall be 65 × 65 × 6 mm ($2^1/_2$ × $2^1/_2$ × $^1/_4$ in.). The minimum nominal thickness of plate for use in formed or built-up stiffening rings shall be 6 mm (0.236 in.). 08

### Table 5-16a—(SI) Dimensions for Drawoff Sumps

| NPS | Diameter of Sump mm *A* | Depth of Sump mm *B* | Distance from Center Pipe to Shell m *C* | Thickness of Plates in Sump mm *t* | Minimum Internal Pipe Thickness mm | Minimum Nozzle Neck Thickness mm |
|---|---|---|---|---|---|---|
| 2 | 610 | 300 | 1.1 | 8 | 5.54 | 5.54 |
| 3 | 910 | 450 | 1.5 | 10 | 6.35 | 7.62 |
| 4 | 1220 | 600 | 2.1 | 10 | 6.35 | 8.56 |
| 6 | 1520 | 900 | 2.6 | 11 | 6.35 | 10.97 |

Note: See Figure 5-19.

08 
### Table 5-16b—(USC) Dimensions for Drawoff Sumps

| NPS | Diameter of Sump in. *A* | Depth of Sump in. *B* | Distance from Center Pipe to Shell ft *C* | Thickness of Plates in Sump in. *t* | Minimum Internal Pipe Thickness in. | Minimum Nozzle Neck Thickness in. |
|---|---|---|---|---|---|---|
| 2 | 610 (24) | 12 | $3\frac{1}{2}$ | $\frac{5}{16}$ | 0.218 | 0.218 |
| 3 | 910 (36) | 18 | 5 | $\frac{3}{8}$ | 0.250 | 0.300 |
| 4 | 1220 (48) | 24 | $6\frac{3}{4}$ | $\frac{3}{8}$ | 0.250 | 0.337 |
| 6 | 1520 (60) | 36 | $8\frac{1}{2}$ | $\frac{7}{16}$ | 0.250 | 0.432 |

Note: See Figure 5-19.

### Table 5-17—Requirements for Platforms and Walkways

| | | |
|---|---|---|
| | 1. | All parts shall be made of metal. |
| 07 | 2. | The minimum width of the walkway shall be 610 mm (24 in.), after making adjustments at all projections. |
| | 3. | Flooring shall be made of grating or nonslip material. |
| | 4. | The height of the top railing above the floor shall be 1070 mm (42 in.).[a] |
| | 5. | The minimum height of the toeboard shall be 75 mm (3 in.). |
| | 6. | The maximum space between the top of the floor and the bottom of the toeboard shall be 6 mm ($\frac{1}{4}$ in.). |
| | 7. | The height of the midrail shall be approximately one-half the distance from the top of the walkway to the top of the railing. |
| | 8. | The maximum distance between railing posts shall be 2400 mm (96 in.). |
| | 9. | The completed structure shall be capable of supporting a moving concentrated load of 4450 N (1000 lbf), and the handrail structure shall be capable of withstanding a load of 900 N (200 lbf) applied in any direction at any point on the top rail. |
| | 10. | Handrails shall be on both sides of the platform but shall be discontinued where necessary for access. |
| | 11. | At handrail openings, any space wider than 150 mm (6 in.) between the tank and the platform should be floored. |
| | 12. | A tank runway that extends from one part of a tank to any part of an adjacent tank, to the ground, or to another structure shall be supported so that free relative movement of the structures joined by the runway is permitted. This may be accomplished by firm attachment of the runway to one tank and the use of a slip joint at the point of contact between the runway and the other tank. (This method permits either tank to settle or be disrupted by an explosion without the other tank being endangered. |
| 07 | | [a]This handrail height is required by OSHA specifications. |

## Table 5-18—Requirements for Stairways

| | |
|---|---|
| 1. | All parts shall be made of metal. |
| 2. | The minimum width of the stairs shall be 710 mm (28 in.). 07 |
| 3. | The maximum angle[a] of the stairway with a horizontal line shall be 50 degrees. |
| 4. | The minimum width of the stair treads shall be 200 mm (8 in.). (The sum of twice the rise of the stair treads plus the run [defined as the horizontal distance between the noses of successive tread pieces] shall not be less than 610 mm [24 in.] or more than 660 mm [26 in.]. Rises shall be uniform throughout the height of the stairway.]) |
| 5. | Treads shall be made of grating or nonslip material. |
| 6. | The top railing shall join the platform handrail without offset, and the height measured vertically from tread level at the nose of the tread shall be 760 mm – 860 mm (30 in. – 34 in.). |
| 7. | The maximum distance between railing posts, measured along the slope of the railing, shall be 2400 mm (96 in.). |
| 8. | The completed structure shall be capable of supporting a moving concentrated load of 4450 N (1000 lbf), and the handrail structure shall be capable of withstanding a load of 900 N (200 lbf) applied in any direction at any point on the top rail. |
| 9. | Handrails shall be on both sides of straight stairs; handrails shall also be on both sides of circular stairs when the clearance between the tank shell and the stair stringer exceeds 200 mm (8 in.). |
| 10. | Circumferential stairways shall be completely supported on the shell of the tank, and the ends of the stringers shall be clear of the ground. Stairways shall extend from the bottom of the tank up to a roof edge landing or gauger's platform. 07 |

