energy API
AMERICAN PETROLEUM INSTITUTE

Date: August 2010

To: Purchasers of API Standard 620, *Design and Construction of Large, Welded, Low-pressure Storage Tanks*, Eleventh Edition

Re: Addendum 2

This package contains Addendum 2 of API Standard 620, *Design and Construction of Large, Welded, Low-pressure Storage Tanks*, Eleventh Edition. This package consists of the pages that have changed since the March 2009 printing of Addendum 1.

To update your copy of API Standard 620, replace, delete, or add the following pages as indicated:

Part of Book Changed	Old Pages to be Replaced	New Pages
Cover	front and back covers	front and back covers
Front Matter	title page to Addendum 1 vii–ix + blank	title page to Addendum 2 vii–ix + blank
Section 1	1-1–1-2	1-1–1-2
Section 2	2-1–2-4	2-1–2-4
Section 4	4-3–4-10	4-3–4-10
Section 5	5-3–5-8	5-3–5-8
Section 6	6-3–6-4	6-3–6-4
Section 7	7-5–7-6	7-5–7-6
Appendix I	I-1 + blank	I-1 + blank
Appendix Q	Q-1–Q-26	Q-1–Q-26
Appendix R	R-1–R-18	R-1–R-19 + blank
Appendix S	S-7–S-8	S-7–S-8

The parts of the text, tables, and figures that contain changes are indicated by a vertical bar and a small "10" in the margin.

Design and Construction of Large, Welded, Low-pressure Storage Tanks

API STANDARD 620
ELEVENTH EDITION, FEBRUARY 2008

ADDENDUM 1, MARCH 2009
ADDENDUM 2, AUGUST 2010

Design and Construction of Large, Welded, Low-pressure Storage Tanks

Downstream Segment

API STANDARD 620
ELEVENTH EDITION, FEBRUARY 2008

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Design and Construction of Large, Welded, Low-pressure Storage Tanks

Section 1—Scope

1.1 General

The API Downstream Segment has prepared this standard to cover large, field-assembled storage tanks of the type described in 1.2 that contain petroleum intermediates (gases or vapors) and finished products, as well as other liquid products commonly handled and stored by the various branches of the industry.

The rules presented in this standard cannot cover all details of design and construction because of the variety of tank sizes and shapes that may be constructed. Where complete rules for a specific design are not given, the intent is for the Manufacturer—subject to the approval of the Purchaser's authorized representative—to provide design and construction details that are as safe as those which would otherwise be provided by this standard.

The Manufacturer of a low-pressure storage tank that will bear the API 620 nameplate shall ensure that the tank is constructed in accordance with the requirements of this standard.

The rules presented in this standard are further intended to ensure that the application of the nameplate shall be subject to the approval of a qualified inspector who has made the checks and inspections that are prescribed for the design, materials, fabrication, and testing of the completed tank.

1.2 Coverage

1.2.1 This standard covers the design and construction of large, welded, low-pressure carbon steel above ground storage tanks (including flat-bottom tanks) that have a single vertical axis of revolution. This standard does not cover design procedures for tanks that have walls shaped in such a way that the walls cannot be generated in their entirety by the rotation of a suitable contour around a single vertical axis of revolution.

1.2.2 The tanks described in this standard are designed for metal temperatures not greater than 250°F and with pressures in their gas or vapor spaces not more than 15 $lbf/in.^2$ gauge.

1.2.3 The basic rules in this standard provide for installation in areas where the lowest recorded 1-day mean atmospheric temperature is –50°F. Appendix S covers stainless steel low-pressure storage tanks in ambient temperature service in all areas, without limit on low temperatures. Appendix R covers low-pressure storage tanks for refrigerated products at temperatures from +40°F to –60°F. Appendix Q covers low-pressure storage tanks for liquefied gases at temperatures not lower than –325°F. 10

1.2.4 The rules in this standard are applicable to tanks that are intended to (a) hold or store liquids with gases or vapors above their surface or (b) hold or store gases or vapors alone. These rules do not apply to lift-type gas holders.

1.2.5 Although the rules in this standard do not cover horizontal tanks, they are not intended to preclude the application of appropriate portions to the design and construction of horizontal tanks designed in accordance with good engineering practice. The details for horizontal tanks not covered by these rules shall be equally as safe as the design and construction details provided for the tank shapes that are expressly covered in this standard.

1.2.6 Appendix A has been deleted. 09

1.2.7 Appendix B covers the use of plate and pipe materials that are not completely identified with any of the specifications listed in this standard.

1.2.8 Appendix C provides information on subgrade and foundation loading conditions and foundation construction practices.

1.2.9 Appendix D provides information about imposed loads and stresses from external supports attached to a tank wall.

1.2.10 Appendix E provides considerations for the design of internal and external structural supports.

1.2.11 Appendix F illustrates through examples how the rules in this standard are applied to various design problems.

1.2.12 Appendix G provides considerations for service conditions that affect the selection of a corrosion allowance; concerns for hydrogen-induced cracking effects are specifically noted.

1.2.13 Appendix H covers preheat and post-heat stress-relief practices for improved notch toughness.

1.2.14 Appendix I covers a suggested practice for peening weldments to reduce internal stresses.

1.2.15 Appendix J is reserved for future use.

1.2.16 Appendix K provides considerations for determining the capacity of tank venting devices.

1.2.17 Appendix L covers requirements for the design of storage tanks subject to seismic load.

1.2.18 Appendix M covers the extent of information to be provided in the Manufacturer's report and presents a suggested format for a tank certification form.

1.2.19 Appendix N covers installation practices for pressure- and vacuum-relieving devices.

1.2.20 Appendix O provides considerations for the safe operation and maintenance of an installed tank, with attention given to marking, access, site drainage, fireproofing, water draw-off piping, and cathodic protection of tank bottoms.

1.2.21 Appendix P summarizes the requirements for inspection by method of examination and the reference paragraphs 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.

1.2.22 Appendix Q covers specific requirements for the materials, design, and fabrication of tanks to be used for the
10 storage of liquefied gases such as ethane, ethylene, and methane..

1.2.23 Appendix R covers specific requirements for the materials, design, and fabrication of tanks to be used for the storage of refrigerated products.

1.2.24 Appendix S covers requirements for stainless steel tanks in non-refrigerated service.

1.2.25 Appendix U covers detailed rules for the use of the ultrasonic examination (UT) method for the examination of tank seams.

1.3 Limitations

1.3.1 General

The rules presented in this standard apply to vertical, cylindrical oil storage tanks built according to API 650 as specifically allowed in 3.7.1.8, F.1, and F.7 of that standard. These rules do not apply to tanks built according to rules established for unfired pressure vessels designated for an internal pressure greater than 15 lbf/in.^{2} gauge.

1.3.2 Piping Limitations

The rules of this standard are not applicable beyond the following locations in piping connected internally or externally to the walls[1] of tanks constructed according to this standard:

a) The face of the first flange in bolted flanged connections.

b) The first threaded joint on the pipe outside the tank wall in threaded pipe connections.

c) The first circumferential joint in welding-end pipe connections that do not have a flange located near the tank. **<text deleted>** 09

[1]The term wall refers to the roof, shell and bottom of a tank as defined in 3.3. **<text deleted>** 09

Section 2—References

The most recent editions or revisions of the following standards, codes, and specifications are cited in this standard.

API Spec 5L*, Specification for Line Pipe*

API RP 520, *Sizing, Selection, and Installation of Pressure-relieving Devices in Refineries, Part II—Installation*

API RP 582, *Recommended Practice and Supplementary Welding Guidelines for the Chemical, Oil, and Gas Industries*

API Std 605*, Large-Diameter Carbon Steel Flanges (Nominal Pipe Sizes 26 Through 60; Classes 75, 150, 300, 400, 600, and 900)* (out-of-print)

API Std 650, *Welded Steel Tanks for Oil Storage*

API Std 2000, *Venting Atmospheric and Low-Pressure Storage Tanks (Non-refrigerated and Refrigerated)*

AAI[2], *Aluminum Design Manual, Specifications for Aluminum Structures* 10

ACI 318[3]*, Building Code Requirements for Reinforced Concrete* (ANSI/ACI 318)

AISC[4], *Manual of Steel Construction*

ANSI H35.2[5]*, Dimensional Tolerances for Aluminum Mill Products*

ASME B1.20.1[6], *General Purpose (in.) Pipe Threads* (ANSI/ASME B1.20.1)

ASME B16.5, *Pipe Flanges and Flanged Fittings* (ANSI/ASME B16.5)

ASME B31.1, *Power Piping*

ASME B31.3, *Chemical Plant and Petroleum Refinery Piping* (ANSI/ASME B31.3)

ASME B36.10M, *Welded and Seamless Wrought Steel Pipe* (ANSI/ASME B36.10)

ASME B96.1, *Welded Aluminum-Alloy Storage Tanks* (ANSI/ASME B96.1)

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

ASNT CP-189[7], *Standard for Qualification and Certification of Nondestructive Testing Personnel*

ASNT SNT-TC-IA*, Personnel Qualification and Certification in Nondestructive Testing*

ASTM A6[8], *General Requirements for Rolled Steel Plates, Shapes, Steel Piling, and Bars for Structural Use*

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[2]Aluminum Association Inc., 1525 Wilson Blvd, Suite 600, Arlington, Virginia 22209, www.aluminum.org.
[3]American Concrete Institute, P.O. Box 9094, Farmington Hills, Michigan 48333, www.aci-int.org.
[4]American Institute of Steel Construction, One East Wacker Drive, Suite 700, Chicago, Illinois 60601, www.aisc.org.
[5]American National Standards Institute, 25 West 43rd Street, 4th floor, New York, New York 10036, www.ansi.org.
[6]ASME International, 3 Park Avenue, New York, New York 10016, www.asme.org.
[7]American Society for Nondestructive Testing, Inc., 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.
[8]ASTM International, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM A20, *General Requirements for Steel Plates for Pressure Vessels*

ASTM A27, *Steel Castings, Carbon, for General Application*

ASTM A36, *Structural Steel*

ASTM A53, *Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*

ASTM A105, *Forging, Carbon Steel, for Piping Components*

ASTM A106, *Seamless Carbon Steel Pipe for High-Temperature Service*

ASTM A131, *Structural Steel for Ships*

ASTM A134, *Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)*

ASTM A139, *Electric-Fusion (Arc) Welded Steel Pipe ([NPS] in 4 in. and Over)*

ASTM A181, *Forgings, Carbon Steel, for General-Purpose Piping*

ASTM A182, *Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*

ASTM A193, *Alloy-Steel and Stainless Bolting Materials for High-Temperature Service*

ASTM A194, *Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service*

ASTM A213, *Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat Exchanger Tubes*

ASTM A240, *Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels*

ASTM A283, *Low and Intermediate Tensile Strength Carbon Steel Plates*

ASTM A285, *Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

ASTM A307, *Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*

ASTM A312, *Seamless and Welded Austenitic Stainless Steel Pipe*

ASTM A320, *Alloy Steel Bolting Materials for Low-Temperature Service*

ASTM A333, *Seamless and Welded Steel Pipe for Low-Temperature Service*

ASTM A334, *Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service*

ASTM A350, *Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components*

ASTM A351, *Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts*

ASTM A353, *Pressure Vessel Plates, Alloy Steel, 9% Nickel, Double-Normalized and Tempered*

ASTM A358, *Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service*

ASTM A370, *Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A403, *Wrought Austenitic Stainless Steel Piping Fittings*

ASTM A479, *Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels*

ASTM A480, *General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*

ASTM A516, *Pressure Vessel Plates, Carbon Steel, for Moderate and Lower Temperature Service*

ASTM A522, *Forged or Rolled Eight and 9% Nickel Alloy Steel Flanges, Fittings, Valves and Parts for Low Temperature Service*

ASTM A524, *Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures*

ASTM A537, *Pressure Vessel Plates, Heat Treated, Carbon-Manganese-Silicon Steel*

ASTM A553, *Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Eight and 9% Nickel*

ASTM A573, *Structural Carbon Steel Plates of Improved Toughness*

ASTM A633, *Normalized High-Strength Low-Alloy Structural Steel*

ASTM A645, *Pressure Vessel Plates, 5% Nickel Alloy Steel, Specially Heat Treated*

ASTM A662, *Pressure Vessel Plates, Carbon-Manganese, for Moderate and Lower Temperature Service*

ASTM A671, *Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures*

ASTM A673, *Sampling Procedure for Impact Testing of Structural Steel*

ASTM A678, *Quenched and Tempered Carbon-Steel and High-Strength Low-Alloy Steel Plates for Structural Applications*

ASTM A737, *Pressure Vessel Plates, High-Strength, Low-Alloy Steel*

ASTM A841, *Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Process (TMCP)*

ASTM A992, *Steel for Structural Shapes for Use in Building Framing*

ASTM B209, *Aluminum and Aluminum-Alloy Sheet and Plate*

ASTM B210, *Aluminum-Alloy Drawn Seamless Tubes*

ASTM B211, *Aluminum and Aluminum-Alloy Bars, Rods, and Wire*

ASTM B221, *Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes*

ASTM B241, *Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube*

ASTM B247, *Aluminum and Aluminum-Alloy Die, Hand and Rolled Ring Forgings*

ASTM B308, *Aluminum-Alloy 6061-T6 Standard Structural Shapes, Rolled or Extruded*

ASTM B444, *Nickel-Chromium-Molybdenum-Columium Alloys (UNS N06625) Pipe and Tube*

ASTM B619, *Welded Nickel and Nickel-Cobalt Alloy Pipe*

ASTM B622*, Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube*

ASTM E23, *Notched Bar Impact Testing of Metallic Materials*

AWS A5.11[9], *Nickel and Nickel Alloy Covered Welding Electrodes* (ANSI/AWS A5.11)

AWS A5.14, *Nickel and Nickel Alloy Bare Welding Rods and Electrodes* (ANSI/AWS A5.14)

CSA G40.21[10], *Structural Quality Steel*

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

EN 10028, *Flat Products Made of Steels for Pressure Purposes*

ISO 630[12]*, Structural Steels*

[9]American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126, www.aws.org.
[10]Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario, L4W 5N6, Canada, www.csa.ca.
10 [11]European Commitee for Standardization, Management Centre: rue de Stassart, 36 B-1050 Brussels, Belgium.
[12]International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

Table 4-1—Minimum Requirements for Plate Specifications to be Used for Design Metal Temperatures

Design Metal Temperature (See 4.2.1)	Plate Thickness Including Corrosion Allowance (in.)	Permissible Specifications			
		Specification	Grade	Special Requirements (in Addition to 4.2.3)	
65°F and over	$\leq 3/4$	Any listed in 4.2.3	—	None	
	≤ 1	ASTM A36	—	None	
	> 1	CSA G40.21	38W, 44W, 50W	Note 1	
25°F and over	$\leq 1/2$	Any listed in 4.2.3	—	None	
	≤ 1	ASTM A36 Mod 2	—	None	
		ASTM A131	B	None	
		CSA G40.21	38W, 44W, 50W	None	
–5°F and over	$\leq 1/2$	ASTMA 131	B	None	
		CSA G40.21	38W, 44W, 50W	None	
	$> 1/2$		**<text deleted>**		09
		ASTM A516	55, 60, 65, 70	Note 1	
		ASTM A573	58, 65, 70	Note 1	
		ASTM A662	B and C	Note 1	
		ASTM A737	B	None	
		ASTM A841	Class 1	None	
		CSA G40.21	38W, 44W, 50W	Note 2	
		ISO 630	E 275, E355 Quality D	Note 1	10
		EN 10025	S 275, S355 Quality J2	Notes 1 and 2	
–35°F and over	$\leq 1/2$		**<text deleted>**		09
		ASTM A516	55, 60, 65, 70	None	
		ASTM A537	Classes 1 and 2	None	
		ASTM A573	58, 65, 70	None	
		ASTM A633	C and D	None	
		ASTM A662	B and C	None	
		ASTM A678	A and B	None	
		ASTM A737	B	None	
		ASTM A841	Class 1	None	
		CSA G40.21	38W, 44W, 50W	Note 2	
		ISO 630	E 275, E355 Quality D	Note 1	10
		EN 10025	S 275, S355 Quality J2	Notes 1 and 2	
	≤ 1		**<text deleted>**		09
		ASTM A516	55, 60, 65, 70	Note 3	
		ASTM A537	Classes 1 and 2	None	
		ASTM A573	58	Note 3	
		ASTM A633	C and D	None	
		ASTM A662	B and C	Note 3	
		ASTM A678	A and B	None	
		ASTM A737	B	None	
		ASTM A841	Class 1	None	
		CSA G40.21	38W, 44W, 50W	Notes 2 and 3	
		ISO 630	E275, E355 Quality D	Note 3	10
		EN 10025	S 275, S355 Quality J2	Notes 1 and 2	
	> 1		**<text deleted>**		
		ASTM A516	55, 60, 65, 70	Notes 3 and 4	
		ASTM A537	Classes 1 and 2	Note 4	
		ASTM A573	58	Notes 3 and 4	
		ASTM A633	C and D	Note 4	
		ASTM A662	B and C	Notes 3 and 4	09
		ASTM A678	A and B	Note 4	
		ASTM A737	B	Note 4	
		ASTM A841	Class 1	None	
		CSA G40.21	38W, 44W, 50W	Notes 2, 3, and 4	
		ISO 630	E275, E355 Quality D	Notes 3, and 4	
		EN 10025	S 275, S355 Quality J2	Notes 1 and 2	10

Notes:
1) All plates over $1\frac{1}{2}$ in. thick shall be normalized.
2) The steel shall be killed and made with fine-grain practice.
3) The plates shall be normalized or quench tembered (see 4.2.4.2).
4) Each plate shall be impact tested in accordance with 4.2.5.

4.2.2 Low-stress Design

The following design criteria, relative to the use of Table 4-1, apply when the actual stress under design conditions does not exceed one-third of the allowable tensile stress:

a) Consideration of the design metal temperature is not required in selecting material from Table 4-1 for tank components that are not in contact with the liquid or vapor being stored and are not designed to contain the contents of an inner tank (see Q.2.3 and R.2.2).

b) The design metal temperature may be increased by 30°F in selecting material from Table 4-1 for tank components that are exposed to the vapor from the liquid or vapor being stored and are not designed to contain the contents of an inner tank.

c) Excluding bottom plates welded to the cylindrical sidewall of flat-bottom tanks, the plates of a non-refrigerated flat-bottom tank, counterbalanced in accordance with 5.11.2, may be constructed of any material selected from Table 4-1.