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

## Table 5-19a—(SI) Rise, Run, and Angle Relationships for Stairways

08

| | $2R + r = 610$ mm | | | $2R + r = 660$ mm | | |
|---|---|---|---|---|---|---|
| Height of Rise mm $R$ | Width of Run mm $r$ | Angle Degrees | Angle Minutes | Width of Run mm $r$ | Angle Degrees | Angle Minutes |
| 135 | 340 | 21 | 39 | — | — | — |
| 140 | 330 | 22 | 59 | 380 | 20 | 13 |
| 145 | 320 | 24 | 23 | 370 | 21 | 24 |
| 150 | 310 | 25 | 49 | 360 | 22 | 37 |
| 155 | 300 | 27 | 19 | 350 | 23 | 53 |
| 165 | 280 | 30 | 31 | 330 | 26 | 34 |
| 170 | 270 | 32 | 12 | 320 | 27 | 59 |
| 180 | 250 | 35 | 45 | 300 | 30 | 58 |
| 185 | 240 | 37 | 38 | 290 | 32 | 32 |
| 190 | 230 | 39 | 34 | 280 | 34 | 10 |
| 195 | 220 | 41 | 33 | 270 | 35 | 50 |
| 205 | 200 | 45 | 42 | 250 | 39 | 21 |
| 210 | 190 | 47 | 52 | 240 | 41 | 11 |
| 215 | — | — | — | 230 | 43 | 4 |
| 220 | — | — | — | 220 | 45 | 0 |
| 225 | — | — | — | 210 | 46 | 58 |

Table 5-19b—(USC) Rise, Run, and Angle Relationships for Stairways

| | $2R + r = 24$ in. | | | $2R + r = 26$ in. | | |
|---|---|---|---|---|---|---|
| Height of Rise in. $R$ | Width of Run in. $r$ | Angle Degrees | Angle Minutes | Width of Run in. $r$ | Angle Degrees | Angle Minutes |
| $5^1/_2$ | $13^1/_2$ | 21 | 39 | — | — | — |
| $5^1/_2$ | 13 | 22 | 59 | 15 | 20 | 13 |
| $5^3/_4$ | $12^1/_2$ | 24 | 23 | $14^1/_2$ | 21 | 24 |
| 6 | 12 | 25 | 49 | 14 | 22 | 37 |
| $6^1/_4$ | $11^1/_2$ | 27 | 19 | $13^1/_2$ | 23 | 53 |
| $6^1/_2$ | 11 | 30 | 31 | 13 | 26 | 34 |
| $6^3/_4$ | $10^1/_2$ | 32 | 12 | $12^1/_2$ | 27 | 59 |
| 7 | 10 | 35 | 45 | 12 | 30 | 58 |
| $7^1/_4$ | $9^1/_2$ | 37 | 38 | $11^1/_2$ | 32 | 32 |
| $7^1/_2$ | 9 | 39 | 34 | 11 | 34 | 10 |
| $7^3/_4$ | $8^1/_2$ | 41 | 33 | $10^1/_2$ | 35 | 50 |
| 8 | 8 | 45 | 42 | 10 | 39 | 21 |
| $8^1/_4$ | $7^1/_2$ | 47 | 52 | $9^1/_2$ | 41 | 11 |
| $8^1/_2$ | — | — | — | 9 | 43 | 4 |
| $8^3/_4$ | — | — | — | $8^1/_2$ | 45 | 0 |
| 9 | — | — | — | 8 | 46 | 58 |

08

08 **5.9.3.2** When the stiffening rings are located more than 0.6 m (2 ft) below the top of the shell, the tank shall be provided with a 65 × 65 × 6 mm ($2^1/_2 \times 2^1/_2 \times {}^3/_{16}$ in.) top curb angle for shells 5 mm ($^3/_{16}$ in.) thick, with a 75 × 75 × 6 mm ($3 \times 3 \times {}^1/_4$ in.) angle for shells more than 5 mm ($^3/_{16}$ in.) thick, or with other members of equivalent section modulus.

07 • **5.9.3.3** Rings that may trap liquid shall be provided with adequate drain holes. Uninsulated tanks having rings shall have small water-shedding slopes and/or drain holes or slots unless the Purchaser approves an alternate means of drainage. If drain holes are provided, they shall be at least 25 mm (1 in.) diameter (or slot width) on 2400 mm (8 ft) centers or less. Insulated tanks where the rings function as insulation closures shall have no drain holes or slots.

**5.9.3.4** Welds joining stiffening rings to the tank shell may cross vertical tank seam welds. Any splice weld in the ring shall be located a minimum of 150 mm (6 in.) from any vertical shell weld. Stiffening rings may also cross vertical tank seam welds with the use of coping (rat hole) of the stiffening ring at the vertical tank seam. Where the coping method is used, the required section modulus of the stiffening ring and weld spacing must be maintained.

### 5.9.4 Stiffening Rings as Walkways

A stiffening ring or any portion of it that is specified as a walkway shall have a width not less than 710 mm (28 in.) clear of projections including the angle on the top of the tank shell. The clearance around local projections shall not be less than 610 mm (24 in.). Unless the tank is covered with a fixed roof, the stiffening ring (used as a walkway) shall be located 1100 mm (42 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 used as a walkway.

### 5.9.5 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. The supports shall be spaced at the intervals required for the dead load and vertical live load; however, the spacing shall not exceed 24 times the width of the outside compression flange.

### 5.9.6 Top Wind Girder

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

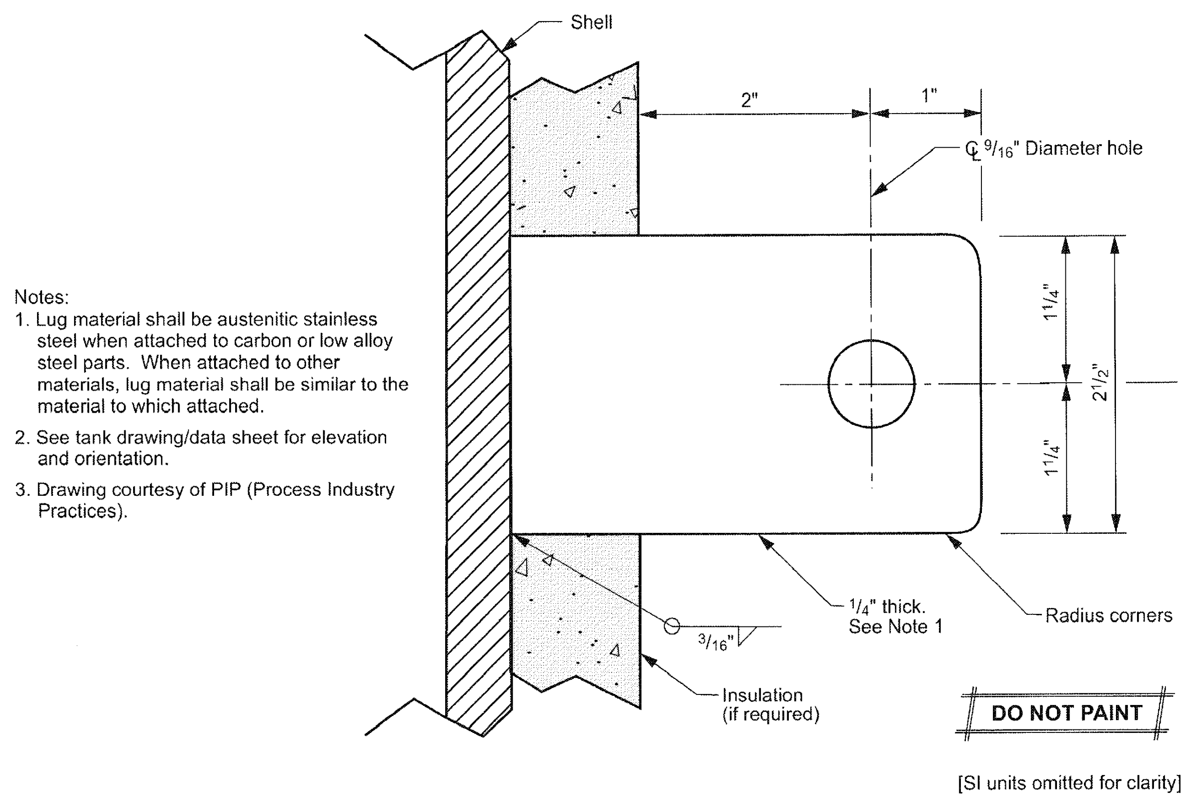



Figure 5-23—Grounding Lug 07

In SI units:

$$Z = \frac{D^2 H_2}{17}\left(\frac{V}{190}\right)^2$$

where

$Z$ = required minimum section modulus (cm$^3$),
$D$ = nominal tank diameter (m),
$H_2$ = height of the tank shell (m), including any freeboard provided above the maximum filling height as a guide for a floating roof,
$V$ = design wind speed (3-sec gust) (km/h) (see 5.2.1[k]). 08

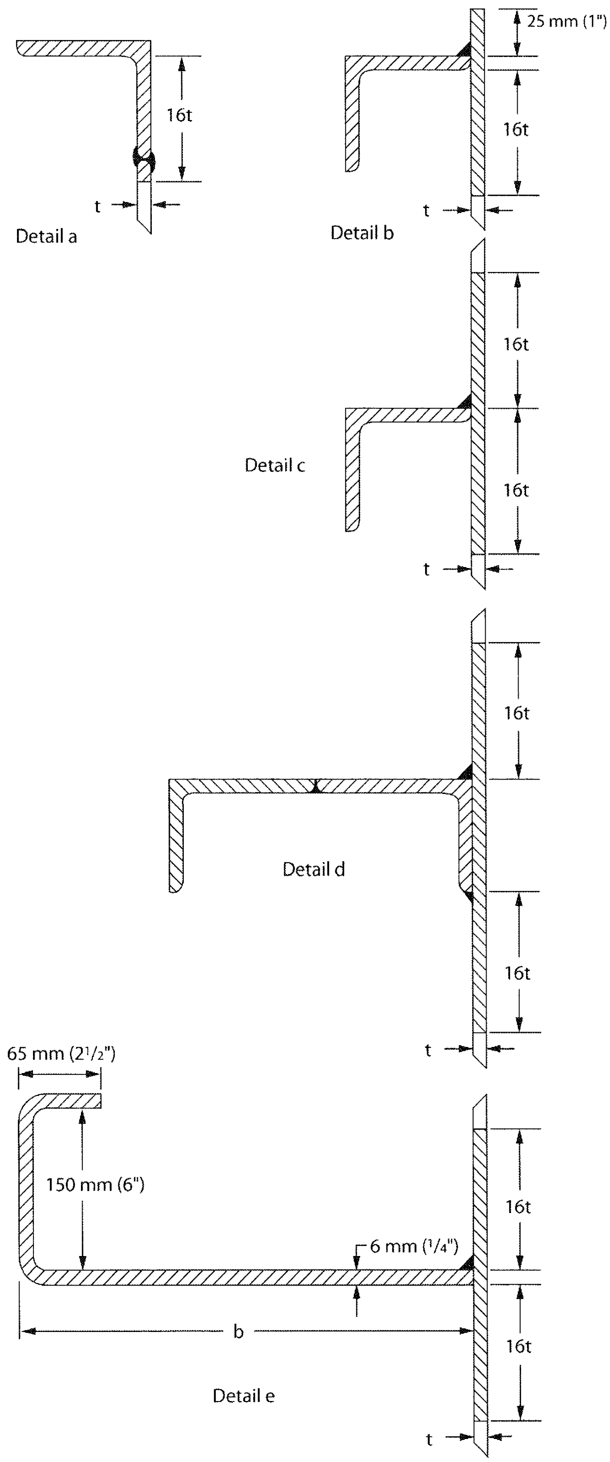
In US Customary units:

$$Z = 0.0001\, D^2 H_2 \left(\frac{V}{120}\right)^2$$

where

$Z$ = required minimum section modulus (in.$^3$),
$D$ = nominal tank diameter (ft),
$H_2$ = height of the tank shell (ft), including any freeboard provided above the maximum filling height as a guide for a floating roof,
$V$ = design wind speed (3-sec gust) (mph) (see 5.2.1[k]). 08

• Note: For tank diameters over 60 m (200 ft), the section modulus required by the equation may be reduced by agreement between the Purchaser and the Manufacturer, but the modulus may not be less than that required for a tank diameter of 61 m (200 ft). (A description of the loads on the tank shell that are included in the design wind speed can be found in Item a of the note to 5.9.7.1.) 08




11 Note: The section moduli given in Tables 5-20a and 5-20b for Details c and d are based on the longer leg being located horizontally (perpendicular to the shell) when angles with uneven legs
08 are used.

09 Figure 5-24—Typical Stiffening-Ring Sections for Tank Shells (See Tables 5-20a and 5-20b)

## Table 5-20a—(SI) Section Moduli ($cm^3$) of Stiffening-Ring Sections on Tank Shells

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | |
|---|---|---|---|---|---|---|
| Member Size | As-Built Shell Thickness (mm) | | | | | 08 |
| mm | 5 | 6 | 8 | 10 | 11 | 09 |
| | | Top Angle: Figure 5-24, Detail a | | | | |
| 65 × 65 × 6 | 6.58 | 6.77 | — | — | — | |
| 65 × 65 × 8 | 8.46 | 8.63 | — | — | — | |
| 75 × 75 × 10 | 13.82 | 13.97 | — | — | — | |
| | | Curb Angle: Figure 5-24, Detail b | | | | |
| 65 × 65 × 6 | 27.03 | 28.16 | — | — | — | |
| 65 × 65 × 8 | 33.05 | 34.67 | — | — | — | |
| 75 × 75 × 6 | 35.98 | 37.49 | — | — | — | |
| 75 × 75 × 10 | 47.24 | 53.84 | — | — | — | |
| 100 × 100 × 7 | 63.80 | 74.68 | — | — | — | |
| 100 × 100 × 10 | 71.09 | 87.69 | — | — | — | |
| | | One Angle: Figure 5-24, Detail c (See Note) | | | | |
| 65 × 65 × 6 | 28.09 | 29.15 | 30.73 | 32.04 | 32.69 | |
| 65 × 65 × 8 | 34.63 | 36.20 | 38.51 | 40.32 | 41.17 | |
| 100 × 75 × 7 | 60.59 | 63.21 | 66.88 | 69.48 | 70.59 | |
| 102 × 75 × 8 | 66.97 | 70.08 | 74.49 | 77.60 | 78.90 | |
| 125 × 75 × 8 | 89.41 | 93.71 | 99.86 | 104.08 | 105.78 | 08 |
| 125 × 75 × 10 | 105.20 | 110.77 | 118.97 | 124.68 | 126.97 | |
| 150 × 75 × 10 | 134.14 | 141.38 | 152.24 | 159.79 | 162.78 | |
| 150 × 100 × 10 | 155.91 | 171.17 | 184.11 | 193.08 | 196.62 | |
| | | Two Angles: Figure 5-24, Detail d (See Note) | | | | |
| 100 × 75 × 8 | 181.22 | 186.49 | 195.15 | 201.83 | 204.62 | |
| 100 × 75 × 10 | 216.81 | 223.37 | 234.55 | 243.41 | 247.16 | |
| 125 × 75 × 8 | 249.17 | 256.84 | 269.59 | 279.39 | 283.45 | |
| 125 × 75 × 10 | 298.77 | 308.17 | 324.40 | 337.32 | 342.77 | |
| 150 × 75 × 8 | 324.97 | 335.45 | 353.12 | 366.82 | 372.48 | |
| 150 × 75 × 10 | 390.24 | 402.92 | 425.14 | 443.06 | 450.61 | |
| 150 × 100 × 10 | 461.11 | 473.57 | 495.62 | 513.69 | 521.41 | |
| | | Formed Plate: Figure 5-24, Detail e | | | | |
| b = 250 | — | 341 | 375 | 392 | 399 | |
| b = 300 | — | 427 | 473 | 496 | 505 | |
| b = 350 | — | 519 | 577 | 606 | 618 | |
| b = 400 | — | 615 | 687 | 723 | 737 | |
| b = 450 | — | 717 | 802 | 846 | 864 | |
| b = 500 | — | 824 | 923 | 976 | 996 | |
| b = 550 | — | 937 | 1049 | 1111 | 1135 | |
| b = 600 | — | 1054 | 1181 | 1252 | 1280 | |
| b = 650 | — | 1176 | 1317 | 1399 | 1432 | |
| b = 700 | — | 1304 | 1459 | 1551 | 1589 | |
| b = 750 | — | 1436 | 1607 | 1709 | 1752 | |
| b = 800 | — | 1573 | 1759 | 1873 | 1921 | |
| b = 850 | — | 1716 | 1917 | 2043 | 2096 | |
| b = 900 | — | 1864 | 2080 | 2218 | 2276 | |
| b = 950 | — | 2016 | 2248 | 2398 | 2463 | |
| b = 1000 | — | 2174 | 2421 | 2584 | 2654 | |