4.2.3 Plate Specifications

4.2.3.1 General

The specifications listed in 4.2.3.2 through 4.2.3.4 are approved for plates, subject to the modifications and limitations of this paragraph, 4.2.4, and Table 4-1.

4.2.3.2 ASTM Specifications

The following ASTM specifications are approved for plates:

a) A20.

b) A36, with the following API modification as required (see Table 4-1): Mod 2 requires the manganese content to have a range of 0.80 – 1.20. The material supplied shall not be rimmed or capped steel.

c) A131 (structural quality only).

d) A283 (Grades C and D only, with a maximum nominal thickness of $^3/_4$ in.).

e) A285 (Grade C only, with a maximum nominal thickness of $^3/_4$ in.).

f) A516, with the following API modifications as required: Mod 1 requires the carbon content to be restricted to a maximum of 0.20% by ladle analysis; a maximum manganese content of 1.50% shall be permitted. Mod 2 requires the minimum manganese content to be lowered to 0.70% and the maximum increased to 1.40% by ladle analysis. The carbon content shall be limited to a maximum of 0.20% by ladle analysis. The steel shall be normalized. The silicon content may be increased to a maximum of 0.50% by ladle analysis.

g) A537, with the following modification: The minimum manganese content shall be 0.80% by ladle analysis. The maximum manganese content may be increased to 1.60% by ladle analysis if maximum carbon content is 0.20% by ladle analysis.

h) A573.

i) A633 (Grades C and D only).

j) A662 (Grades B and C only).

k) A678 (Grades A and B only).

l) A737 (Grade B only).

m) A841 (Class 1 only).

4.2.3.3 CSA Specification

The following CSA specification is approved for plates: G40.21 (Grades 38W, 44W, and 50W only; if impact tests are required, these grades are designated 38WT, 44WT, and 50WT).

Elements added for grain strengthening shall be restricted in accordance with Table 4-2. Plates shall have a tensile strength not more than 20 ksi above the minimum specified for the grade. Fully killed steel made to a fine grain practice must be specified when required.

Table 4-2—Maximum Permissible Alloy Content

Alloy	%	Notes
Columbium	0.05	1, 2, and 3
Vanadium	0.10	1, 2, and 4
Columbium (0.05–% maximum) Plus Vanadium	0.10	1, 2, and 3
Nitrogen	0.015	1, 2, and 4
Copper	0.35	1 and 2
Nickel	0.50	1 and 2
Chromium	0.25	1 and 2
Molybdenum	0.08	1 and 2

Notes:
1) When not included in the material specification, the use of these alloys, or combinations thereof, 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.
2) The material shall conform to these requirements on product analysis subject to the product analyses tolerances of the specification.
3) Columbium, when added either singly or in combination with vanadium, shall be restricted to plates of 0.50-in. maximum thickness unless it is combined with a minimum of 0.15% silicon.
4) When added as a supplement to vanadium, nitrogen (a maximum of 0.015%) shall be reported and the minimum ratio of vanadium to nitrogen shall be 4:1.

4.2.3.4 ISO Specification

The following ISO specification is approved for plates: 630 (Grades E275 and E355 in Qualities C and D only). **<text deleted>** Elements added for grain refining or strengthening shall be restricted in accordance with Table 4-2. 10

4.2.3.5 EN Specification

The following EN specification is approved for plates: EN 10025 (Grades S275 and S355 in Qualities J0, J2, and K2 only). Elements added for grain refining or strengthening shall be restricted in accordance with Table 4-2.

4.2.4 Plate Manufacture

4.2.4.1 All material for plates shall be made using the open-hearth, electric-furnace, or basic-oxygen process. Universal mill plates shall not be used. All plates for pressure parts, with the exception of those whose thicknesses are established by the requirements of Table 5-6, shall be ordered on the basis of edge thickness to ensure that the plates furnished from the mill will not underrun the specified thickness by more than 0.01 in. This stipulation shall not be construed to prohibit the use of plates purchased based on weight if it is established by actual measurements (taken at a multiplicity of points along the edges of the plates) that the minimum thicknesses of the plates do not underrun the required design thickness by more than 0.01 in.

4.2.4.2 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 10

10 heat treated plates are normally required by Table 4-1 (note 1) because of thickness over 1½ in. In this case, each TMCP plate-as-rolled shall receive Charpy V-notch impact energy testing in accordance with 4.2.5.

4.2.5 Impact Test Requirements for Plates

4.2.5.1 Table 4-1 provides exemption and impact testing requirements of plates for various grades for given thickness range and design metal temperature. Any material listed in Table 4-1 may be used for any thickness and temperature provided the material meets impact test requirements as specified in 4.2.5 and Table 4-3 and welding procedure requirements specified in 6.7. When the plate is not exempted from impact testing per Table 4-1 or 4.2.2, each plate shall be impact tested; plate refers to the unit plate rolled from a slab or directly from an ingot. The ASTM A370, Type A, Charpy V-notch test shall be used. The long dimension of the specimen shall be parallel to the direction of the expected maximum stress. When the coincident stresses are approximately equal, the specimens shall be taken transverse to the final direction of the plate rolling. The minimum energy absorption values of Table 4-3 shall be satisfied.

4.2.5.2 All other impact requirements of ASTM A20, Supplementary Requirement S5, shall apply for all materials listed in Table 4-3, including specifications that do not refer to ASTM A20.

4.2.5.3 For thickness exceeding the range in Table 4-3, impact test requirements shall be mutually agreed by the Manufacturer and the Purchaser. ASME Section VIII, Division 1, Part UG-84 may be used as a guide.

4.3 Pipe, Flanges, Forging, and Castings

All pipe, flanges, forgings, and castings used in the parts of the tanks that are subject to internal pressure shall conform to applicable requirements of 4.3.1 to 4.3.5 inclusive.

4.3.1 Pipe[12]

4.3.1.1 Carbon steel pipe shall conform to one of the following specifications:

a) ASTM A53.

b) ASTM A106.

c) ASTM A134, excluding helical (spiral) welded pipe.

d) ASTM A139, excluding helical (spiral) welded pipe.

e) ASTM A333.

f) ASTM A524.

g) ASTM A671 (Grades CA, CC, CD, and CE only).

h) API 5L (Grades A and B only).

[12] For design metal temperatures below –20°F, the materials shall conform to Tables R-1 and/or R-3.

Table 4-3—Minimum Charpy V-notch Requirements for Plate Specimens

Group	Specification Number	Grade	Range in Thickness (in.)	Impact Value[a] (foot-pounds)		
				Average	Individual	
I (semikilled)	A 36		3/16 – 1	13	9	
	A 36	Mod 2[b]	3/16 – 1	13	9	
	A 131	A and B	3/16 – 1	13	9	
	A283	C and D	3/16 – 3/4	13	9	
	A285	C	3/16 – 3/4	13	9	
	ISO 630	E275 Quality C	3/16 – 1 1/2	13	9	
	EN 10025	S275 J0	3/16 – 1 1/2	13	9	10
II (fully killed)	A 573	58[c]	3/16 – 1 1/2	15	10	
	A 131	CS	3/16 – 1 1/2	15	10	
	A 516	55 and 60	3/16 – 2	15	10	
	A 516	55 and 60[d]	3/16 – 1/2	15	10	
	ISO 630	E275 Quality D	3/16 – 1 1/2	15	10	
	EN 10025	S275 J2	3/16 – 1 1/2	15	10	10
	CSA G40.21	38WT	3/16 – 2	15	10	
III (fully killed and high strength)	A 573	65 and 70	3/16 – 2	15	10	
	A 516	65 and 70	3/16 – 2	15	10	
	A 516	65 and 70 Mod 1[b]	3/16 – 2	15	10	
	A 516	65 and 70 Mod 2[b]	3/16 – 2	15	10	
	A 537	1	3/16 – 2	15	10	
	A 537	2	3/16 – 2	20	15	
	A 633	C and D	3/16 – 2	15	10	
	A 662	B and C	3/16 – 2	15	10	
	A 678	A	3/16 – 1 1/2	20	15	
	A 678	B	3/16 – 2	20	15	
	ISO 630	E355 Quality C and D	3/16 – 2	15	10	
	EN 10025	S355 J2 and K2	3/16 – 2	15	10	10
	CSA G40.21	44WT	3/16 – 2	15	10	
	CSA G40.21	50WT	3/16 – 2	15	10	
	A 737	B	3/16 – 2	15	10	
	A 841	1	3/16 – 2	15	10	

Notes:
[a]The stated values apply to full-sized specimens. For sub-size specimen acceptance criteria, see ASTM A20. An impact test temperature lower than the design metal temperature may be used by the Manufacturer, but the impact value at the test temperature must comply with Table 4-3. When plate is selected, consideration must be given to the possible degradation of the impact properties of the plate in the weld heat-affected zone.
[b]See 4.2.3 for a complete description of this material.
[c]The steel shall be fully killed and made with fine-grain practice, without normalizing, for thicknesses of 3/16 in. – 1 1/2 in.
[d]The manganese content shall be in the range from 0.85% to 1.20% by ladle analysis.

4.3.1.2 When ASTM A134, A139, or A671 pipe is used, it shall comply with the following:

a) The pipe shall be certified to have been pressure tested.

b) The plate specification for the pipe shall satisfy the requirements of 4.2.3, 4.2.4, and 4.2.5 that are applicable to that plate specification.

c) Impact tests for qualifying the welding procedure for the pipe longitudinal welds shall be performed in accordance with 4.7.1.

4.3.2 Built-up Fittings

Built-up fittings, such as ells, tees, and return bends, may be fabricated by fusion welding when they are designed according to the applicable paragraphs in this standard.

4.3.3 Flanges

4.3.3.1 Hub, slip-on welding neck and long welding neck flanges shall conform to the material requirements of ASME B16.5 for forges carbon steel flanges. Plate material used for nozzle flanges shall have physical properties better than or equal to those required by ASME B16.5. Plate flange material shall conform to 4.2.3.

4.3.3.2 For nominal pipe sizes greater than 24 in., 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.

4.3.4 Castings and Forgings

Large castings and forgings (see Footnote 12 for both materials) not covered in 4.1.3 shall be of welding grade if welding is to be done on them, and they shall conform to one of the following ASTM specifications:

a) A27 (Grade 60-30, for structural parts only).

b) A105.

c) A181.

d) A350.

4.3.5 Toughness Requirements

Except as covered in 4.3.1.2, the toughness requirements of pipe, flanges, and forgings shall be established as described in 4.3.5.1 through 4.3.5.4.

4.3.5.1 No impact testing is required for ASME B16.5 ferritic steel flanges used at minimum design metal temperature, no colder than –20°F. Piping materials made according to ASTM A333 and ASTM A350 may be used at a minimum design metal temperatures, no lower than the impact test temperature required by the ASTM specification for the applicable material grade, unless additional impact tests (see 4.3.5.4) are conducted.

4.3.5.2 Other pipe and forging materials shall be classified under the material groups shown in Figure 4-2 as follows:

a) Group I—API 5L, Grades A, B, ASTMA 106, Grades A and B; ASTM A53, Grades A and B; ASTM A181; and ASTM A105.

b) Group II—ASTM A524, Grades I and II.

4.3.5.3 The materials in the groups listed in 4.3.5.2 may be used at nominal thicknesses, including corrosion allowance, at minimum design metal temperatures no lower than those shown in Figure 4-2 without impact testing (see 4.3.5.4). The governing thickness (see Figure 4-3) to be used in Figure 4-2 shall be as follows:

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

b) For corner weld (groove or fillet) or lap welds, it is the thinner of the two parts joined.

c) For nonwelded parts (such as bolted flanges), it is 1/4 of flat cover nominal thickness.

4.3.5.4 When impact tests are required by 4.3.5.2 or 4.3.5.3, they shall be performed in accordance with the requirements, including minimum energy requirements of ASTM A333, Grade 1 for pipe, or ASTM A350 Grade LF1, for forgings at a test temperature no higher than the minimum design metal temperature. Except for the plate specified in 4.2.3, the material specified in 4.3 shall have a minimum Charpy V-notch impact strength of 13 ft-lb (full size specimen) at a temperature no higher than the minimum design metal temperature.

4.4 Bolting Material

Carbon steel bolts[13] may be used if they conform to the following, or to better[14], specifications:

a) ASTM A193.

b) ASTM A307.

c) ASTM A320.

4.5 Structural Shapes

All structural shapes (see Footnote 12) that are subject to pressure-imposed loads or are otherwise important to the structural integrity of a tank shall be made only by the open-hearth, electric-furnace, or basic-oxygen process and shall conform to one of the following specifications:

a) ASTM A36 and the following API modification as required (see Appendix R): Mod 1 requires the steel to be made with fine grain practice, with manganese content in the range of 0.80% to 1.20% of by ladle analysis.

b) ASTM A131.

c) ASTM A633 (Grade A only).

d) ASTM A992.

e) CSA G40.21 (Grades 38W, 44W, and 50W only; if impact tests are required, these grades are designated 38WT, 44WT, and 50WT).

10 f) ISO 630, Grade E275, Qualities B, C, and D.

g) EN 10025, Grade S275, Qualities JR, J0, J2, and K2.

[13]For design metal temperatures below –20°F, the materials shall conform to Tables R-1 and/or R-3.
[14]If better grades of bolts are used, higher bolt stress values are not recommended with full-faced gaskets.

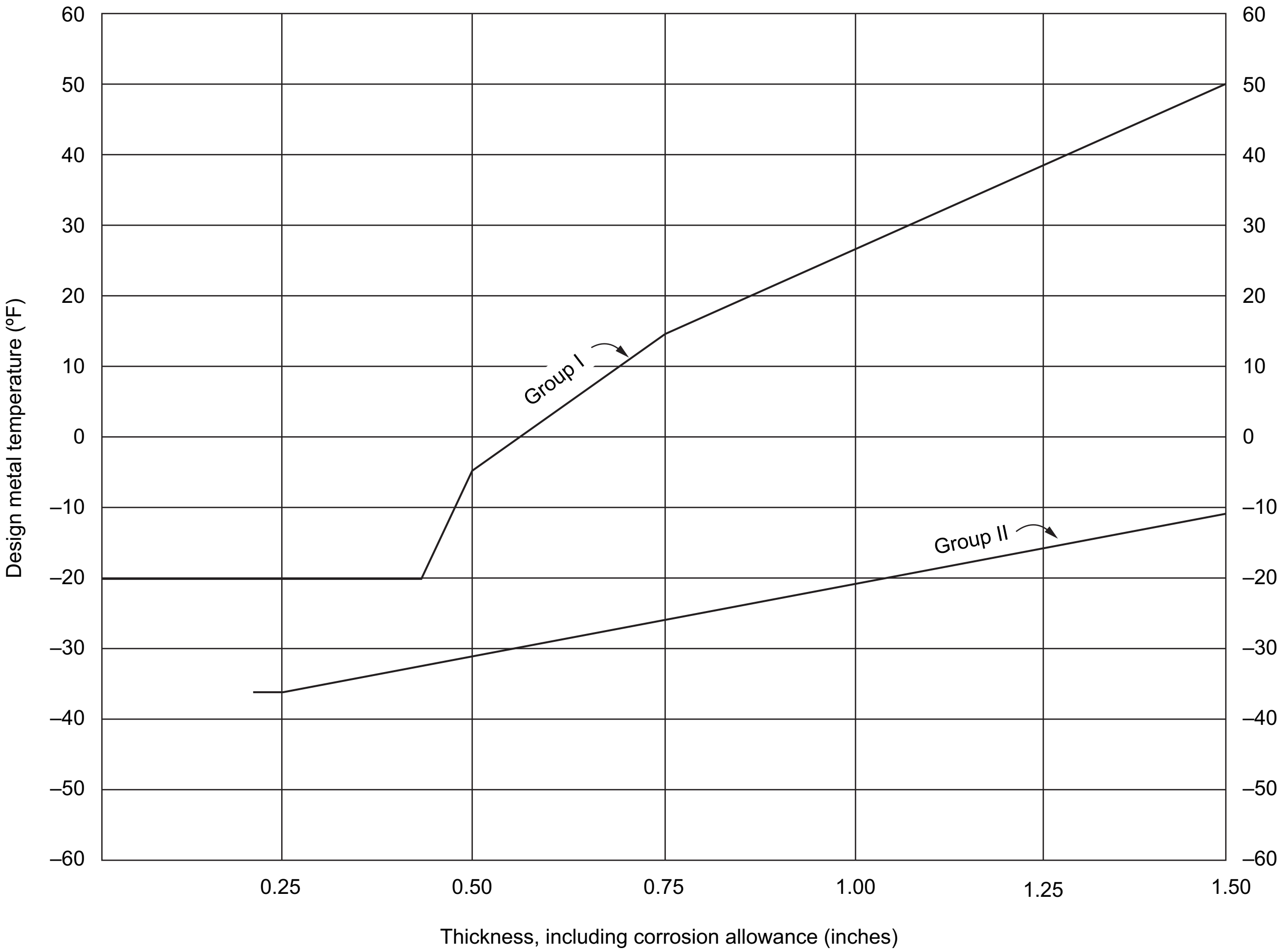


Figure 4-2—Minimum Permissible Design Metal Temperature for Pipe, Flanges, and Forgings without Impact Testing

design wind pressures normal to the tank's outside surface shall be the pressures below, multiplied by $(V/120)^2$. For tank components located more than 80 ft above ground, use ASCE 7 to determine wind pressures.

Surface	Direction	Average Pressure (lbf/ft^2)	Maximum Pressure (lbf/ft^2)
cylinder	inward	16	31
sphere	inward or outward	16	31
dome or cone roof or bottom	outward	30	50

Alternatively, pressures may be determined in accordance with ASCE 7 or a national standard for the specific conditions for the tank being designed.

Average wind pressure on the roof shall be used to design the roof to shell compression region and for overturning. Maximum wind pressure shall be used to design the roof and shell.