Note: The section moduli for Details c and d are based on the longer leg being located horizontally (perpendicular to the shell) when angles with uneven legs are used.

08 Table 5-20b—(USC) Section Moduli (in.$^3$) of Stiffening-Ring Sections on Tank Shells

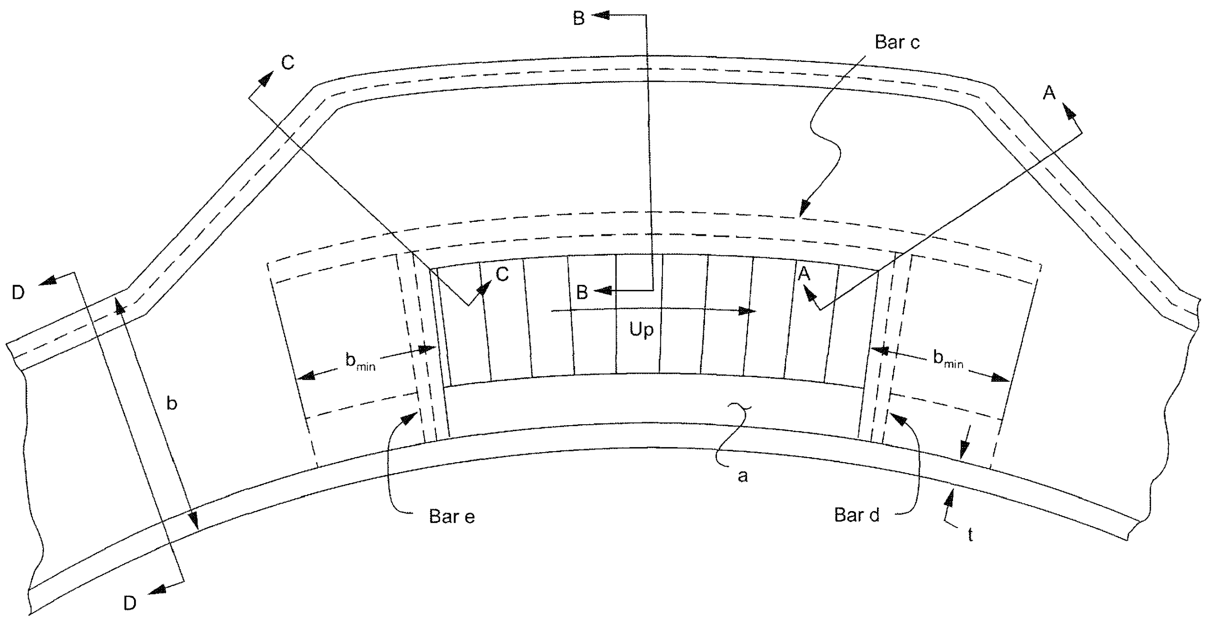
| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
|---|---|---|---|---|---|
| 09 Member Size | As-Built Shell Thickness (in.) | | | | |
| in. | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ |
| | | Top Angle: Figure 5-24, Detail a | | | |
| $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ | 0.41 | 0.42 | — | — | — |
| $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ | 0.51 | 0.52 | — | — | — |
| $3 \times 3 \times \frac{3}{8}$ | 0.89 | 0.91 | — | — | — |
| | | Curb Angle: Figure 5-24, Detail b | | | |
| $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ | 1.61 | 1.72 | — | — | — |
| $2\frac{1}{2} \times 2\frac{1}{2} \times /_{16}$ | 1.89 | 2.04 | — | — | — |
| $3 \times 3 \times \frac{1}{4}$ | 2.32 | 2.48 | — | — | — |
| $3 \times 3 \times \frac{3}{8}$ | 2.78 | 3.35 | — | — | — |
| $4 \times 4 \times \frac{1}{4}$ | 3.64 | 4.41 | — | — | — |
| $4 \times 4 \times \frac{3}{8}$ | 4.17 | 5.82 | — | — | — |
| | | One Angle: Figure 5-24, Detail c (See Note) | | | |
| $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ | 1.68 | 1.79 | 1.87 | 1.93 | 2.00 |
| $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ | 1.98 | 2.13 | 2.23 | 2.32 | 2.40 |
| $4 \times 3 \times \frac{1}{4}$ | 3.50 | 3.73 | 3.89 | 4.00 | 4.10 |
| $4 \times 3 \times \frac{5}{16}$ | 4.14 | 4.45 | 4.66 | 4.82 | 4.95 |
| $5 \times 3 \times \frac{5}{16}$ | 5.53 | 5.96 | 6.25 | 6.47 | 6.64 |
| $5 \times 3\frac{1}{2} \times \frac{5}{16}$ | 6.13 | 6.60 | 6.92 | 7.16 | 7.35 |
| $5 \times 3\frac{1}{2} \times \frac{3}{8}$ | 7.02 | 7.61 | 8.03 | 8.33 | 8.58 |
| 08 $6 \times 4 \times \frac{3}{8}$ | 9.02 | 10.56 | 11.15 | 11.59 | 11.93 |
| | | Two Angles: Figure 5-24, Detail d (See Note) | | | |
| $4 \times 3 \times \frac{5}{16}$ | 11.27 | 11.78 | 12.20 | 12.53 | 12.81 |
| $4 \times 3 \times \frac{3}{8}$ | 13.06 | 13.67 | 14.18 | 14.60 | 14.95 |
| $5 \times 3 \times \frac{5}{16}$ | 15.48 | 16.23 | 16.84 | 17.34 | 17.74 |
| $5 \times 3 \times \frac{3}{8}$ | 18.00 | 18.89 | 19.64 | 20.26 | 20.77 |
| $5 \times 3\frac{1}{2} \times \frac{5}{16}$ | 16.95 | 17.70 | 18.31 | 18.82 | 19.23 |
| $5 \times 3\frac{1}{2} \times \frac{3}{8}$ | 19.75 | 20.63 | 21.39 | 22.01 | 22.54 |
| $6 \times 4 \times \frac{3}{8}$ | 27.74 | 28.92 | 29.95 | 30.82 | 31.55 |
| | | Formed Plate: Figure 5-24, Detail e | | | |
| 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 |

Note: The section moduli for Details c and d are based on the longer leg being located horizontally (perpendicular to the shell) when angles with uneven legs are used.

**5.9.6.2** The section modulus of the stiffening ring shall be based on the properties of the applied members and may include a portion of the tank shell for a distance of 16*t* below and, if applicable, above the shell-ring attachment where *t* is the as-built shell thickness, unless otherwise specified. 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 (see Figure 5-24 and Tables 5-20a and 5-20b). 09 08

**5.9.6.3** When a stair opening is installed through a stiffening ring, the section modulus of the portion of the ring outside the opening, including the transition section, shall conform to the requirements of 5.9.6.1. The shell adjacent to the opening shall be stiffened with an angle or a bar, the wide side of which is placed in a horizontal plane. The other sides of the opening shall also be stiffened with an angle or a bar, the wide side of which is placed in a vertical plane. The cross-sectional area of these rim stiffeners shall be greater than or equal to the cross-sectional area of the portion of shell included in the section-modulus calculations for the stiffening ring. These rim stiffeners or additional members shall provide a suitable toe board around the opening.

The stiffening members shall extend beyond the end of the opening for a distance greater than or equal to the minimum depth of the regular ring sections. The end stiffening members shall frame into the side stiffening members, and the end and side stiffening members shall be connected to ensure that their full strength is developed. Figure 5-25 shows the opening described in this section. Alternative details that provide a load-carrying capacity equal to that of the girder cross-section away from the opening may be provided.




09

Notes:
1. The cross-sectional area of a, c, d, and e must equal $32t^2$. The section of the figure designated "a" may be a bar or an angle whose wide leg is horizontal. The other sections may be bars or angles whose wide legs are vertical.
2. Bars c, d, and e may be placed on the top of the girder web, provided they do not create a tripping hazard.
3. The section modulus of Sections A-A, B-B, C-C, and D-D shall conform to 5.9.6.1.
4. The stairway may be continuous through the wind girder or may be offset to provide a landing.
5. See 5.9.6.3 for toeboard requirements.

Figure 5-25—Stairway Opening through Stiffening Ring

### 5.9.7 Intermediate Wind Girders

**5.9.7.1** The maximum height of the unstiffened shell shall be calculated as follows:

In SI units:

$$H_1 = 9.47t\sqrt{\left(\frac{t}{D}\right)^3}\left(\frac{190}{V}\right)^2$$

where

$H_1$ = vertical distance, in m, between the intermediate wind girder and the top angle of the shell or the top wind girder of an open-top tank,

11 • $t$ = nominal thickness, unless otherwise specified, of the thinnest shell course (mm) (see Note 1),

$D$ = nominal tank diameter (m),

08 $V$ = design wind speed (3-sec gust) (km/h) (see 5.2.1[k]).

In US Customary units:

$$H_1 = 600{,}000t\sqrt{\left(\frac{t}{D}\right)^3}\left(\frac{120}{V}\right)^2$$

where

$H_1$ = vertical distance, in ft, between the intermediate wind girder and the top angle of the shell or the top wind girder of an open-top tank,

11 • $t$ = nominal thickness, unless otherwise specified, of the thinnest shell course (in.) (see Note 1),

$D$ = nominal tank diameter (ft),

08 $V$ = design wind speed (3-sec gust) (mph) (see 5.2.1[k]).