5.4.2 Load Combinations

The tank shall be designed for the following load combinations. If the absence of any load other than dead load results in a more severe condition, that load shall not be included in the combination.

a) $D_L + P_g + P_l$

b) $D_L + W_L + 0.7P_g$

c) $D_L + W_L + 0.4P_v$

d) $D_L + P_v + 0.4(L_r \text{ or } S)$

e) $D_L + 0.4P_v + (L_r \text{ or } S)$

f) $D_L + 0.7P_g + P_l + E + 0.1S$

g) $D_L + H_t$

h) $D_L + L_s$

i) $D_L + L_p + P_g + P_l$

5.5 Maximum Allowable Stress for Walls[15]

5.5.1 General

Higher localized shear and secondary bending stresses may exist in the walls of tanks designed and fabricated according to this standard, and the prescribed test loadings may result in some localized reshaping. This is permissible, since localized reshaping is expected as part of a legitimate fabrication operation, if the reshaping is not so severe that upon release of the test pressure, plastic straining occurs in the opposite direction. This would tend to develop continuing plastic straining in subsequent normal operation.

[15]See *Biaxial Stress Criteria for Large Low-Pressure Tanks*, written by J. J. Dvorak and R. V. McGrath and published as Bulletin No. 69 (June 1961) by the Welding Research Council, 3 Park Avenue, 27th Floor, New York, New York 10016.

5.5.2 Nomenclature

5.5.2.1 Variables relating to stresses common to the requirements of 5.5.3 through 5.5.5 and Figure 5-1 are defined as follows:

t = thickness of the wall, in in.,

R = radius of the wall, in in.,

c = corrosion allowance, in in.,

S_{ts} = maximum allowable stress for simple tension, in lbf/in.^{2}, as given in Table 5-1,

S_{cs} = maximum allowable longitudinal compressive stress, in lbf/in.^{2}, for a cylindrical wall acted upon by an axial load with neither a tensile nor a compressive force acting concurrently in a circumferential direction (determined in accordance with 5.5.4.2 for the thickness-to-radius ratio involved),

s_{ta} = allowable tensile stress, in lbf/in.^{2}; s_{ta} lower than S_{ts} because of the presence of a coexistent compressive stress perpendicular to it,

s_{ca} = allowable compressive stress, in lbf/in.^{2}; s_{ca} is lower than S_{cs} because of the presence of a coexistent tensile or compressive stress perpendicular to it,

s_{tc} = computed tensile stress, in lbf/in.^{2}, at the point under consideration,

s_{cc} = computed compressive stress, in lbf/in.^{2}, at the point under consideration,

s_t = general variable for indicating a tensile stress, in lbf/in.^{2}, which may be either an allowable or computed value depending on the context in which the variable is used,

s_c = general variable for indicating a compressive stress, in lbf/in.^{2}, which may be either an allowable or computed value depending on the context in which the variable is used,

N = ratio of the tensile stress, s_t, to the maximum allowable stress for simple tension, S_{ts},

M = ratio of the compressive stress s_c, to the maximum allowable compressive stress, S_{cs} (see Figure F-1).

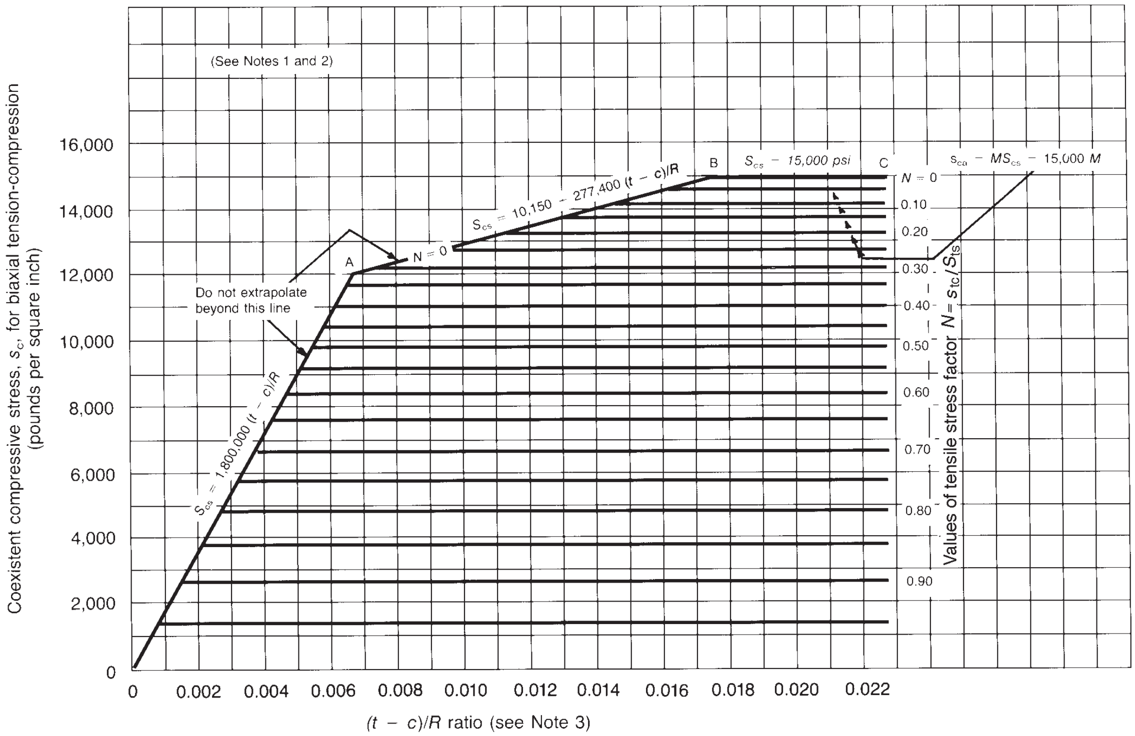
5.5.2.2 The term tank wall is defined in 3.3. Unless otherwise stipulated in this standard, the stresses in nozzle and manway necks, reinforcing pads, flanges, and cover plates shall not exceed the values that apply for the walls of the tank.

5.5.3 Maximum Tensile Stresses

5.5.3.1 The maximum tensile stresses in the outside walls of a tank, as determined for any of the loadings listed in 5.4 or any concurrent combination of such loadings that is expected to be encountered in the specified operation, shall not exceed the applicable stress values determined in accordance with provisions described in 5.5.3.2 and 5.5.3.3.

5.5.3.2 If both the meridional and latitudinal unit forces, T_1 and T_2, are tensile or if one force is tensile and the other
10 is zero, the computed tensile stress, S_{tc}, shall not exceed the applicable value given in Table 5-1.

5.5.3.3 If the meridional force, T_1, is tensile and the coexistent latitudinal unit force, T_2, is compressive or if T_2 is tensile and T_1 is compressive, the computed tensile stress, s_{tc}, shall not exceed a value of the allowable tensile stress, s_{ta}, obtained by multiplying the applicable stress value given in Table 5-1 by the appropriate value of N obtained from Figure 5-1 for the value of compressive stress ($s_c = s_{cc}$) and the co-related ratio of $(t – c)/R$ involved. However, in cases where the unit force acting in compression does not exceed 5% of the coexistent tensile unit force acting perpendicular to it, the designer has the option of permitting a tensile stress of the magnitude specified in 5.5.3.2 instead of complying strictly with the provisions of this paragraph, (see F.1 for examples illustrating the determination of allowable tensile stress values, s_{ta}, in accordance with this paragraph). In no event shall the value of s_{ta} exceed the product of the applicable joint efficiency for tension as given in Table 5-2 and the allowable stress for simple tension shown in Table 5-1.



Notes:
1. At no time can a compressive stress for a particular value of $(t - c)/R$ exceed S_{cs} represented by curve 0ABC; no values of compressive stress or N are permitted to fall to the left or above this curve.
2. See Figure F-1 for relationship between factors M and N.
3. If compressive stress is latitudinal, use $R = R_1$; if compressive stress is meridional, use $R = R_2$.

Figure 5-1—Biaxial Stress Chart for Combined Tension and Compression, 30,000 lbf/in.^{2} – 38,000 lbf/in.^{2} Yield Strength Steels

5.5.4 Maximum Compressive Stresses

5.5.4.1 Except as provided in 5.12.4.3 for the compression-ring region, the maximum compressive stresses in the outside walls of a tank, as determined for any of the loadings listed in 5.4 or any concurrent combination of loadings expected to be encountered in the specified operation, shall not exceed the applicable stress values determined in accordance with the provisions described in 5.5.4.2 through 5.5.4.8. These rules do not purport to apply when the circumferential stress on a cylindrical wall is compressive (as in a cylinder acted upon by external pressure). However, values of S_{cs} computed as in 5.5.4.2, with R equal R_1 when the compressive unit force is latitudinal or to R_2 when the compressive unit force is meridional, in some degree form the basis for the rules given in 5.5.4.3, 5.5.4.4, and 5.5.4.5, which apply to walls of double curvature.

5.5.4.2 If a cylindrical wall, or a portion thereof, is acted upon by a longitudinal compressive force with neither a tensile nor a compressive force acting concurrently in a circumferential direction, the computed compressive stress, s_{cc}, shall not exceed a value, S_{cs}, established for the applicable thickness-to-radius ratio as follows:

For values of $(t - c)/R$ less than 0.00667,

$$S_{cs} = 1{,}800{,}000[(t - c)/R]$$

For values of $(t - c)/R$ between 0.00667 and 0.0175,

$$S_{cs} = 10{,}150 + 277{,}400[(t - c)/R]$$

For values of $(t - c)/R$ greater than 0.0175,

$$S_{cs} = 15{,}000$$

Table 5-1—Maximum Allowable Stress Values for Simple Tension

Specification (See Note 1)	Grade	Notes	Specified Minimum Tensile Strength (lbf/in.^{2})	Specified Minimum Yield Point (lbf/in.^{2})	Maximum Allowable Tensile Stress for Tension, S_{ts} (lbf/in.^{2}, See Notes 2 and 3)
Plates					
ASTM A36	—	4	58,000	36,000	16,000
ASTM A131	A	4, 5 and 6	58,000	34,000	15,200
ASTM A131	B	4	58,000	34,000	16,000
ASTM A131	CS	4	58,000	34,000	16,000
ASTM A283	C	4 and 5	55,000	30,000	15,200
ASTM A283	D	4, 5 and 6	60,000	33,000	15,200
ASTM A285	C	5	55,000	30,000	16,500
ASTM A516	55	—	55,000	30,000	16,500
ASTM A516	60	—	60,000	32,000	18,000
ASTM A516	65	—	65,000	35,000	19,500
ASTM A516	70	—	70,000	38,000	21,000
ASTM A537	Class 1	7	70,000	50,000	21,000
ASTM A537	Class 2	7	80,000	60,000	24,000
ASTM A573	58	4	58,000	32,000	16,000
ASTM A573	65	4	65,000	35,000	18,000
ASTM A573	70	4	70,000	42,000	19,300
ASTM A633	C and D	4 and 7	70,000	50,000	19,300
ASTM A662	B	—	65,000	40,000	19,500
ASTM A662	C	7	70,000	43,000	21,000
ASTM A678	A	4 and 8	70,000	50,000	19,300
ASTM A678	B	4 and 7	80,000	60,000	22,100
ASTM A737	B	7	70,000	50,000	21,000
ASTM A841	Class 1	7	70,000	50,000	21,000
CSA G40.21	38W and 38WT	4	60,000	38,000	16,500
CSA G40.21	44W and 44WT	4	65,000	44,000	18,000
CSA G40.21	50W	4	65,000	50,000	18,000
CSA G40.21	50WT	4	70,000	50,000	19,300
ISO 630	E275 Quality C, D	4	59,500	37,000	16,400
ISO 630	E355 Quality C, D	4	71,000	48,500	19,600
10 EN 10025	S275 Quality J0, J2, K2	4	59,500	37,000	16,400
EN 10025	S275 Quality J0, J2, K2	4	71,000	48,500	19,600
Pipe					
Seamless					
API Spec 5L	B	—	60,000	35,000	18,000
ASTM A33	B	—	60,000	35,000	18,000
ASTM A106	B	—	60,000	35,000	18,000
ASTM A106	C	—	70,000	40,000	21,000
ASTM A333	1	—	55,000	30,000	16,500
ASTM A333	3	—	65,000	35,000	19,500
09 ASTM A333	6	—	60,000	35,000	18,000
ASTM A524	I	—	60,000	35,000	18,000
ASTM A524	I1	—	55,000	30,000	16,500
Electric-fusion Welded					
ASTM A134	A283 Grade C	4, 5 and 9	55,000	30,000	12,100
ASTM A134	A285 Grade C	5 and 9	55,000	30,000	13,200
ASTM A139	B	9	60,000	35,000	14,400
ASTM A671	CA55	9	55,000	30,000	13,200

Table 5-1—Maximum Allowable Stress Values for Simple Tension (Continued)

Specification (See Note 1)	Grade	Notes	Specified Minimum Tensile Strength (lbf/in.^{2})	Specified Minimum Yield Point (lbf/in.^{2})	Maximum Allowable Tensile Stress for Tension, S_{ts} (lbf/in.^{2}, See Notes 2 and 3)
ASTM A671	CC60	9	60,000	32,000	14,400
ASTM A671	CC65	9	65,000	35,000	15,600
ASTM A671	CC70	9	70,000	38,000	16,800
ASTM A671	CD70	7 and 9	70,000	50,000	16,800
ASTM A671	CD80	7 and 9	80,000	60,000	19,200
ASTM A671	CE55	9	55,000	30,000	13,200
ASTM A671	CE60	9	60,000	32,000	14,400
Forgings					
ASTM A105	—	—	60,000	30,000	18,000
ASTM A181	I	—	60,000	30,000	18,000
ASTM A181	II	—	70,000	36,000	21,000
ASTM A350	LF1	—	60,000	30,000	18,000
ASTM A350	LF2	—	70,000	36,000	21,000
ASTM A350	LF3	—	70,000	40,000	21,000
Castings and Bolting					
ASTM A27	60-30	10	60,000	30,000	14,400
ASTM A36	For anchor bolting	11	58,000	36,000	15,300
ASTM A193	B7	11	125,000	105,000	24,000
ASTM A307	B for flanges and pressure parts	11 and 12	55,000	—	8,400
ASTM A307	B for structural parts and anchor	11	55,000	—	15,000
ASTM A320	bolting L7	11	125,000	105,000	24,000
Structural Shapes Resisting Internal Pressure					
ASTM A36	—	4 and 6	58,000	36,000	15,200
ASTM A131	A	4 and 6	58,000	34,000	15,200
ASTM A633	A	4	63,000	42,000	17,400
ASTM A992	—	4 and 6	65,000	50,000	15,200
CSA G40.21	38W and 38WT	4 and 6	60,000	38,000	15,200
CSA G40.21	44W and 44WT	4 and 6	65,000	44,000	15,200
CSA G40.21	50W	4 and 6	65,000	50,000	15,200
CSA G40.21	50WT	4 and 6	70,000	50,000	15,200
ISO 630	E275 Quality B, C, D	4 and 6	59,500	37,000	15,200
ISO 630	E355 Quality B, C, D	4 and 6	71,000	48,500	15,200
EN 10025	S275 Quality JR, J0, J2, K2	4 and 6	59,500	37,000	15,200
EN 10025	S275 Quality JR, J0, J2, K2	4 and 6	71,000	48,500	15,200

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Notes:
1. All pertinent modifications and limitations of specifications required by 4.2. through 4.6 shall be complied with.
2. Except for those cases where additional factors or limitations are applied as indicated by references to Notes 4, 6, 10 and 12, the allowable tensile stress values given in this table for materials other than bolting steel are the lesser of (a) 30% of the specified minimum ultimate tensile strength for the material or (b) 60% of the specified minimum yield point.
3. Except when a joint efficiency factor is already reflected in the specified allowable stress value, as indicated by the references to Note 10, or where the value of *N* determined in accordance with 5.5.3.3. is less than the applicable joint efficiency given in Table 5-2 (and, therefore, effects a greater reduction in allowable stress than would the pertinent join efficiency factor, if applied), the specified stress values for welds in tension shall be multiplied by the applicable joint efficiency factor, *E*, given in Table 5-2.
4. Stress values for structural quality steels include a quality factor of 0.92.
5. Plates and pipe shall not be used in thickness greater than $^3/_4$ in.
6. Stress values are limited to those for steel that has an ultimate tensile strength of only 55,000 lbf/in.^{2}.
7. Less than or equal to $2^1/_2$ in. thickness.
8. Less than or equal to $1^1/_2$ in. thickness.
9. Stress values for fusion-welded pipe include a welded-joint efficiency factor of 0.80 (see 5.23.3). Only straight-seam pipe shall be used; the use of spiral-seam pipe is prohibited.
10. Stress values for castings include a quality factor of 0.80.
11. See 5.6.
12. Allowable stress based on Section VIII of the *ASME Boiler and Pressure Vessel Code* multiplied by the ratio of the design stress factors in this standard and Section V111 of the ASME *Code*, namely 0.30/0.25.

Table 5-2—Maximum Allowable Efficiencies for Arc-welded Joints

Type of Joint	Limitations	Basic Joint Efficiency (%)	Radiographed (See Note 1)	Maximum Joint Efficiency (%; see Note 2)
09 Butt joints, attained by double-welding or other means approved by the Purchaser, that will obtain the quality of deposited weld metal on the inside and outside weld surfaces that agrees with the requirements of Paragraph UW-35 in Section VIII of the ASME *Code*; welds using metal backing strips that remain in place are excluded.	None, for all double-welded joints, except for roofs above liquid level.	85	Spot Full (see Note 3)	85 100
	Roofs above liquid level.	70	— Spot Full (see Note 3)	70 85 100
Single-welded butt joint with backing strip or equivalent other than those included above.	Longitudinal or meridional circumference or latitudinal joints between plates not more than 1 1/4 in. thick; nozzle attachment welding without thickness limitation.	75	Spot Full (see Note 3)	75 85
	Roofs above liquid level.	70	— Spot Full (see Note 3)	70 75 85
Single-welded butt joint without backing strip.	Nozzle attachment welding.	70	—	70
Double full-fillet lap joint (see Note 4).	Longitudinal or meridional joints and equivalent (see Note 5) circumferential or latitudinal joints between plates not more and 3/8 in. thick; joints of this type shall not be used for longitudinal or meridional joints that the provisions of 5.12.2 require to be butt-welded.	70	—	70
	Other circumferential or latitudinal joints between plates not more than 5/8 in. thick.	65	—	65
Single full-fillet lap joint (see Note 4).	Longitudinal or meridional joints and circumferential or latitudinal joints between plates not more than 3/8 in. thick; joints of this type shall not be used for longitudinal or meridional joints that the provisions of 5.12.2 require when the thinner plate joined exceeds 1/4 in.	35	—	35
Single full-fillet lap joints for head-to-nozzle joints	For attachment of heads convex to pressure not more than 5/8 in. required thickness, only with use of the fillet weld on the inside of the nozzle.	35	—	35
Nozzle-attachment fillet welds	Attachment welding for nozzles and their reinforcements.		(Included in the strength factors in 5.16.8.3)	
Plug welds (see 5.24.5)	Attachment welding for nozzle reinforcements (see Note 6).	80	—	80

Notes:
1. See 5.26 and 7.15 for examination requirements.
2. Regardless of any values given in this column, the efficiency for lap-welded joints between plates with surfaces of double curvature that have a compressive stress across the joint from a negative value of P_g or other external loading may be taken as unity; such compressive stress shall not exceed 700 lbf/in.^{2}. For all other lap-welded joints, the joint efficiency factor must be applied to the allowable compressive stress, S_{ca}. The efficiency for full-penetration butt-welded joints, which are in compression across the entire thickness of the connected plates, may be taken as unity.
3. All main butt-welded joints (see 5.26.4.2) shall be completely radiographed or ultrasonically examined as specified in 5.26 and nozzle and reinforcement attachment welding shall be examined by the magnetic-particle method as specified in 7.15.2.
4. Thickness limitations do not apply to flat bottoms supported uniformly on a foundation.
5. For the purposes of this table, a circumferential or latitudinal joins shall be considered subject to the same requirements and limitations as are longitudinal or meridional joints when such a circumferential or latitudinal joint is located (a) in a spherical, tori spherical or ellipsoidal shape or in any other surface of double curvature, (b) at the junction between a conical or dished roof (or bottom) and cylindrical sidewalls, as considered in 5.12.3 or (c) at a similar juncture at either end of a transition section or reducer as shown in Figure 5-9.
6. The efficiency factors shown for fillet welds and plug welds are not to be applied to the allowable shearing stress values shown in Table 5-3 for structural welds.

6.5.2.2 The out-of-plumbness in one shell plate shall not exceed the permissible variations for flatness and waviness specified in ASTM A6 or ASTM A20, whichever is applicable for carbon and alloy steels. For stainless steels, ASTM A480 is applicable. For aluminum plates, Table 5.13 of ANSI H35.2 provides the dimensional flatness tolerance.

6.5.3 Roundness

6.5.3.1 For cylindrical sidewalls, the horizontal circular cross section of a large, low pressure storage tank shall be sufficiently true to round so that the difference between the maximum and minimum diameters (measured inside or outside) at any section in a cylindrical wall shall not exceed 1% of the average diameter or 12 in., whichever is less, except as modified for flat-bottom tanks for which the radii measured at 1 ft 0 in. above the bottom corner weld shall not exceed the tolerances listed in Table 6-1.

6.5.3.2 The skirts or cylindrical ends of formed tops or bottoms shall be sufficiently true to round so that the difference between the maximum and minimum diameters shall not exceed 1% of the nominal diameter.

6.5.4 Local Deviations

Local deviations from the theoretical shape, such as weld discontinuities and flat spots, shall be limited as follows:

a. Using a horizontal sweep board 36-in. long, peaking at vertical joints shall not exceed $^1/_2$ in. This may be increased to 1 in. for aluminum shells (see Appendix Q).

Table 6-1—Diameter Range Versus Radius Tolerance

Diameter Range (ft)	Radius Tolerance (in.)
< 40	± $^1/_2$
40 to < 150	± $^3/_4$
150 to < 250	± 1
≥ 250	± $1^1/_4$

b. Using a vertical sweep board 36-in. long, banding at horizontal joints shall not exceed $^1/_2$ in. This may be increased to 1 in. for aluminum shells (see Appendix Q).

c. Flat spots in the vertical plane shall not exceed the appropriate plate flatness and waviness requirements of 6.5.2.2.

6.5.5 Fitting Attachments

All lugs, brackets, nozzles, manhole frames, reinforcement around openings, and other appurtenances shall fit and conform to the curvature of the surface to which they are attached.

6.5.6 Foundation

6.5.6.1 To achieve the tolerances outlined in 6.5, a level foundation must be provided for the tank erection. The foundation should have adequate bearing power to maintain the levelness of the foundation.

6.5.6.2 The top of the foundation with a concrete ringwall shall be level within ± $^1/_8$ in. in any 30 ft of circumference and within ± $^1/_4$ in. in the total circumference. Without a concrete ringwall, the foundation shall be within ± $^1/_2$ in. of the design shape.

6.5.6.3 For concrete slab foundations, from the outside of the tank radially toward the center, the first foot of the foundation (or width of the annular ring) shall comply with the concrete ringwall requirement. The remainder of the foundation shall be within ± $^1/_2$ in. of the design shape.

6.5.7 Measurements

When measurements are required by agreement between the Purchaser and the Manufacturer, they shall be taken before the hydrostatic test. Measurements of local deviations shall be taken during construction. They shall be taken with a steel tape—making corrections for temperature, sag, and wind—when the length being measured makes such corrections necessary. Deviation measurements shall be taken on the surface of the plate and not on welds.

6.5.8 Double-curvature Roofs, Bottoms, and Sidewalls

For double-curvature roofs, bottoms and sidewalls, the tolerances shall be as follows: The surface shall not deviate outside the design shape by more than 1.25% of *D* and inside the specified shape by more than $^{5}/_{8}$% of *D* where *D* is the nominal inside diameter of the roof (or bottom) under consideration. Such deviations shall be measured perpendicular to the design shape and shall not be abrupt but shall merge smoothly into the adjoining surfaces in all directions. For a knuckle, *D* shall be considered to be twice the radius of the knuckle.

6.6 Details of Welding

6.6.1 General

6.6.1.1 Tanks and tank parts fabricated under these rules shall be welded by the processes defined in 6.6.2. Welding may be performed by manual, semi-automatic arc, or machine welding according to procedures described in ASME Section IX, and by welders and welder operators qualified under 6.7 and 6.8.

6.6.1.2 Welding shall be fusion welding without the application of mechanical pressure or blows.

6.6.1.3 Peening is permitted in accordance with 6.19.

6.6.1.4 Pipe materials that have longitudinal joints of the types permitted by the specifications listed in 4.3 are allowed.

6.6.2 Welding Processes

Tanks and their structural attachments shall be welded by the shielded metal-arc, gas metal-arc, gas tungsten-arc, oxyfuel, flux-cored-arc, submerged-arc, electroslag, or electrogas process using suitable equipment. Use of the oxy-
09 fuel, electroslag, or electrogas process shall be by agreement between the Manufacturer and the Purchaser. Use of the oxyfuel process is not permitted when impact testing of the material is required. Welding may be performed by
09 manual, semi-automatic arc, machine, or automatic welding according to procedures described in ASME Section IX. Welding shall be performed in such a manner as to ensure complete fusion with the base metal.The Purchaser may designate applicable sections of API 582 for supplementary welding guidelines and practices.

6.7 Qualification of Welding Procedure

6.7.1 Each Welding Procedure Specification (WPS) shall be qualified in accordance with the latest practice as given in Section IX of the ASME *Code*. When impact tests are required by 4.2.5 or when required by appropriate appendices, the weld metal and heat affected zone shall be tested and the Supplementary Essential Variables in Section IX of the ASME *Code* shall be applied. In addition, the heat treated condition and the application or omission of fine grain prac-
10 tice for the base metal shall be an additional Supplementary Essential Variable. Plates produced by the controlled-rolled process are not to be considered as having received any heat treatment. Welding procedures for ladder and platform assemblies, handrails, stairways, and other miscellaneous assemblies but not their attachments to the tank, shall comply with either AWS D1.1, AWS D1.6, or Section IX of the ASME *Code*, including the use of SWPSs.

6.7.2 Carbon steel materials not listed in Table QW-422 of Section IX of the ASME *Code* shall be considered as P-Number 1 material with group numbers assigned as follows, according to the minimum tensile strength specified:

a. < 70 kips/in.^{2} (Group 1).
b. ≥ 70 kips/in.^{2} but < 80 kips/in.^{2} (Group 2).
c. ≥ 80 kips/in.^{2} (Group 3).

6.7.3 The required tests to qualify the Welding Procedure Specification (WPS) shall be conducted by the fabricator.

6.7.4 The stress-relieving requirements in the procedures to be followed in each case should be agreed upon
09 between the Manufacturer and the Purchaser. Peening may be done if it is part of the welding procedure and is approved by the Purchaser.

b) The examiner is competent in the techniques of the liquid penetrant examination method for which the examiner is certified, including making the examination and interpreting and evaluating the results; however, where the examination method consists of more than one operation, the examiner may be certified as being qualified only for one or more of these operations.

7.15.4.4 The acceptance standards, defect removal, and repair shall be in accordance with Section VIII, Appendix 8, Paragraphs 8-3, 8-4, and 8-5 of the ASME *Code*.

7.15.5 Visual Examination Method

7.15.5.1 The Manufacturer shall determine and certify that each visual examiner meets the following requirements:

a) Has vision (with correction, if necessary) to be able to read a Jaeger Type 2 standard chart at a distance of not less than 300 mm (12 in.) and is capable of passing a color contrast test. Examiners shall be checked annually to ensure that they meet this requirement.

b) Is competent in the technique of the visual examination, including performing the examination and interpreting and evaluating the results; however, where the examination method consists of more than one operation, the examiner performing only a portion of the test need only be qualified for the portion that the examiner performs. 10

7.15.5.2 All welds shall be visually examined in accordance with 7.15.5.3 and 7.15.5.4.

7.15.5.3 A weld shall be acceptable by visual examination if examination shows the following:

a) The weld has no crater cracks or other surface cracks.

b) Undercut does not exceed the applicable limit in 6.13.

c) The frequency of surface porosity in welds does not exceed one cluster (one or more pores) in each 4 in. of length, and the maximum diameter of each cluster does not exceed $^{3}/_{32}$ in.

d) Complete fusion and required penetration exists at the joint between the weld metal and the base metal.

7.15.5.4 Welds that fail to meet the visual examination criteria of 7.15.5.2 shall be reworked before hydrostatic testing in accordance with the following: 10

a) Defects shall be repaired in accordance with 6.16.

b) Rewelding shall be required if the resulting thickness is below the minimum required for design and hydrostatic test conditions. All defects in areas above the minimum thickness shall be feathered to at least 4:1 taper.

c) The repair weld shall be examined visually for defects.

7.15.6 Examination Method for Spot Radiographic/Ultrasonic Examination

7.15.6.1 The procedure prescribed in 7.15.1.1 shall be followed as closely as is practicable when the spot examination is made by radiography. A spot radiograph shall not be considered equivalent to a recheck where complete radiography is mandatory and applied.

7.15.6.2 Spot radiographic or ultrasonic examination shall be not less than 6 in. extending along the weld. Spot radiography shall comply with the standards given in 7.15.1.3. Where spot radiographic or ultrasonic examination is applied at joint intersections, the surface shall be prepared and examined for a distance of 3 in. on each side of the intersection, making the minimum length of examination 6 in. on the horizontal weld and 3 in. on the vertical weld.

7.15.6.3 Retest radiographs prescribed in 7.17.4, when required, shall comply with the standards of acceptability given in 7.15.1.3. Spot radiographs or ultrasonic records may be discarded after the tank has been accepted by the inspector, unless previously requested by the Purchaser.

7.16 Inspection of Welds

Note: Appendix P summarizes the requirements by method of examination and provides the acceptance standards, examiner qualifications, and procedure requirements. Appendix P is not intended to be used alone to determine the inspection requirements for work covered by this document. The specific requirements as listed in Sections 1 through 9, and Appendices Q and R shall be followed in all cases.

7.16.1 Butt-welds

Complete penetration and complete fusion is required (to the degree mandated by the acceptance criteria for examination method utilized) for welds joining tank wall plates to tank wall plates. Examination for quality of welds shall be made using either the radiographic method specified in 7.15.1 and applied in 7.17, or alternatively, by agreement between the Purchaser and the Manufacturer, using the ultrasonic method specified in 7.15.3.1. In addition to the radiographic or ultrasonic examination, these welds shall also be visually examined as specified in 7.15.5. Furthermore, the Purchaser's inspector may visually inspect all butt-welds for cracks, arc strikes, excessive undercuts, surface porosity, incomplete fusion, and other defects. Acceptance and repair criteria for the visual method are specified in 7.15.5.

7.16.2 Fillet Welds

Fillet welds shall be examined by the visual method. Acceptance and repair criteria are specified in 7.15.5.

7.16.3 Permanent and Temporary Attachment Welds

7.16.3.1 Permanent attachments are items welded to the tank wall that will remain while the tank is in its intended service. This does not include openings such as nozzles, manholes and flush type cleanouts. It does include items such as wind girders, stairs, gauging systems, davits, riser pipe supports, tank anchors, walkways, supports for internal items such as heating coils or other piping, ladders, floating roof supports welded to the shell wall, and electrical conduit and fixtures. Items installed above the maximum liquid level of the tank are not permanent attachments. The weld connecting the permanent attachment to the tank surface shall be inspected visually and by the magnetic particle method (or at the option of the Purchaser, by the liquid penetrant method). Refer to Section 7 for the appropriate inspection criteria.

7.16.3.2 Temporary attachments are items welded to the tank wall that will be removed prior to the tank being utilized in its intended service. These are usually construction items such as alignment clips, scaffolding clips, stabilizers, fitting equipment, and lifting clips. The area from which a temporary attachment is removed shall be inspected visually for any indication of flaws requiring repair. Additionally, on any tank material listed in Table 4-1 at –15°C (5°F) and greater than 12 mm ($^1/_2$ in.) thick, and on all materials listed in Table 2-1 at –37°C (–35°F), shall be examined by the magnetic particle method (or at the option of the Purchaser, by the liquid penetrant method). Refer to Section 7 for the appropriate inspection criteria.

7.16.4 Examination of Welds Following Stress Relieving

After any stress relieving, but before hydrostatic testing of the tank, welds attaching nozzles, manholes, and cleanout openings shall be examined visually and by the magnetic particle method (or at the option of the Purchaser, the liquid penetrant method). Refer to 7.15.2, 7.15.4, or 7.15.5 for the appropriate examination and repair criteria.

7.16.5 Responsibility

The Manufacturer shall be responsible for examinations and any necessary repairs; however, if the Purchaser's inspector requires examinations in excess of the number specified in 7.17 or requires chip-outs of fillet welds in excess of one per 100 ft of weld and no defect is disclosed, the additional examination and related work shall be the responsibility of the Purchaser.

7.17 Radiographic/Ultrasonic Examination Requirements

7.17.1 Application

7.17.1.1 Any butt-welded joint in the wall of any tank to which these rules apply, and for which complete examination is mandatory under 5.26, shall be examined throughout its entire length by the radiographic or ultrasonic method as

Appendix I

Suggested Practice for Peening

I.1 General

Peening is used to eliminate distortion in thin plates and to prevent cracking in thick plates when the weld is built up of several layers of weld metal. Peening is intended to reduce the internal stresses introduced in welded structures because the weld shrinks more than the relatively cold adjacent base metal. Proper peening strains the stressed weld metal above its yield point and, in this manner, adjusts the stresses in proportion to the amount of flow caused by peening.

I.2 Effective Peening

Effective peening occurs below the red-hot temperature. Peening is wasted when it occurs above a temperature at which the weld metal begins to take on strength. The first two layers and the last layer of weld metal must not be peened.

To be effective, peening must move the weld metal. The shape, size, and hardness of peening tools are important. Bruises and surface roughness of the weld metal caused by peening are not objectionable, since these are melted by the deposition of subsequent layers of weld metal.

I.3 Peening as an Alternative to Thermal Stress Relief

When peening occurs as an alternative to thermal stress relief under permissible procedures, it shall be done carefully to minimize distortion of the weldment. Some steels that are weldable have to be peened sufficiently to temporarily create stresses in the reverse direction, which will disappear on cooling. These are the steels which get so hard when they are cold that the metal is only burnished by the peening tool instead of being cold-worked. When peening is done to avoid the formation of cracks on welds that are subsequently to be stress relieved, underpeening may be satisfactory.

I.4 Factors Involved in Peening

I.4.1 General

For peening to be acceptable or dependable as a means of stress relief, a thorough study must be made of all the factors involved, including the type of steel, the thickness of the weld, and the thicknesses of successive layers of welding (see 6.19.2). Two guides to satisfactory results are outlined in I.4.2 and I.4.3.

I.4.2 Amount of Peening Necessary

An approximation of the amount of peening that is necessary may be obtained by welding two small plates of a given material and thickness, with one plate held rigidly and the other free to move as the weld shrinks. The peening required to overcome the shrinkage gives a fair idea of the degree of peening that will be required in the actual operation.

I.4.3 Measurements during Welding and Peening

Punch marks shall be made on opposite sides of the weld, and the distance between these marks shall be kept within $^{1}/_{32}$ in. by peening during the welding of the seam. The initial measurement shall be made after two layers of weld metal have been deposited. After the weld has been built up to a depth of $1^{1}/_{4}$ – $1^{1}/_{2}$ in., the likelihood of deviation in the distance between punch marks is greatly reduced, since the stresses caused by shrinkage of the recently deposited weld metal are more fully resisted by the cooler prior layers. Cracking of unpeened welds in ordinary steel is most likely to occur at this point. If the peening has been done so that the deviation in distance between punch marks is kept to a minimum up to this point, the same degree of peening for the remainder of the weld will protect the weld from cracking.

Appendix Q

Low-pressure Storage Tanks for Liquefied Gases at –325°F or Warmer 10

Q.1 Scope

Q.1.1 General

This appendix, together with the basic sections of API 620, provides requirements for the materials, design, and fabrication of the metallic portions of a *refrigerated tank system*. The requirements for a basic API 620 tank apply to *primary and secondary liquid containers, refrigerated temperature roofs, warm product vapor containers, purge gas containers* and their appurtenances except where they are superseded by any requirements of this appendix. Requirements for the complete tank system, of which the metallic components are a part, are found in API 625.

Q.1.2 Piping Limitations

Piping limitations given in API 620 1.3.2 are superseded by API 625, Section 1.6.

Q.1.3 Pressure

The provisions in this appendix apply to design pressures from –0.25 psig to +7.00 psig.

Q.1.4 Temperature

The provisions in this appendix apply to design metal temperatures of –325°F or warmer.