Note 1: The structural stability check of wind girder stiffened shells in accordance with 5.9.6 and 5.9.7, shall be based upon nominal dimensions of the shell course and the wind girders irrespective of specified corrosion allowances whenever the "No" option is selected for "Check Buckling in Corroded Cond.?" on the Data Sheet, Line 9. Whenever the "Yes" option is selected, the check must be based upon the nominal dimensions minus the specified corrosion allowance.

Note 2: This formula is intended to cover tanks with either open tops or closed tops and is based on the following factors (for the background for the factors given in this note, see ASCE 7 and R. V. McGrath's "Stability of API Standard 650 Tank Shells"):[19]

a. The velocity pressure is:

$$p = 0.00256K_z K_{zt} K_d V^2 I G = 1.48 \text{ kPa } (31 \text{ lbf/ft}^2)$$

where

$K_z$ = velocity pressure exposure coefficient = 1.04 for exposure $C$ at a height of 40 ft,

$K_{zt}$ = 1.0 for all structures except those on isolated hills or escarpments,

$K_d$ = directionality factor = 0.95 for round tanks,

08 $V$ = 3-second gust design wind speed = 190 km/h (120 mph) at 10 m (33 ft) above ground (see 5.2.1[k]),

$I$ = importance factor = 1.0 for Category II structures,

$G$ = gust factor = 0.85 for exposure $C$.

A 0.24 kPa (5 lbf/ft$^2$) internal vacuum is added for inward drag on open-top tanks or for external pressure on closed top tanks for a total of 1.72 kPa (36 lbf/ft$^2$).

[19] R.V. McGrath, "Stability of API Standard 650 Tank Shells," *Proceedings of the American Petroleum Institute, Section III—Refining,* American Petroleum Institute, New York, 1963, Vol. 43, pp. 458 – 469.

b. The wind pressure is uniform over the theoretical buckling mode of the tank shell, which eliminates the need for a shape factor for the wind loading.

c. The modified U.S. Model Basin formula for the critical uniform external pressure on thin-wall tubes free from end loadings, subject to the total pressure specified in Item a.

● d. When other factors are specified by the Purchaser that are greater than the factors in Items a – c, the total load on the shell shall be modified accordingly, and $H_1$ shall be decreased by the ratio of 1.72 kPa (36 lbf/ft$^2$) to the modified total pressure.

**5.9.7.2** After the maximum height of the unstiffened shell, $H_1$, has been determined, the height of the transformed shell shall be calculated as follows:

a. With the following equation, change the actual width of each shell course into a transposed width of each shell course having the top shell thickness:

$$W_{tr} = W\sqrt{\left(\frac{t_{\text{uniform}}}{t_{\text{actual}}}\right)^5}$$

where

$W_{tr}$ = transposed width of each shell course, mm (in.),

$W$ = actual width of each shell course, mm (in.),

● $t_{\text{uniform}}$ = nominal thickness, unless otherwise specified, of the thinnest shell course, mm (in.), 11

● $t_{\text{actual}}$ = nominal thickness, unless otherwise specified, of the shell course for which the transposed width is being calculated, mm (in.).

b. Add the transposed widths of the courses. The sum of the transposed widths of the courses will give the height of the transformed shell.

**5.9.7.3** If the height of the transformed shell is greater than the maximum height $H_1$, an intermediate wind girder is required.

**5.9.7.3.1** For equal stability above and below the intermediate wind girder, the girder should be located at the mid-height of the transformed shell. The location of the girder on the actual shell should be at the same course and same relative position as the location of the girder on the transformed shell, using the thickness relationship in 5.9.7.2. 07

**5.9.7.3.2** Other locations for the girder may be used, provided the height of unstiffened shell on the transformed shell does not exceed $H_1$ (see 5.9.7.5).

**5.9.7.4** If half the height of the transformed shell exceeds the maximum height $H_1$, a second intermediate girder shall be used to reduce the height of unstiffened shell to a height less than the maximum.

**5.9.7.5** Intermediate wind girders shall not be attached to the shell within 150 mm (6 in.) of a horizontal joint of the shell. When the preliminary location of a girder is within 150 mm (6 in.) of a horizontal joint, the girder shall preferably be located 150 mm (6 in.) below the joint; however, the maximum unstiffened shell height shall not be exceeded.

**5.9.7.6** The required minimum section modulus of an intermediate wind girder shall be determined by the following equation:

In SI units:

$$Z = \frac{D^2 H_1}{17}\left(\frac{V}{190}\right)^2$$

where

$Z$ = required minimum section modulus (cm$^3$),

$D$ = nominal tank diameter (m),

$H_1$ = vertical distance (m), between the intermediate wind girder and the top angle of the shell or the top wind girder of an open-top tank,

$V$ = design wind speed (3-sec gust) (km/h) (see 5.2.1[k]). 08

In US Customary units:

$$Z = \frac{D^2 H_1}{10\,000}\left(\frac{V}{120}\right)^2$$

where

$Z$ = required minimum section modulus (in.$^3$),

$D$ = nominal tank diameter (ft),

$H_1$ = vertical distance (ft), between the intermediate wind girder and the top angle of the shell or the top wind girder of an open-top tank,

08 $V$ = design wind speed (3-sec gust) (mph) (see 5.2.1[k]).