Q.1.5 Definitions

The definitions of the following specialized terms used in this appendix are found in API 625:

Q.1.5.1 *Refrigerated Tank System* 10

Q.1.5.2 *Single Containment Tank System*

Q.1.5.3 *Double Containment Tank System*

Q.1.5.4 *Full Containment Tank System*

Q.1.5.5 *Primary Liquid Container*

Q.1.5.6 *Secondary Liquid Container*

Q.1.5.7 *Warm product vapor container*

Q.1.5.8 *Purge gas container*

Q.1.5.9 *Refrigerated temperature roof*

Q.1.5.10 *Design Pressure*

Q.1.5.11 *Annular Space*

Q.1.5.12 *Suspended deck*

Q.1.5.13 *Design Metal Temperature*

10 Text deleted.

Q.2 Materials

The material requirements are based on the storage of refrigerated products at the design metal temperature.

Q.2.1 Product Temperature Materials

Q.2.1.1 Materials for the following metallic components (including their penetrations, piping, anchors, stiffeners, and attachments) shall be selected from Table Q-1 and shall comply with the requirements of Q.2.2.

a) *primary liquid containers,*

b) *secondary liquid containers,*

c) *refrigerated temperature roofs*
(this includes inner roofs of double roof tanks, and single roofs of tanks with external roof insulation),

d) thermal distance pieces connecting cold piping to *warm vapor* or *purge gas containers*,

e) for *full containment tank systems*; portions of *warm product vapor containers* that may experience cold gas flows in the event of primary liquid container leakage,

10 f) metallic *suspended decks* for insulation,

g) Liner plates, if required for liquid containment, in concrete *primary or secondary liquid containers*, loaded in tension under cool down, operating, or other design conditions.

Q.2.1.2 Materials for liner plates, if required for liquid containment, in concrete *primary or secondary liquid containers*, loaded in compression under all design conditions shall be selected from materials explicitly listed in Table 4-1, excluding materials rated for design metal temperature 65°F and higher.

Q.2.1.3 Two stainless steel plates identical in material type may be welded together prior to erection in order to form a single shell plate subassembly. Plates welded together shall have thicknesses within $^{1}/_{16}$ in. of each other with the maximum plate thickness being $^{1}/_{2}$ in. No more than two plates shall be used to form one subassembly. Vertical edges of the pair of plates comprising a subassembly shall be aligned. The subassembly shall conform to the dimensional tolerances contained in Section 6 and shall be subjected to inspection requirements contained in Section 7, Q.5.5 and Q.5.6. All welding procedure specifications shall be in accordance with Section 6 and Q.4.

Q.2.2 Impact Test Requirements for Product Temperature Materials

Q.2.2.1 9% or 5% nickel steel shall be impact tested in accordance with Q.2.2.2 through Q.2.2.4. Impact testing is not required for austenitic stainless steel, nickel alloy, and aluminum materials. Welds in high-alloy (austenitic) stainless steel shall be impact tested if required by Q.4.3.

Q.2.2.2 Impact testing of plates, including structural members made of plate, shall comply with the following:

a) Impact test specimens shall be taken transverse to the direction of final plate rolling.

b) For ASTM A353 and A553 steels, Charpy V-notch specimens shall be cooled to a temperature of –320°F.

10 Note: This temperature is selected to be consistent with the standard requirements of the ASTM specifications. The temperature of –320°F also provides a convenient and safe medium (liquid nitrogen) for cooling; for testing techniques, see ASTM A370.

Table Q-1—ASTM Standards for Product Temperature Materials

Plates and Structural Members	Piping, Pipe Fittings, and Tubing	Forgings	Bolting
A353	A333, Grade 8 (see note 2)	A522	
A553, Type 1	A334, Grade 8 (see note 2)		
A645, Grade A	B444 (UNS-N06625), Gr. 1		
A645, Grade B	B444 (UNS-N06625), Gr. 2		
	B619 (UNS-N10276) (see notes 3 & 6)		
	B622 (UNS-N10276)		
A240, Type 304	A213, Grade TP 304	A182, Grade F304	A320, Grades B8, B8C, B8M, and B8T
A240, Type 304L	A213, Grade TP 304L	A182, Grade F304L	
	A312, Grade TP 304 (see note 3)		
	A312, Grade TP 304L (see note 3)		
	A403, Grade WP304		
	A403, Grade WP304L		
A240, Type 316	A213, Grade TP316	A182, Grade F316	
A240, Type 316L	A213, Grade TP316L	A182, Grade F316L	
	A312, Grade TP316 (see note 3)		
	A312, Grade TP316L (see note 3)		
	A403, Grade WP316		
	A403, Grade WP316L		
A240, Type 201LN (UNS-S20153)	A358, Grade 304, Class 1 (see note 4)		
B209, Alloy 3003-0 (see note 5)	B210, Alloy 3003-0	B247, Alloy 3003-H112	F468, Alloy 6061-T6
B209, Alloy 5052-0 (see note 5)	B210, Alloy 3003-H113	B247, Alloy 5083-H112	
B209, Alloy 5083-0 (see note 5)	B210, Alloy 5052-0	B247, Alloy 6061-T6	
B209, Alloy 5086-0 (see note 5)	B210, Alloy 5086-0		
B209, Alloy 5154-0 (see note 5)	B210, Alloy 5154-0		
B209, Alloy 5456-0 (see note 5)	B241, Alloy 5052-0		
B221, Alloy 6061-T4 and T6	B241, Alloy 5083-0		
B308, Alloy 6061-T6	B241, Alloy 5086-0		
	B241, Alloy 5454-0		
	B241, Alloy 5456-0		

10

Notes:

1. Note void.
2. Seamless piping and tubing only.
3. Purchased welded pipe shall be welded without the addition of filler metal using a process permitted by the named ASTM specification and shall be tested hydrostatically or by eddy current to ASTM requirements.
4. Impact test of welds shall be made for the welding procedure when required by Q.4.3.
5. ASTM B221 structural sections are also permitted.
6. Pipe conforming to ASTM B619 and note 3 of this table may be used in diameters exceeding the 8-in. limit stated in B619 when approved by Purchaser. Further, for this pipe over 8-in. diameter, the addition of filler metal is permitted.

c) For ASTM A645 steels, Charpy V-notch specimens shall be cooled to a temperature of –320°F unless the *design metal temperature* is –155°F or warmer, in which case, the specimens may be cooled to the alternate temperature of –220°F.

10 d) The transverse Charpy V-notch impact values shall conform to Table Q-2.

e) Each test shall consist of three specimens, and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. (15 mils) as required by ASTM A353, A553, and A645.

f) Retests shall be in accordance with ASTM A353, A553, and A645.

Q.2.2.3 Impact testing of structural members shall comply with the following:

a) For each different shape in each heat-treatment lot, one set of three specimens taken in the longitudinal direction from the thickest part of each shape shall be tested. If the heat-treatment lot consists of shapes from several ingots, tests shall be conducted on the various shapes of each ingot.

10 b) Charpy V-notch specimens shall be cooled to a temperature of –320°F (see Q.2.2.2, Items b and c) for A353, A553, and A645 Grade A or B steels for impact testing.

c) The longitudinal Charpy V-notch impact values shall conform to Table Q-2.

10 d) Each test shall consist of three specimens, and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. (15 mils) as required by ASTM A353, A553, and A645.

e) Retests shall be in accordance with ASTM A353, A553, and A645.

Q.2.2.4 Impact testing of forgings, piping, and tubing shall comply with the following:

a) Impact test specimens shall be taken from each heat included in any heat-treatment lot.

10 b) Charpy V-notch specimens shall be cooled to a temperature of –320°F (see Q.2.2.2, Items b and c) for A522, A333 (Grade 8), and A334 (Grade 8) steels for impact testing.

c) The minimum Charpy V-notch impact values shall conform to the longitudinal values in Table Q-2.

Table Q-2—Charpy V-notch Impact Values[a]

	Transverse		Longitudinal	
Size of Specimen (mm)	Value Required for Acceptance[b] (ft-lb)	Minimum Value Without Requiring Retest[c] (ft-lb)	Value Required for Acceptance[b] (ft-lb)	Minimum Value Without Requiring Retest[c] (ft-lb)
10 × 10.00	20	16	25	20
10 × 7.50	15	12	19	16
10 × 6.67	13	10	17	13
10 × 5.00	10	8	13	10
10 × 3.33	7	5	8	7
10 × 2.50	5	4	6	5

Notes:
[a]When the alternate flaw acceptance criteria of Table U-2 are applied, the higher impact values of Table U-3 are required for plates.
[b]Average of three specimens.
[c]Only one specimen of a set.

d) Each test shall consist of three specimens, and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. (15 ml) as required by ASTM A 522, A 333, (Grade 8), and A 334 (Grade 8).

e) Retests shall be in accordance with ASTM A 522, A 333 (Grade 8), and A 334 (Grade 8).

Q.2.3 Atmospheric Temperature Materials

Q.2.3.1 The following are considered *warm product vapor container* components:

a) roofs over *suspended decks*; 10

b) outer shells of double wall, *single containment tank systems*;

c) outer bottoms of double wall, *single containment tank systems*;

d) metallic liners for concrete *secondary liquid containers* where the liners are acting as *warm product vapor containers*, but not required for secondary liquid containment.

Q.2.3.2 Material for *warm product vapor containers* shall conform to one of the following:

a) Table 4-1 for *design metal temperatures* down to –35°F (lowest one-day mean ambient temperature of –35°F) without impact tests unless they are required by Table 4-1 or by the Purchaser.

b) Table R-3 for *design metal temperatures* down to –60°F without impact tests unless they are required by Table R-4 or by the Purchaser. 10

c) Paragraph Q.2.1 without impact tests unless they are specified by the Purchaser.

d) If approved by the Purchaser, the material may be selected according to the requirements of 4.2.2. Where wall liner systems are composed of embedded plates with liner plates less than 3/16 in. thick attached by lap welds, 4.2.2 shall not be applied to the liner or embed plate material.

Q.2.3.3 The following are considered *purge gas container* components:

a) outer roofs of double wall, double roof, *single containment tank systems*; 10

b) outer shells of double wall, double roof, *single containment tank systems*;

c) outer bottoms of double wall, double roof, *single containment tank systems*;

d) metallic liners functioning with a concrete *secondary liquid container* as a moisture vapor barrier but not acting as a *warm product vapor container* and not required for secondary liquid containment.

Q.2.3.4 Material for *purge gas containers* shall conform to one of the approved materials listed in Table 4-1. Consideration of the design metal temperature is not required if the actual stress does not exceed one-half the allowable tensile design stress for the material.

Q.2.4 Structural Shapes

Structural shapes of 9% and 5% nickel steel may be furnished to the chemical and physical requirements of ASTM A353, A553, or A645. Physical tests shall be in accordance with the requirements of ASTM A6.

Q.2.5 Piping, Tubing, and Forgings

10 **Q.2.5.1** In addition to the specific requirements of this appendix, all piping within the limitations of Q.1.2 shall fulfill the minimum material requirements of ASME B31.3.

Q.2.5.2 Except as allowed by Q.2.5.3 and Q.2.5.4, piping, tubing, and forgings used for openings within a distance of $2 \times \sqrt{(d \times t_n)}$ from the tank wall shall be compatible in welding, strength, and thermal expansion coefficient with the tank wall material (d and t_n are defined in Figure 5-7).

Q.2.5.3 Nickel alloy material B444 (UNS-N06625), B622 and B619 (UNS-N10276) in Table Q-1 may be used for piping and tubing as a substitute for A333, Grade 8 or A334, Grade 8 for openings through 9% Ni (A353, A553) and 5% Ni (A645) storage tanks, providing these materials meet the applicable requirements in this appendix and are not used for reinforcement.

Q.2.5.4 300 series stainless steel materials in Table Q-1 may be used for piping and tubing for openings through 201LN storage tanks, providing these materials meet the applicable requirements in this appendix and are not used for reinforcement.

Q.3 Design

Q.3.1 General

Design considerations shall be as specified in API 625, Section 6, "Design and Performance Criteria" together with the additional provisions of this Section Q.3.

10
Q.3.2 Density of Liquid Stored

The density of the liquid stored shall be its maximum density within the range of design temperatures.

Text deleted.

Q.3.3 Allowable Design Stresses

Q.3.3.1 The maximum allowable design stresses for the materials outlined in Q.2.1 shall be in accordance with Table Q-3.

Q.3.3.2 The values for the allowable design tensile stress given in Table Q-3 for materials other than bolting steel are the lesser of (a) $33^1/_3$% of the specified minimum ultimate tensile strength for the material or (b) $66^2/_3$% of the specified minimum yield strength, but they are 75% of the specified minimum yield strength for the stainless steel,
10 nickel alloy, and aluminum materials. Allowable test stresses are based on the limitation of Q.6.1.2.

Q.3.3.3 For the base materials associated with Table Q-3, notes a and b; if:

a) the weld filler metal has an unspecified yield strength, or

b) the weld filler metal has specified minimum yield or ultimate tensile strength below the specified minimums for the base metal, or when

c) the welding procedure qualification test shows the deposited weld metal tensile strength is lower than the specified minimum ultimate tensile strength of the base metal, then allowable stresses should be based on the weld metal and
10 heat affected zone strengths as determined by Q.4.1.1 and Q.4.1.2.

Table Q-3—Maximum Allowable Stress Values

	Stress Value (lbf/in.^{2})				
	Specified Minimum		Allowable Stress		
ASTM Specifications	Tensile Strength	Yield Strength	Design	Test	
	Plate and Structural Members				
A353	100,000	75,000	[a]	[a]	
A553, Type 1	100,000	85,000	[a]	[a]	
A645, Grade B	100,000	85,000	[a]	[a]	
A645, Grade A	95,000	65,000	31,700[b]	42,000[b]	
A240, Type 304	75,000	30,000	22,500	27,000	
A240, Type 304L	70,000	25,000	18,750	22,500	
A240, Type 201LN (UNS-S20153)	95,000	45,000	31,700	40,500	
A240, Type 316	75,000	30,000	22,500	27,000	
A240, Type 316L	70,000	25,000	18,750	22,500	
B209, Alloy 3003-0	14,000	5,000	3,750	4,500	
B209, Alloy 5052-0	25,000	9,500	7,100	8,550	
B209, Alloy 5083-0	40,000[g]	18,000[g]	13,300[g]	16,200[g]	
B209, Alloy 5086-0	35,000	14,000	10,500	12,600	
B209, Alloy 5154-0	30,000	11,000	8,250	9,900	
B209, Alloy 5456-0	42,000[g]	19,000[g]	14,000[g]	17,100[g]	
B221, Alloy 3003-0	14,000	5,000	3,750	4,500	
B221, Alloy 5052-0	25,000	10,000	7,500	9,000	
B221, Alloy 5083-0	39,000	16,000	12,000	14,400	10
B221, Alloy 5086-0	35,000	14,000	10,500	12,600	
B221, Alloy 5154-0	30,000	11,000	8,250	9,900	
B221, Alloy 5456-0	41,000	19,000	13,650	17,100	
B221, Alloys 6061-T4 and T6 (welded)	24,000		8,000	10,000	
B308, Alloys 6061-T4 and T6 (welded)	24,000		8,000	10,000	
	Piping and Tubing				
A333, Grade 8	100,000	75,000	[a]	[a]	
A334, Grade 8	100,000	75,000	[a]	[a]	
A213, Grade TP, Type 304	75,000	30,000	22,500	27,000	
A213, Grade TP, Type 304L	70,000	25,000	18,750	22,500	
A312, Grade TP, Type 304[c]	75,000	30,000	22,500	27,000	
A312, Grade TP, Type 304L[c]	70,000	25,000	18,750	22,500	
A358, Grade 304, Class I	75,000	30,000	22,500	27,000	
A213, Grade TP316	75,000	30,000	22,500	27,000	
A213, Grade TP316L	70,000	25,000	18,750	22,500	
A312, Grade TP316	75,000	30,000	22,500	27,000	
A312, Grade TP316L	70,000	25,000	18,750	22,500	
B210, Alloy 3003-0	14,000	5,000	3,750	4,500	

Table Q-3—Maximum Allowable Stress Values (Continued)

	Stress Value (lbf/in.^{2})			
	Specified Minimum		Allowable Stress	
ASTM Specifications	Tensile Strength	Yield Strength	Design	Test
B210, Alloy 3003-H113	14,000	5,000	3,750	4,500
B210, Alloy 5052-0	25,000	10,000	7,500	9,000
B210, Alloy 5086-0	35,000	14,000	10,500	12,600
B210, Alloy 5154-0	30,000	11,000	8,250	9,900
B241, Alloy 5052-0	25,000	10,000	7,500	9,000
B241, Alloy 5083-0	39,000	16,000	12,000	14,400
B241, Alloy 5086-0	35,000	14,000	10,500	12,600
B241, Alloy 5454-0	31,000	12,000	9,000	10,800
B241, Alloy 5456-0	41,000	19,000	13,650	17,100
B444 (UNS-N06625), Grade 1	120,000	60,000	40,000[f]	54,000[f]
B444 (UNS-N06625), Grade 2	100,000	40,000	30,000[f]	36,000[f]
B619 (UNS-N10276), Class I[c]	100,000	41,000	30,750[f]	36,900[f]
B622 (UNS-N10276)	100,000	41,000	30,750[f]	36,900[f]
Forgings				
A522	100,000	75,000	[a]	[a]
A182, Grade F, Type 304	75,000	30,000	22,500	27,000
A182, Grade F, Type 304L	65,000	25,000	18,750	22,500
A240, Trade F316	75,000	30,000	22,500	27,000
A240, Grade F316L	70,000	25,000	18,750	22,500
10 B247, Alloy 3003-H112	14,000	5,000	3,750	4,500
B247, Alloy 5083-H112	40,000	18,000	13,300	16,200
B247, Alloy 6061-T6 (unwelded)	38,000	35,000	12,650	20,900
Bolting[e]				
F468, Alloy 6061-T6	42,000	35,000	14,000	
A320 (strain-hardened: Grade B8, B8C, B8M and B8T)				
≤ ¾ in.	125,000	100,000	30,000	
> ¾ – 1 in.	115,000	80,000	26,000	
> 1 – 1¼ in.	105,000	65,000	21,000	
> 1¼ – 1½ in.	100,000	50,000	16,000	
A320 (solution-treated and strain-hardened grades when welded)				
Grades B8, B8M, and B8T-all sizes	75,000	30,000	15,000	

Notes:

[a]The allowable stresses for these materials are based on the lower yield and tensile strength of the weld metal or base metal, as determined by Q.4.1.1 and Q.4.1.2, and the design rules in Q.3.3.2 and Q.3.3.3. Further, the allowable stresses shall be considered joint by joint as limits on the stress acting across that joint considering the weld metal used at that joint. The minimum measured tensile strength shall be 95,000 lbf/in.^{2} and minimum measured yield strength shall be 52,500 lbf/in.^{2}, except that for circumferential seams only in the sidewall of a cylindrical tank, the minimum measured tensile strength shall be 80,000 lbf/in.^{2} and the minimum measured yield strength shall be 42,000 lbf/in.^{2}. For all seams, the maximum permitted values to be used for determining the allowable stress are 100,000 lbf/in.^{2} for tensile strength and 58,000 lbf/in.^{2} for yield strength.

[b]Based on the yield and tensile strength of the weld metal, as determined by Q.4.1. The minimum measured tensile strength shall be 95,000 lbf/in.^{2} and the minimum measured yield strength shall be 52,500 lbf/in.^{2}.

[c]For welding piping or tubing, a joint efficiency of 0.80 shall be applied to the allowable stresses for longitudinal joints in accordance with 5.23.3.

[d]Not used.

[e]See 5.6.6.

[g]These allowable stresses are for thicknesses up to and including 1.5 in. For thicknesses over 1.5 in., determine allowable stresses per Q.3.3.2 using ASTM minimum tensile strength and minimum yield strength for these thicknesses.

[f]Not to be used for opening reinforcement when used with A353, A553, and A645.

Q.3.3.4 Where plates or structural members are used as anchor bars for resisting the shell uplift, the allowable design and test stresses for the material shall be used for the design and overload test conditions, respectively.

Q.3.3.5 Allowable compressive stresses shall be in accordance with 5.5.4 except that for aluminum alloy plate the allowable compressive stresses shall be reduced by the ratio of the modulus of compressive elasticity to 29,000 for values of $(t - c)/R$ less than 0.0175 and by the ratio of the minimum yield strength for the aluminum alloy in question to 30,000 for values of $(t - c)/R$ equal to or greater than 0.0175 (see 5.5.2 for definitions). In all other equations in this standard where yield strength or modulus of elasticity is used, such as Equations 27 and 28, similar corrections shall be made for aluminum alloys.

Q.3.3.6 The maximum allowable tensile stress for design loadings combined with wind or earthquake loadings shall not exceed 90% of the minimum specified yield strength for stainless steel or aluminum.

Q.3.3.7 For aluminum structural members, determine allowable stresses and compressive modulus of elasticity using the Aluminum Association, *Aluminum Design Manual*, "Specification for Aluminum Structures". Materials shall be those listed in Table Q-1.

Q.3.4 Piping

All process piping within the limitations of Q.1.2 (except pump columns as governed by API 625, Section 7.3.3) shall fulfill the minimum design requirements of ASME B31.3, but using the allowable stresses of Table Q-3. 10

Q.3.5 Bottom Plates for Primary and Secondary Liquid Containers

Q.3.5.1 *Primary liquid containers* and *secondary liquid containers* shall have butt-welded annular bottom plates with a radial width that provides at least 24 in. between the inside of the shell and any lap-welded joint in the remainder of the bottom and at least a 2-in. projection outside the shell. A greater radial width (L_{min}) of annular plate is required when calculated by the following equations:

For steel,

$$L_{min} = \frac{390 t_b}{\sqrt{(H)(G)}} \text{ in.}$$

For aluminum,

$$L_{min} = \frac{255 t_b}{\sqrt{(H)(G)}} \text{ in.}$$

where

t_b = nominal thickness of the annular plate, in inches,

H = design height of the liquid, in ft, 10

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

Q.3.5.2 The thickness of the annular bottom plates shall be in accordance with Table Q-4 (for steel or aluminum, as applicable). The thicknesses shown are minimums.

Q.3.5.3 The ring of annular plates shall have a circular outside circumference, but it may have a regular polygonal shape inside the tank shell with the number of sides equal to the number of annular plates. These pieces shall be butt-welded in accordance with Q.5.1.1, Item a. 10

Q.3.5.4 The plates of the first shell course shall be attached to the annular bottom plates by a weld as required by 5.9.5 except when a full-penetration weld is used or required (see Q.5.1.1). 10

Table Q-4A—Minimum Thickness for the Annular Bottom Plate: Steel Tanks

Nominal Thickness of First Shell Course (in.)	Design Stress[a] in First Shell Course (lbf/in.^{2})					
	≤ 19,000	22,000	25,000	28,000	31,000	34,000
≤ 0.75	1/4	1/4	1/4	9/32	11/32	13/32
> 0.75 – 1.00	1/4	1/4	9/32	11/32	7/16	17/32
> 1.00 – 1.25	1/4	1/4	11/32	7/16	17/32	21/32
> 1.25 – 1.50	—	9/32	13/32	17/32	21/32	25/32

Notes:

10 The thicknesses and widths (see Q.3.5.1) in this table are based on the foundation providing a 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. The thickness of the annular bottom plates need not exceed the thickness of the first shell course. The minimum thicknesses for annular bottom plates were derived based on a fatigue cycle life of 1000 cycles for
10 steel tanks.

[a]The stress shall be calculated using the formula [(2.6*D*) × (*HG*)]/*t*, where *D* = nominal diameter of the tank, in ft; *H* = maximum filling height of the tank for design, in ft; *G* = design specific gravity; and *t* = design thickness of the first shell course, excluding corrosion allowance, in in.

Table Q-4B—Minimum Thickness for the Annular Bottom Plate: Aluminum Tanks

Nominal Thickness of First Shell Course (in.)	Design Stress[a] in First Shell Course (lbf/in.^{2})					
	12,000	13,000	14,000	15,000	16,000	17,000
≤ 0.50	1/4	1/4	9/32	9/32	5/16	5/16
> 0.50 – 0.75	11/32	3/8	13/32	15/32	1/2	17/32
> 0.75 – 1.00	15/32	17/32	19/32	5/8	11/16	23/32
> 1.00 – 1.25	5/8	11/16	3/4	13/16	7/8	29/32
> 1.25 – 1.50	3/4	13/16	29/32	31/32	1 1/32	1 1/8
> 1.50 – 1.75	7/8	1	1 1/16	1 5/32	1 1/4	1 5/16
> 1.75 – 2.00	1	1 1/8	1 7/32	1 5/16	1 13/32	1 1/2

Notes:

10 The thicknesses and widths (see Q.3.5.1) in this table are based on the foundation providing a 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. The thickness of the annular bottom plates need not exceed the thickness of the first shell course. The minimum thicknesses for annular bottom plates were derived based on a fatigue cycle life of 1000 cycles for aluminum tanks.

[a]The stress shall be calculated using the formula [(2.6*D*) × (*HG*)] *t*, where *D* = nominal diameter of the tank, in ft; *H* = maximum filling height of the tank for design, in ft; *G* = design specific gravity; and *t* = design thickness of the first shell course, excluding corrosion allowance, in in.

Q.3.5.5 Butt-welds in annular plates shall be not closer than 12 in. from any vertical weld.

Q.3.5.6 Three-plate laps or butt-weld junctions in tank bottoms shall be not closer than 12 in. from each other.

Q.3.5.7 Bottom plates, other than annular bottom plates for a 9% or 5% nickel steel or stainless steel *primary or secondary liquid container*, shall have a minimum thickness of $^{3}/_{16}$ in. exclusive of any specified corrosion allowance. 10

Q.3.6 Shell Stiffening Rings for Primary and Secondary Liquid Containers 10

Q.3.6.1 Internal or external shell stiffening rings may be required to maintain roundness when the tank is subjected to wind, vacuum, or other specified loads. When stiffening rings are required, the stiffener-to-shell weld details shall be in accordance with Figure Q-1 and Q.3.6.2 through Q.3.6.5. 10

Q.3.6.2 The stiffener ring and backing strip (if used) shall comply with the requirements of Q.2.1. The stiffener rings may be fabricated from plate using an intermittent weld on alternating sides between the web and the flange.

Q.3.6.3 One rat hole with a minimum radius of $^{3}/_{4}$ in. shall be provided at each longitudinal shell joint and ring juncture weld (see Figure Q-1).

Q.3.6.4 Except for aluminum or stainless steel tanks, all fillet welds shall consist of a minimum of two passes. The ends of the fillet welds shall be 2 in. from the rat hole (see Figure Q-1), and these welds shall be deposited by starting 2 in. from the rat hole and welding away from the rat hole. An acceptable alternative to the detail that includes stopping fillet welds 2 in. short of the rat hole would be to weld continuously through the rat hole from one side of the stiffener to the opposite side. All craters in fillet welds shall be repaired by back welding.

Q.3.6.5 Any joints between the adjacent sections of stiffening rings, as shown in Figure Q-1, shall be made so that the required moment of inertia of the combined ring-shell section is provided. Weld joints between adjacent sections shall be made with full-thickness and full-penetration butt-welds. Stiffening-ring butt-welds may employ metal backing strips. Backing strips and the associated welding shall be made in a manner that provides a smooth contour in the rat hole and all other weld joint ends. All weld passes shall be started at the rat hole and other weld joint ends and shall be completed by moving away from these ends. Passes shall be overlapped away from edges to provide a smooth continuous weld.

Q.3.7 Tank Anchorage for Primary and Secondary Liquid Containers

Q.3.7.1 In addition to the loads in Q.3.8, the anchorage for the *primary liquid container* and any *secondary liquid container* shall be designed to meet the requirements of Q.3.7.2 through Q.3.7.5. 10

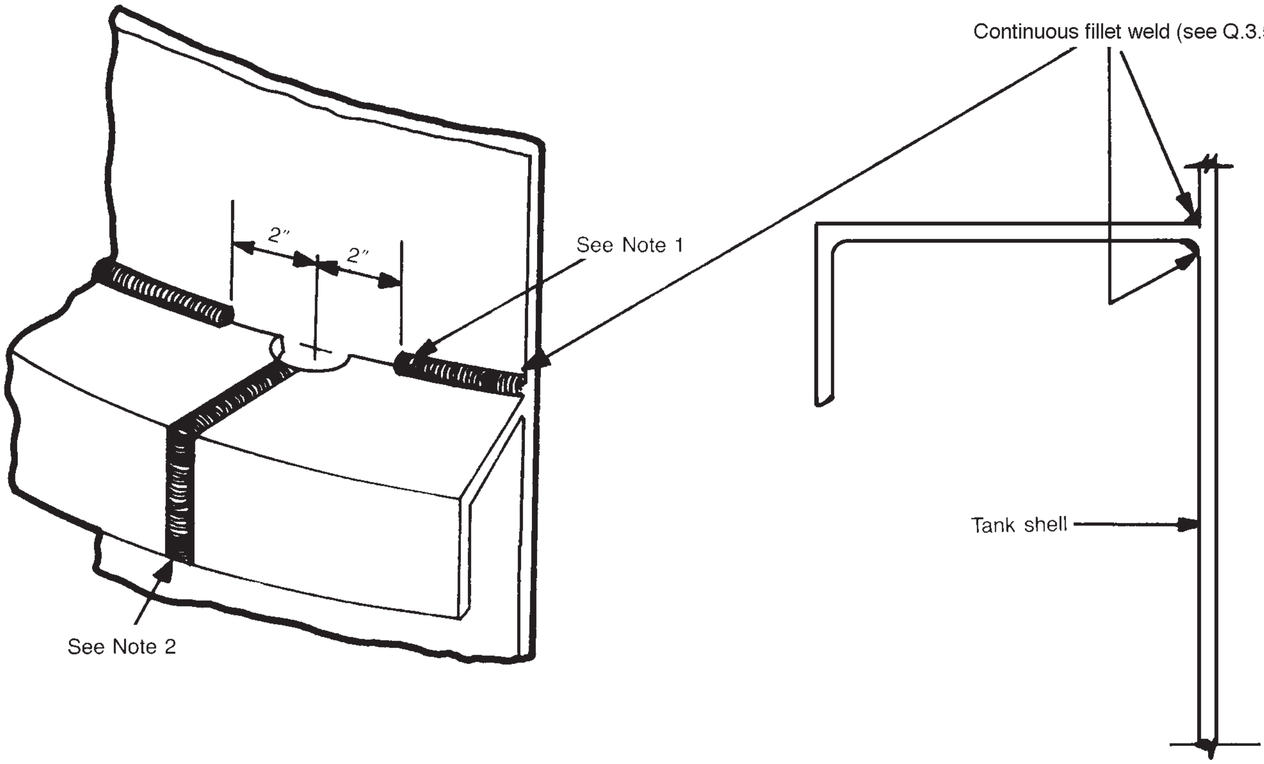
Q.3.7.2 The anchorage shall accommodate movement of the tank wall and bottom caused by thermal changes.

Q.3.7.3 For Appendix Q tanks, 9% or 5% nickel steel, stainless steel, or aluminum anchorage may be used. Aluminum anchorage shall not be imbedded in reinforced concrete unless it is suitably protected against corrosion.

Q.3.7.4 Anchorage subject to load from internal pressure shall be designed as described in Q.3.7.4.1 through Q.3.7.4.3. 10

Q.3.7.4.1 When the top shell course is the minimum thickness indicated in Table 5-6, the minimum anchorage shall be designed for normal loads as specified by the Purchaser and by this standard. See 5.11.2.3 for the allowable stress.

Q.3.7.4.2 When the top shell course is thickened beyond the minimum thickness provided in Table 5-6 or as in Figure 5-6, details f and g, or a knuckle is used, the minimum anchorage shall be designed for three times the internal design pressure. The allowable stress for this loading is 90% of the minimum specified yield strength of anchorage material.



Notes:
1. See Q.3.5.4 for alternative fillet-weld termination details.
2. Backing strips are permitted on stiffening-ring junction welds.

Figure Q-1—Typical Stiffening-ring Weld Details

10 **Q.3.7.4.3** As an alternative to Q.3.7.4.2, the Purchaser may specify a combination of normal anchorage design, (see Q.3.7.4.1) and emergency venting. The Purchaser shall specify required emergency venting discharge rates considering upset conditions including those addressed in API 2000 (see 9.2 and K.1).

Q.3.7.5 The foundation design loading for Q.3.7.4 is described in Q.8.

Q.3.8 Combination of Design Loads for Double-Wall Tanks

The inner and outer containers shall be designed for the most critical load combinations per 5.4.2 and per Q.3.8.1 through Q.3.8.5 as applicable.

Q.3.8.1 Inner Tank

10 The primary liquid container (inner tank) shall also be designed for the static insulation pressure, the insulation pressure as the inner tank expands during warming after an in-service period, and the purging or operating pressure of the space between the inner and outer tank shells, unless the pressure is equalized on both sides of the inner tank.

Q.3.8.2 Single Containment Outer Wall

A metallic *warm vapor* or *purge gas container* for a double wall, *single containment tank system* shall also be designed for the purging and operating pressure of the space between the inner and outer tank shells and for the loading from the insulation.

Q.3.8.3 Double Containment Outer Wall

A metallic *warm vapor, purge gas*, or *secondary liquid container* for a *double containment tank system* shall be designed for the load combinations specified for the outer wall of a *single containment tank system*. A metallic *secondary liquid container* shall also be designed for the following upset conditions:

a) Dead load and liquid head [$D_L + P_L$],

b) Dead load, liquid head, and seismic [$D_L + P_L + E$],

where D_L, P_L, and E are defined in Q.3.8.5.

Q.3.8.4 Full Containment Outer Wall

A metallic outer wall for a *full containment tank system* shall be designed for the load combinations specified for the outer wall of a *single containment tank system*. The metallic outer wall shall also be designed for the following upset conditions:

a) Dead load, design pressure and liquid head [$D_L + P_g + P_L$],

b) Dead load, design pressure, liquid head, and seismic [$D_L + P_g + P_L + E$], 10

where D_L, P_g, P_L, and E are defined in Q.3.8.5.

Q.3.8.5 Nomenclature

D_L = dead load,

P_g = design pressure of the *secondary liquid container*,

P_L = liquid head in the *secondary liquid container* determined from the maximum normal operating capacity of the *primary liquid container*,

E = ALE seismic as required by L.4, including 10% snow load.

Q.3.9 Minimum Wall Requirements

Q.3.9.1 Warm Product Vapor and Purge Gas Containers

Design of *warm vapor and purge gas containers* shall be in accordance with Section 5 of this standard together with the additional provisions of this Section Q.3.9.1. *Warm vapor and purge gas containers* shall have a minimum nominal thickness of $3/16$ in. except for metallic wall liners for concrete containers which shall have a minimum nominal thickness of 0.12 in.

Q.3.9.2 Primary and Secondary Liquid Containers

The sidewall thickness of a metallic *primary or secondary liquid container* shall in no case be less than that described in Table Q-5.

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

Q.3.9.3 Primary and Secondary Liquid Container Tank Tolerances

The tolerances of the sidewall of a metallic *primary or secondary liquid container* shall be in accordance with 6.5.2, 6.5.3, 6.5.4, and Table Q-6, which supersedes Table 6-1.

10 **Table Q-5—Nominal Thickness of Primary and Secondary Liquid Container Cylindrical Sidewall Plates**

Nominal Cylinder Diameter (ft)	Nominal Plate Thickness (in.)
Stainless steel and nickel steel	
< 60	3/16
60 – 140	1/4
> 140 – 220	5/16
> 220	3/8
Aluminum	
< 20	3/16
20 – 120	1/4
> 120 – 200	5/16
> 200	3/8

10 **Table Q-6—Radius Tolerances for Primary and Secondary LIquid Container Shells**

Diameter Range (ft)	Radius Tolerance (in.)
Stainless steel and nickel steel	
< 140	± 3/4
140 – 220	± 1
> 220	± 1 1/4
Aluminum	
< 20	± 1/2
20 – 120	± 3/4
> 120 – 200	± 1
> 200	± 1 1/4

10 Text deleted.

Q.4 Welding Procedures

The rules in this section shall apply to *primary* and *secondary liquid containers*, *refrigerated temperature roofs*, and *suspended insulation decks*. Covered electrodes, bare-wire electrodes, and flux cored electrodes used to weld 9% and 5% nickel steel shall be limited to those listed in AWS 5.11, AWS 5.14, and AWS 5.34. *Warm vapor* and *purge*
10 *gas containers* shall be welded in accordance with the basic rules of this standard unless the requirements of this appendix or Appendix R are applicable.

Purge gas containers may be of single-welded lap or single-welded partial penetration butt construction when the thickness does not exceed $3/8$ in. Such single side welds shall be made from the outside to prevent corrosion and the entrance of moisture. At any thickness, the outer tank may be of single welded butt construction from either side with
full penetration and fusion or double-welded butt construction without necessarily having full fusion and penetration. 10

Warm product vapor containers shall conform to the lap- or butt-welded construction described in this standard except as required in Q.5.2.1.

Q.4.1 Welding Procedure Qualification

Q.4.1.1 Specifications for the standard welding procedure tests and confirmation of the minimum ultimate tensile strength are in 6.7.

Q.4.1.2 When required by Q.3.3.3, two all-weld-metal specimens that conform to the dimensional standard of 10
Section 12.1 of AWS A5.11 shall be tested to determine the minimum yield and ultimate tensile strength required by Table Q-3; or for determining allowable stress values in Q.3.3.2. The yield strength shall be determined by the 0.2% Offset Method.

Q.4.2 Impact Tests for 9% and 5% Nickel Steel

Impact tests for components of 9% and 5% nickel steel shall be made for each welding procedure as described in 10
Q.4.2.1 through Q.4.2.5.

Q.4.2.1 Charpy V-notch specimens shall be taken from the weld metal and from the heat-affected zone of the welding procedure qualification test plates or from duplicate test plates.

Q.4.2.2 Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. The specimen shall be oriented so that the notch is normal to the surface of the material. One face of the specimen shall be substantially parallel to and within $1/16$ in. of the surface.

Q.4.2.3 Heat-affected zone impact specimens shall be taken across the weld and as near the surface of the material as is practicable. The specimens shall be of sufficient length to locate the notch in the heat-affected zone after etching. The notch shall be cut approximately normal to the material surface to include as much heat-affected zone material as possible in the resulting fracture.

Q.4.2.4 Impact test specimens shall be cooled to the temperature stated in Q.2.2.

Q.4.2.5 The required impact values and lateral expansion values of the weld metal and the heat-affected zone shall
be as given in Q.2.2.2, Items d and e, respectively. Where erratic impact values are obtained, retests will be allowed if 10
agreed upon by the Purchaser and the Manufacturer.

Q.4.3 Impact Tests for High Alloys

Q.4.3.1 Impact tests are not required for the high-alloy (austenitic stainless steel) base materials, nickel alloy based materials, aluminum base materials, and weld deposited for the nonferrous (aluminum) materials.

Q.4.3.2 Impact tests are not required for austenitic stainless steel welds deposited by all the welding processes for services of –200°F and above.

Q.4.3.3 Austenitic stainless steel welds deposited for service below –200°F by all welding processes shall be impact
tested in accordance with Q.4.2 except that the required impact values shall be 75% of the values as given in Q.2.2.2, 10
Item d. Electrodes used in the production welding of the tank shall be tested to meet the above requirements.

Q.4.3.4 Impact tests are not required for nickel alloy welds made with electrodes/filler metals covered by AWS Specification A5.11 or AWS Specification A5.14, provided the nominal nickel content is 50% or greater, and the weld is deposited by the shielded metal-arc welding (SMAW), gas metal-arc welding (GMAW), gas tungsten-arc welding (GTAW), or plasma-arc welding (PAW) processes. When A5.11/A5.14 specifies the nickel content as a "remainder," the nickel content shall be determined by summing the maximum specified values of the other elements (use the average specified value for elements with specified ranges) and subtracting from 100%.

Q.4.4 Impact Tests for Warm Product Vapor Container Components

10 When impact tests are required by Q.2.3.2 for *warm product vapor container* components, they shall conform to the requirements of ASTM A20, Supplementary Requirement, paragraph S 5, this appendix, or Appendix R, whichever is applicable. Weld material for lap welded wall liners shall meet requirements for design metal temperature without exception (i.e., including cases where 4.2.2 is applied for liner selection).

Q.4.5 Production Welding Procedures

The production welding procedures and the production welding shall conform to the requirements of the procedure qualification tests within the following limitations:

a) Individual weld layer thickness shall not be substantially greater than that used in the procedure qualification test.

b) Electrodes shall be of the same AWS classification and shall be of the same nominal size or smaller.

c) The nominal preheat and interpass temperatures shall be the same.

Q.4.6 Production Weld Tests

Q.4.6.1 Production weld test plates shall be welded for *primary* and *secondary liquid container* butt-welded shell plates when welding procedure qualifications are required to be impact tested per Q.4.2 and Q.4.3. The number of
10 production weld tests shall be based on the requirements of Q.4.6.3 and Q.4.6.4. The locations impact tested (i.e., HAZ and/or weld deposits) shall likewise be the same as required for weld procedure qualifications per Q.4.2 and Q.4.3. Weld testing shall be in accordance with Q.4.6.5. Test plates shall be made from plates produced only from the heats that are used to produce the shell plates for the tank.

Q.4.6.2 Test plates shall be welded using the same qualified welding procedure and electrodes that are required for the tank shell plate joints. The test plates need not be welded as an extension of the tank shell joint but shall be welded in the required qualifying positions.

Q.4.6.3 One test weld shall be made on a set of plates from each specification and grade of plate material, using a thickness that would qualify for all thicknesses in the shell. Each test welded of thickness t shall qualify for plate thicknesses from $2t$ down to $t/2$, but not less than $5/8$ in. For plate thicknesses less than $5/8$ in., a test weld shall be made for the thinnest shell plate to be welded; this test weld will qualify plate thicknesses from t up to $2t$.

10 **Q.4.6.4** Test welds shall be made for each position and for each process used in welding *primary* and *secondary liquid containers'* shell plates except for the following:

a) A manual or semi-automatic vertical test weld will qualify manual or semi-automatic welding using the same weld process in all positions.

b) A semi-automatic vertical test weld will qualify machine welding using the same weld process in all positions.

c) Test welds are not required for machine welded circumferential joints in cylindrical shells.

Q.4.6.5 The impact specimens and testing procedure shall conform to Q.4.2.1 through Q.4.2.5 for 9% and 5% 10
nickel steel. The impact specimens and testing procedure shall conform to Q.4.3.3 for austenitic stainless steel welds deposited for service below –200°F.

Q.4.6.6 By agreement between the Purchaser and the Manufacturer, production test welds for the first tank shall satisfy the requirements of this paragraph for similar tanks at the same location if the tanks are fabricated within 6 months of the time the impact tests were made and found satisfactory and the same weld procedure specifications are used.

Q.5 Requirements for Fabrication, Openings, Examination, and Testing

Q.5.1 Miscellaneous Requirements for Primary and Secondary Liquid Containers and Refrigerated Temperature Roofs 10

Q.5.1.1 The following shall be joined with double butt-welds that have complete penetration and complete fusion except as noted:

a) Longitudinal and circumferential shell joints and joints that connect the annular bottom plates together. When approved by Purchaser, these may be welded from a single side provided temporary non-fusible backing is used with
complete penetration and complete fusion. Both sides of the joint shall be 100% visually examined as specified in 7.15.5. 09

b) Joints that connect sections of compression rings and sections of shell stiffeners together. Backup bars may be used for these joints with complete penetration and complete fusion detail.

c) Joints around the periphery of a shell insert plate.

d) Joints that connect the shell to the bottom, unless a method of leak checking is used (see Q.6.2.2), in which case double fillet welds are acceptable (see Q.6.2.2).

e) Joints that connect nozzle necks to flanges.

f) Butt-welds in piping nozzles, manway necks, and pipe fittings, including weld neck flanges, shall be made using double butt-welded joints. When accessibility does not permit the use of double butt-welded joints, single butt-welded joints that ensure full penetration through the root of the joint are permitted.

Q.5.1.2 Fillet welds shall be made in the manner described in Q.5.1.2.1 through Q.5.1.2.2.

Q.5.1.2.1 All fillet welds shall have a minimum of two passes, except aluminum material and as permitted for stiffening ring attachment to shell (see Q.3.6.4).

Text removed.

Q.5.1.2.2 For 9% nickel material, sandblasting or other adequate means must be used to remove mill scale from all 10
plate edges and surfaces before fillet welds in contact with the refrigerated liquid and vaporized liquefied gas are welded. Sandblasting, or other adequate means, is required to remove slag from the first welding pass if coated electrodes are used.

Text removed.

Q.5.1.3 Connections:

Q.5.1.3.1 Slip-on flanges may be used where specifically approved by the Purchaser.

Q.5.1.3.2 All connections shall have complete penetration and complete fusion.

Q.5.1.3.3 Acceptable types of welded opening connections are shown in Figure 5-8, Panels a, b, c, g, h, m, and o.

Q.5.1.3.4 Flanges for nozzles shall be in accordance with this standard; however, the material shall comply with the requirements of Q.2.1 or Q.2.2.

Q.5.1.3.5 Manways shall have welded closures rather than depending on gaskets.

10 **Q.5.2 Warm Product Vapor Container Welds**

Q.5.2.1 *Warm product vapor container* bottom components joined together by fillet welds shall have a minimum of two passes.

Q.5.2.2 Metallic wall liners for concrete *secondary liquid containers* where the liners are acting as *warm product vapor containers* but not required for secondary liquid containment shall be butt welded together or lap welded to embedment plates. Fillet welds for lap welded wall liners shall be two pass minimum except that wall liners less than $^{3}/_{16}$ in. may be single pass.

Q.5.3 Postweld Heat Treatment

Q.5.3.1 Cold-formed 9% and 5% nickel plates shall be postweld heat treated (or stress relieved) when the extreme fiber strain from cold forming exceeds 3%. Cold-formed 201LN stainless steel shall be reheat-treated in accordance with ASTM A480 when the extreme fiber strain from cold forming exceeds 4%. Forming strain shall be as determined by the formula:

$$s = \frac{65t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

where

s = strain, in percent,

t = plate thickness, in inches,

R_f = final radius, in inches,

R_o = original radius, in inches (infinity for flat plate).

Q.5.3.2 If postweld heat treatment (or stress relief) is required for 9% and 5% nickel, the procedure shall be in accordance with paragraph UCS-56 in Section VIII of the ASME *Code* (with a holding temperature range from 1025°F to 1085°F), but the cooling rate from the postweld heat treatment shall be not less than 300°F per hour down to a temperature of 600°F. A vessel assembly, or plate that requires postweld heat treatment, must be postweld heat treated in its entirety at the same time. Methods for local or partial postweld heat treatment cannot be used. Pieces individually cold formed that require postweld heat treatment may be heat treated before being welded into the vessel or assembly.

Q.5.3.3 Postweld heat treatment of nonferrous materials is normally not necessary or desirable. No postweld heat treatment shall be performed except by agreement between the Purchaser and the Manufacturer.

Q.5.3.4 Postweld heat treatment of austenitic stainless steel materials is neither required nor prohibited, but
10 paragraphs UHA-100 through UHA-109 in Section VIII of the *ASME Code* shall be reviewed if postweld heat treatment is considered by the Purchaser or the Manufacturer.

Q.5.4 Spacing of Connections and Welds

Q.5.4.1 In *primary* and *secondary liquid containers*, all opening connections 12 in. or larger in nominal diameter in a shell plate that exceeds 1 inch in thickness shall conform to the spacing requirements for butt and fillet welds 10 described in Q.5.4.2 through Q.5.4.4.

Q.5.4.2 The butt-weld around the periphery of a thickened insert plate, or the fillet weld around the periphery of a reinforcing plate, shall be at least the greater of 10 times the shell thickness or 12 in. from any butt-welded seam or the bottom-to-shell or roof-to-shell joint. As an alternative, the insert plate (or the reinforcing plate in an assembly that does not require stress relief) may extend to and intersect a flat-bottom-to-shell corner joint at approximately 90 degrees.

Q.5.4.3 In cylindrical tank walls, the longitudinal weld joints in adjacent shell courses, including compression ring welds, shall be offset from each other a minimum distance of 12 in.

Q.5.4.4 Radial weld joints in a compression ring shall be not closer than 12 in. from any longitudinal weld in an adjacent shell or roof plate.

Q.5.5 Examination of Welds by the Liquid-penetrant Method

Q.5.5.1 The following *primary* and *secondary liquid container* welds shall be examined by the liquid-penetrant method after stress relieving, if any, and before the hydrostatic test of the tank: 10

a) All longitudinal and circumferential butt-welds not completely radiographed. Examination shall be on both sides of the joint.

b) The welded joint that joins the cylindrical wall of the tank to the bottom annular plates.

c) All welds of opening connections that are not completely radiographed, including nozzle and manhole neck welds and neck-to-flange welds. Examination shall also include the root pass and every $\frac{1}{2}$ in. of thickness of deposited 10 weld metal (see 5.27.11) as welding progresses.

d) All welds of attachments, such as stiffeners, compression rings, clips, and other nonpressure parts. 10

e) All welded joints on which backing strips are to remain shall also be examined by the liquid-penetrant method after the first complete layer (normally two beads) of weld metal have been deposited.

Q.5.5.2 All longitudinal and circumferential butt-welds in thermal distance pieces connecting cold piping to *warm vapor* or *purge gas containers* shall also be examined by the liquid-penetrant method. 10

Q.5.6 Radiographic/Ultrasonic Examination of Butt-welds in Plates

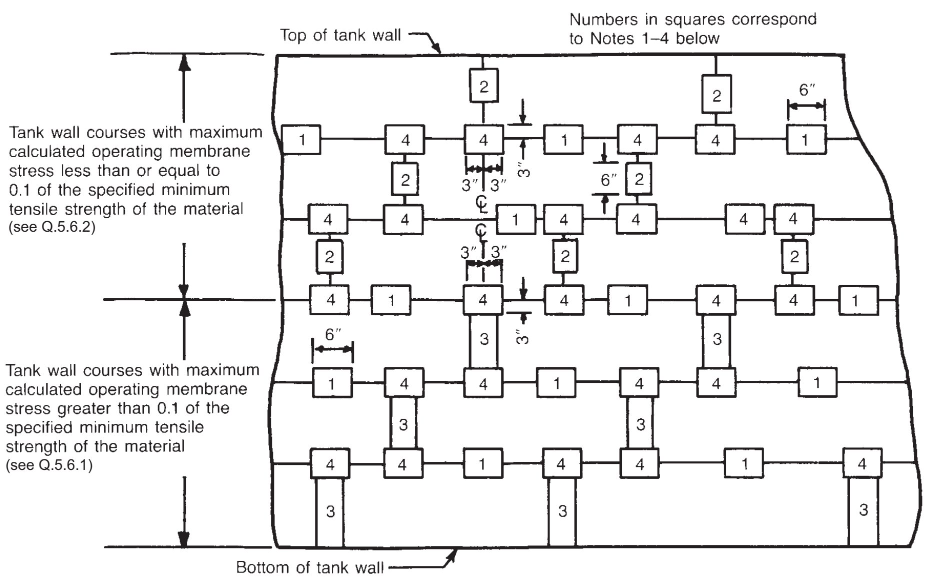
Primary and *secondary liquid container* butt-welds shall be examined by radiographic or ultrasonic methods. When the term "examination" is used in Q.5.6 and its subsections, it shall be understood to refer to radiographic or ultrasonic 10 examination. The extent of the examination shall be as described in Q.5.6.1 through Q.5.6.7. When the examination is by the ultrasonic method, it shall be done in accordance with the requirements of Appendix U.

Q.5.6.1 Butt-welds in all tank wall courses subjected to a maximum actual operating membrane tensile stress, perpendicular to the welded joint, greater than 0.1 times the specified minimum tensile strength of the plate material shall be completely examined.

Q.5.6.2 Butt-welds in all tank wall courses subjected to maximum actual operating membrane tensile stress, perpendicular to the welded joint, less than or equal to 0.1 times the specified minimum tensile strength of plate material shall be spot examined in accordance with Figure Q-2.

Q.5.6.3 Butt-welds around the periphery of a thickened insert plate shall be completely examined. This does not include the weld that joins the insert plate with the bottom plate of a flat-bottom tank.

Q.5.6.4 Butt-welds at all three-plate junctions in the tank wall shall be examined except in the case of a flat bottom (wall) supported uniformly by the foundation. This does not include the shell-to-bottom weld of a flat-bottom tank. See Figure Q-2 for minimum examination dimensions.



Notes:

1) One circumferential spot examination shall be performed in the first 10 ft for each welding operator of each type and thickness. After the first 10 ft, without regard to the number of welders, one circumferential spot examination shall be performed between each longitudinal joint on the course below.

09 2) One longitudinal spot examination shall be performed in the first 10 ft for each welder or welding operator of each type and thickness. After the first 10 ft, without regard to the number of welders, one longitudinal spot examination shall be performed in each longitudinal joint.

3) Longitudinal joints shall be 100% examined.

4) All intersections of joints shall be examined.

10 **Figure Q-2—Radiographic/Ultrasonic Examination Requirements for Butt-welded Shell Joints in Primary and Secondary Liquid Containers**

Q.5.6.5 Twenty-five percent of the butt-welded annular plate radial joints shall be spot examined for a minimum length of 6 in. The location shall be at the outer edge of the joint and under the tank shell.

Q.5.6.6 Twenty-five percent of the butt-welded compression bar radial joints shall be spot examined for a minimum length of 6 in., except as required by 5.26.4.3.

10 **Q.5.6.7** For aluminum tanks the radiography shall satisfy API 650, Appendix AL.

Q.5.7 Examination of Butt-welds in Piping

Q.5.7.1 Butt-welds in piping and in pipe fittings within the limitations of API 625, Section 1.6 shall be examined in conformance with Q.5.7.2 through Q.5.7.9.

Q.5.7.2 Longitudinal welded joints in piping carrying liquid shall be completely radiographed except for manufactured pipe welded without filler metal, 12 in. or less in diameter, which is tested hydrostatically or by eddy current to ASTM requirements.

Q.5.7.3 Longitudinal welded joints in piping carrying vapor shall be completely radiographed except for manufactured pipe welded without filler metal, 18 in. or less in diameter, which is tested hydrostatically or by eddy current to ASTM requirements.

Q.5.7.4 Thirty percent of the circumferential welded joints (including weld neck flange to pipe joints) in liquid and vapor carrying piping shall be 100% radiographed. 10

Q.5.7.5 Butt-welded joints used to fabricate liquid and vapor carrying built-up pipe fittings shall be completely radiographed.

Q.5.7.6 Lines carrying liquid located outside the *primary liquid container* in double wall tanks shall be hydrostatically or pneumatically pressurized at a minimum pressure of 35 $lbf/in.^2$ and butt welded joints shall be simultaneously visually examined (hydrostatic) or solution film tested (pneumatic) for tightness. If manufactured pipe has been hydrostatically tested previously to ASTM requirements, then only circumferential welds need to be examined.

Q.5.7.7 Lines carrying product vapor within a *purge gas container's annular space* shall be pneumatically pressurized at a minimum pressure of 5 $lbf/in.^2$ and circumferential butt-welded joints shall be simultaneously solution film tested for tightness.

Q.5.7.8 For piping that does not carry liquid or product vapor (e.g., instrument conduit and purge lines) examination shall satisfy only the applicable requirements of Q.2.

Q.5.7.9 Method of examination and acceptance criteria for radiography of butt-welds in piping shall comply with ASME B31.3 *Process Piping* rules, Normal Fluid Service conditions.

Q.5.8 Permanent Attachments

All permanent structural attachments welded directly to 9% and 5% nickel steel shall be of the same material or of an austenitic stainless steel type that cannot be hardened by heat treatment.

Q.5.9 Non-pressure Parts

Welds for pads, lifting lugs, and other nonpressure parts, as well as temporary lugs for alignment and scaffolding attached to *primary* and *secondary liquid containers* and *refrigerated temperature roofs*, shall be made in full compliance with a welding procedure qualified in accordance with Q.4.1. Lugs attached for erection purposes shall be removed, and any significant projections of weld metal shall be ground to a smooth contour. Plate that is gouged or torn in removing the lugs shall be repaired using a qualified procedure and then ground to a smooth contour. Where 10
such repairs are made in *primary* and *secondary liquid containers*, the area shall be examined by the liquid-penetrant method. A visual examination is adequate for repairs in *warm vapor* and *purge gas containers*.

Q.5.10 Repairs to Welded Joints

When repairs are made to welded joints, including the welds in Q.5.9, the repair procedure shall be in accordance with a qualified welding procedure.

Q.5.11 Marking of Materials

Q.5.11.1 Material for *primary* and *secondary liquid containers,* and *refrigerated temperature roofs* shall be marked so that the individual components can be related back to the mill test report. For aluminum materials, a certificate of
10 conformance shall be provided in place of a mill test report stating that the material has been sampled, tested, and examined in accordance with the specifications and has met the requirements.

Q.5.11.2 All mill markings shall be in accordance with the requirements of ASTM A20 and ASTM A480 as applicable. All material markings performed by the tank Manufacturer shall be in accordance with the requirements of Sections 7.7 and Q.5.11.1.

Q.5.11.3 Under some conditions, marking material that contains carbon or heavy-metal compounds can cause corrosion of aluminum. Chalk, wax-base crayons, or marking inks with organic coloring are usually satisfactory.

Q.5.12 Construction Practices

Excessive hammering during fabrication and construction shall be avoided on *primary and secondary liquid containers, and refrigerated temperature roofs* so that the material is not hardened or severely dented. Any
10 objectionable local thinning caused by hammering can be repaired by welding using a qualified procedure, followed by grinding. The extent of rework for any repair that is permissible must be agreed to between the Purchaser and the Manufacturer. If the rework is determined to have been excessive, the reworked area shall be cut out and replaced.

Q.5.13 Protection of Plates during Shipping and Storage

Plates shall be adequately protected during shipping and storage to avoid damage to plate surfaces and edges from handling (scratches, gouge marks, etc.) and from environmental conditions (corrosion, pitting, etc.).

Q.5.13.1 Plates shall be protected from moisture or stored in inclined position to prevent water from collecting and standing on surface.

Q.5.13.2 Nine percent and five percent nickel plates which are exposed to humid or corrosive atmosphere shall be sand or grit blasted and coated with a suitable coating. The Purchaser shall specify when plates are exposed to humid or corrosive atmosphere.

Q.6 Testing the Primary Liquid and Primary Vapor Containers

The provisions stated in Q.6.1 through Q.6.4 are testing requirements for the *primary liquid container*. Provisions stated in Q.6.5 cover the pneumatic testing of the *warm product vapor container* (or when inner tank is not open top, the *refrigerated temperature roof*).

Q.6.1 General Procedure

10

Q.6.1.1 A thorough check for tightness and structural adequacy is essential for the *primary liquid container*. Except as permitted by Q.6.5.8 and Q.6.6, the test shall be conducted after the entire tank is complete, before the insulation is applied. The test shall consist of filling the tank with water to a height equal to the design liquid height times the product design specific gravity times 1.25, but not greater than the design liquid level and applying an overload air pressure of 1.25 times the pressure for which the vapor space is designed.

Q.6.1.2 The maximum fill shall not produce a stress in any part of the tank greater than 85% (may be 90% for stainless steel and aluminum materials) of the specified minimum yield strength of the material or 55% of the specified minimum tensile strength of the material.

Q.6.2 Test Preliminaries

Before the tank is filled with water, the procedures described in Q.6.2.1 through Q.6.2.6 shall be completed. 10

Q.6.2.1 All welded joints in the bottom and complete penetration and complete fusion sidewall-to-bottom welds shall be examined by applying a solution film to the welds and pulling a partial vacuum of at least 3 lbf/in.^{2} gauge above the 10 welds by means of a vacuum box with a transparent top.

Q.6.2.2 When the sidewall-to-bottom weld in Q.6.2.1 does not have complete penetration and complete fusion, the initial weld passes, inside and outside of the shell, shall have all slag and nonmetals removed from the surface of the welds and the welds examined visually. After completion of the inside and outside fillet or partial penetration welds, the welds shall be tested by pressurizing the volume between the inside and outside welds with air pressure to 15 lbf/in.^{2} gauge and applying a solution film to both welds. To assure that the air pressure reaches all parts of the welds, a sealed blockage in the annular passage between the inside and outside welds must be provided by welding at one or more points. Additionally, a small pipe coupling on the outside weld and communicating with the volume between the welds must be welded on each side of and adjacent to the blockages. The air supply must be connected at one end and a pressure gauge connected to a coupling on the other end of the segment under test.

Q.6.2.3 The attachment welding around all openings and their reinforcements in the bottom, shell, and roof shall be examined by magnetic particle method and solution film test in accordance with 7.18.2.2 and 7.18.2.3. 10

Q.6.2.4 For 9% nickel tanks, all testing surfaces of bottom lap-welds and shell-to-bottom welds shall be cleaned by sandblasting or other adequate means before the vacuum box test to prevent slag or dirt from masking leaks.

Q.6.2.5 Where the pneumatic pressure to be applied in Q.6.5 will be equalized on both sides of the inner tank, all welded joints above the test water level shall be checked with a solution film and by a vacuum box examination. 10

Q.6.2.6 The attachment fillet welds around bottom openings, which do not permit the application of air pressure behind their reinforcing plates, shall be examined by applying a solution film and by a vacuum box examination.

Q.6.2.7 All welds of bottom, wall, and roof metallic liners of concrete containers shall be examined by applying a solution film to the welds and applying a partial vacuum of between 3 lbf/in.^{2} and 5 lbf/in.^{2} gage above the welds by means of a vacuum box with transparent top. Where single pass lap welds less than $^{3}/_{16}$ in. are used for wall liners, a second partial vacuum of at least 8 lbf/in.^{2} shall be applied. 10

Q.6.3 Quality of Test Water

Q.6.3.1 The materials used in the construction of Appendix Q tanks may be subject to severe pitting, cracking, or rusting if they are exposed to contaminated test water for extended periods of time. The Purchaser shall specify a minimum quality of test water that conforms to Q.6.3.2 through Q.6.3.8. After the water test is completed, the tank shall be promptly drained, cleaned, and dried.

Q.6.3.2 Water shall be substantially clean and clear.

Q.6.3.3 Water shall have no objectionable odor (that is, no hydrogen sulfide).

Q.6.3.4 Water pH shall be between 6 and 8.3.

Q.6.3.5 Water temperature shall be below 120°F.

Q.6.3.6 For austenitic stainless steel tanks, in addition to Q.6.3.2 through Q.6.3.5, the chloride content of the water shall be below 50 parts per million. 10

Q.6.3.7 For aluminum tanks, in addition to Q.6.3.2 through Q.6.3.5, the mercury content of the water shall be less than 0.005 parts per million, and the copper content shall be less than 0.02 parts per million. Further, the water used to test the tank shall either:

10 1) be potable water with a free residual chlorine of at least 0.2 ppm, or

2) have chloride content not exceeding 200 ppm.

Q.6.3.8 If the water quality outlined in Q.6.3.1 through Q.6.3.7 cannot be achieved, alternative test methods that utilize suitable inhibitors (for example, Na_2CO_3 and/or NaO_3) may be used if agreed to by the Purchaser and the Manufacturer.

Q.6.4 Hydrostatic Test

Q.6.4.1 The tank shall be vented to the atmosphere when it is filled with or emptied of water.

10 **Q.6.4.2** During water filling, the elevations of at least eight equidistant points at the bottom of the tank shell and on top of the ringwall or slab shall be checked. Differential settlement, or uniform settlement of substantial magnitude, requires an immediate stop to water filling. Any further filling with water will depend on an evaluation of the measured settlement.

10 **Q.6.4.3** The tank shall be filled with water to the level given in Q.6.1.

Q.6.4.4 After the tank is filled with water and before the pneumatic pressure is applied, anchorage, if provided, shall be tightened against the hold-down brackets.

Q.6.4.5 All welds in the shell, including the corner weld between the shell and the bottom, shall be visually checked for tightness.

Q.6.5 Pneumatic Pressure

Q.6.5.1 An air pressure equal to 1.25 times the pressure for which the vapor space is designed shall be applied to the enclosed space above the water level. In the case of a double-wall tank with an open-top inner tank, where the air pressure acts against the outer tank and the inner tank is thus not stressed by the air pressure, the inner tank may be emptied of water before the pneumatic pressure test begins.

Q.6.5.2 The test pressure shall be held for 1 hour.

Q.6.5.3 The air pressure shall be reduced until the design pressure is reached.

Q.6.5.4 Above the water level, all welded joints shall be checked with a solution film. A prior vacuum box check may be substituted for the solution-film examination. The solution-film examination shall still be made, above the water level, on all welds around openings, all piping joints, and the compression ring welds to the roof and shell except any listed below:

10 — Continuous double lap roof to compression ring welds.

— Shell to compression ring welds, continuous inside and outside, and applying a thickened upper shell ring detail similar to Figure 5-6 details f or f-1. The thickened upper shell ring shall be greater than half of the conical compression ring thickness and greater than two times the adjacent shell ring thickness.

— Full fusion butt welded connections.

Q.6.5.5 The opening pressure or vacuum of the pressure relief and vacuum relief valves shall be checked by pumping air above the water level and releasing the pressure and then partially withdrawing water from the tank.

Q.6.5.6 After the tank has been emptied of water and is at atmospheric pressure, the anchorage, if provided, shall be rechecked for tightness. 10

Q.6.5.7 Air pressure, equal to the design pressure, shall be applied to the empty tank, and the anchorage, if provided, and the foundation shall be checked for uplift.

Q.6.5.8 Following the hydrostatic and pneumatic test, all welded seams in the *primary liquid container* bottom, and complete penetration and complete fusion sidewall-to-bottom welds in the *primary liquid container*, shall be examined by means of a vacuum box test as described in Q.6.2.1. Sidewall-to-bottom welds not having complete penetration and complete fusion shall be examined by means of either a vacuum box test of the inside weld as described in 10
Q.6.2.1, or where approved by the Purchaser, a direct pressure solution film test as described in Q.6.2.2. If any leaks are detected, they shall be repaired and the vacuum box test repeated. The *primary liquid container* hydrostatic test need not be repeated.

Q.6.6 Temporary Openings after Hydrostatic Test

When approved by the Purchaser in writing, and only in the case of tanks which when complete have no shell penetrations, it is permitted to restore by welding up to four temporary shell openings after the hydrostatic test in accordance with the provisions of this section.

Q.6.6.1 Each temporary opening shall be restored by the insertion of a shell plate that matches the thickness and specification of adjacent shell material, and is welded into place with full fusion butt-welds. The insert plate shall be round with diameter no less than 24 in. and no greater than 42 in.

Q.6.6.2 The insert plate weld shall not cross any shell seams and shall be at least the greater of 10 times the shell thickness or 12 in. from any other weld in the shell including shell seams, shell-to-bottom weld or attachment welds.

Q.6.6.3 The butt weld around the periphery of the plate shall be examined over 100% of its length by both liquid penetrant method and radiographic method. The liquid penetrant examination is required on the root pass, on the back-gouged surface, and on the inside and outside finished weld surfaces. Additionally, the weld shall be vacuum box leak tested.

Q.7 Testing a Purge Gas Container 10

Q.7.1 General

The tightness test shall be made before insulation is installed. Where the pneumatic pressure described in Q.6.5 acts against the *warm product vapor container*, the testing requirements of Q.6.5 will result in a check of the outer tank, 10
and the procedure outlined in Q.7.2.1 through Q.7.2.5 may be omitted.

Q.7.2 Test Procedure

Q.7.2.1 The inner tank shall be opened to the atmosphere, and a sufficient amount of water shall be added to the inner tank to balance the upward pressure against the inner tank bottom produced by the pneumatic test of the outer tank; as an alternative, the pressure between the inner and outer tanks can be equalized.

Q.7.2.2 Air pressure shall be applied to the space enclosed by the outer tank equal to at least the design gas pressure but not exceeding a pressure that would overstress either the inner or outer tank.

Q.7.2.3 While the test pressure is being held, all lap welded seams and all welds in connections in the outer shell and roof shall be thoroughly examined with a solution film unless they were previously checked with a vacuum box. 10

Q.7.2.4 The air pressure shall be released.

Q.7.2.5 Pressure relief and vacuum relief valves shall be checked by applying the design gas pressure to the outer tank, followed by evacuation of the outer space to the vacuum setting of the relief valve.

Q.8 Foundations

Q.8.1 Foundations shall be in accordance with API 625, Section 6.7.

10 Text deleted.

Q.8.2 Uplift on Foundation

10 **Q.8.2.1** The increased uplift described in Q.8.2.2 and Q.8.2.3 is intended to apply to the size of the ringwall and foundation but not the anchorage.

Q.8.2.2 For tanks with an internal design pressure less than 1 lbf/in.^{2} gauge, the uplift shall be taken as the smaller of the maximum uplift values computed under the following conditions:

a) The internal design pressure times 1.5 plus the design wind load on the shell and roof.

b) The internal design pressure plus 0.25 lbf/in.^{2} gauge plus the design wind load on the shell and roof.

Q.8.2.3 For tanks with an internal design pressure of 1 lbf/in.^{2} gauge and over, the uplift, if any, shall be calculated under the combined conditions of 1.25 times the internal design condition plus the design wind load on the shell and roof.

10 **Q.8.2.4** When the anchorage is designed to meet the requirements of Q.3.7.4.2, the foundation should be designed to resist the uplift that results from three times the design pressure with the tank full to the design liquid level. When designing to any of the conditions in this paragraph, it is permissible to utilize friction between the soil and the vertical face of the ringwall and all of the effective liquid weight.

Q.9 Marking

10 Except for 8.2 on Division of Responsibility, marking requirements of Section 8 are superseded by the requirements of API 625, Section 11.

Text deleted.

Q.10 Reference Standards

10 For rules and requirements not covered in this appendix or in the basic rules of this standard, the following documents shall be referred to for the type of material used in the tank:

a) API 625;

b) For 9% and 5% nickel steels, Part UHT in Section VIII of the *ASME Code*;

c) For stainless steel, Part UHA in Section VIII of the *ASME Code*;

d) For aluminum, Part UNF in Section VIII of the *ASME Code* and API 650, Appendix AL.

09 < Notes moved to Figure Q-2. >

Appendix R

Low-pressure Storage Tanks Operating Between +40°F and –60°F 10

R.1 Scope

R.1.1 General

This appendix together with the basic sections of API 620 provides requirements for the materials, design, and fabrication of the metallic portions of a *refrigerated tank system*. The requirements for a basic API 620 tank apply to *primary* and *secondary liquid containers, refrigerated temperature roofs, warm product vapor containers, purge gas containers,* and their appurtenances except where they are superseded by any requirements of this appendix. Requirements for the complete tank system, of which the metallic components are a part, are found in API 625.

R.1.2 Piping Limitations

R.1.2.1 Piping limitations given in API 620, 1.3.2 are superseded by API 625, Section 1.6.

R.1.3 Pressure Range

The provisions in this appendix apply to design pressures from –0.25 psig to +7.00 psig.

R.1.4 Temperature

The provisions in this appendix apply to design metal temperatures from +40°F to –60°F, inclusive.

R.1.5 Definitions

The definitions of the following specialized terms used in this appendix are found in API 625: 10

R.1.5.1 *Refrigerated Tank System*

R.1.5.2 *Single Containment Tank System*

R.1.5.3 *Double Containment Tank System*

R.1.5.4 *Full Containment Tank System*

R.1.5.5 *Primary Liquid Container*

R.1.5.6 *Secondary Liquid Container*

R.1.5.7 *Warm product vapor container*

R.1.5.8 *Purge gas container*

R.1.5.9 *Refrigerated temperature roof*

R.1.5.10 *Design Pressure*

R.1.5.11 *Annular Space*

R.1.5.12 *Suspended deck*

R.1.5.13 *Design Metal Temperature*

R.2 Materials

The material requirements are based on the storage of refrigerated products at the design metal temperature.

R.2.1 Product Temperature Materials

R.2.1.1 General

R.2.1.1.1 Materials for the following metallic components (including their penetrations, piping, anchors, stiffeners, and attachments) shall be selected from Table R-1 and shall be impact tested in accordance with R.2.1.2 through R.2.1.5.

a) *Primary Liquid Containers*;

10

b) *Secondary Liquid Containers*;

c) *Refrigerated Temperature Roofs* (see R.2.2.3 for low stress exception):

— This includes inner roofs of double roof tanks, and single roofs of tanks with external roof insulation);

d) Thermal distance pieces connecting cold piping to *warm vapor* or *purge gas containers*;

e) For *full containment tank systems*: Portions of *warm product vapor containers* that may experience cold gas flows in the event of primary liquid container leakage;

f) Liner plates, if required for liquid containment, in concrete *primary or secondary liquid containers*, loaded in tension under cool down, operating, or other design conditions.

R.2.1.1.