Note: A description of the loads on the tank shell that are included in the design wind speed can be found in Item a of the note to 5.9.7.1.

**5.9.7.6.1** Where the use of a transformed shell permits the intermediate wind girder to be located at a height that is less than $H_1$ calculated by the formula in 5.9.7.1, 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 the minimum section modulus if the girder is attached at the transposed location.

**5.9.7.6.2** The section modulus of the intermediate wind girder shall be based on the properties of the attached members and may include a portion of the tank shell for a distance above and below the attachment to the shell, in mm (in.), of:

In SI units:

$$13.4\,(Dt)^{0.5}$$

where

$D$ = nominal tank diameter (m),

$t$ = as-built shell thickness, unless otherwise specified, at the attachment (mm).

09 In US Customary units:

$$1.47\,(Dt)^{0.5}$$

where

$D$ = nominal tank diameter (ft),

$t$ = as-built shell thickness, unless otherwise specified, at the attachment (in.).

• **5.9.7.7** An opening for a stairway in an intermediate stiffener is unnecessary when the intermediate stiffener extends no more than 150 mm (6 in.) from the outside of the shell and the nominal stairway width is at least 710 mm (28 in.). For greater outward extensions of a stiffener, the stairway shall be increased in width to provide a minimum clearance of 450 mm (18 in.) between the
07 outside of the stiffener and the handrail of the stairway, subject to the Purchaser's approval. If an opening is necessary, it may be designed in a manner similar to that specified in 5.9.6.3 for a top wind girder with the exception that only a 560 mm (22 in.) width through the stiffener need be provided.

## 5.10 ROOFS

### 5.10.1 Definitions

07 The following definitions apply to roof designs but shall not be considered as limiting the type of roof permitted by 5.10.2.8.

a. A supported cone roof is a roof formed to approximately the surface of a right cone that is supported principally either by rafters on girders and columns or by rafters on trusses with or without columns.

b. A self-supporting cone roof is a roof formed to approximately the surface of a right cone that is supported only at its periphery.

c. A self-supporting dome roof is a roof formed to approximately a spherical surface that is supported only at its periphery.

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

### 5.10.2 General

**5.10.2.1** ***Loads***: All roofs and supporting structures shall be designed for load combinations (a), (b), (c), (e), (f) and (g) of Appendix R. 08

• **5.10.2.2** ***Roof Plate Thickness:*** Roof plates shall have a nominal thickness of not less than 5 mm ($^3/_{16}$ in.) or 7-gauge sheet. Increased thickness may be required for supported cone roofs (see 5.10.4.4). Any required corrosion allowance for the plates of self-supporting roofs shall be added to the calculated thickness unless otherwise specified by the Purchaser. Any corrosion allowance for the plates of supported roofs shall be added to the greater of the calculated thickness or the minimum thickness 11 or [5 mm ($^3/_{16}$ in.) or 7-gauge sheet]. For frangible roof tanks, where a corrosion allowance is specified, the design must have frangible characteristics in the nominal (uncorroded) condition.

**5.10.2.3** ***Structural Member Attachment:*** Roof plates of supported cone roofs shall not be attached to the supporting members 08 unless otherwise approved by the Purchaser. Continuously attaching the roof to cone supporting members may be beneficial when interior lining systems are required, however, the tank roof cannot be considered frangible (see 5.10.2.6).

• **5.10.2.4** ***Structural Member Thickness:*** All internal and external structural members shall have a minimum nominal thickness (new) of 4.3 mm (0.17 in.), and a minimum corroded thickness of 2.4 mm (0.094 in.), respectively, in any component, except 11 that the minimum nominal thickness shall not be less than 6 mm (0.236 in.) for columns which by design normally resist axial compressive forces.

**5.10.2.5** ***Top Attachment:*** Roof plates shall be attached to the top angle of the tank with a continuous fillet weld on the top 08 side.

• **5.10.2.6** ***Frangible Roof:*** A roof is considered frangible (see 5.8.5 for emergency venting requirement) if the roof-to-shell joint will fail prior to the shell-to-bottom joint in the event of excessive internal pressure. When a Purchaser specifies a tank with a frangible roof, the tank design shall comply with a, b, c, or d, of the following:

a. For tanks 15 m (50 ft) in diameter or greater, the tank shall meet all of the following:

1. The slope of the roof at the top angle attachment does not exceed 2:12.
2. The roof support members shall not be attached to the roof plate.
3. The roof is attached to the top angle with a single continuous fillet weld on the top side (only) that does not exceed 5 mm ($^3/_{16}$ in.). No underside welding of roof to top angle (including seal welding) is permitted.
4. The roof-to-top angle compression ring is limited to details a - e in Figure F-2.
5. All members in the region of the roof-to-shell joint, including insulation rings, are considered as contributing to the roof-to-shell joint cross-sectional area (A) and this area is less than the limit shown below:

$$A = \frac{DL_s}{2 \pi F_y \tan\theta}$$ 11

Notes: The terms for this equation are defined in Appendix F.

The top angle size required by 5.1.5.9.e may be reduced in size if required to meet the cross sectional area limit.

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b. For self-anchored tanks with a diameter greater than or equal to 9 m (30 ft) but less than 15 m (50 ft), the tank shall meet all of the following: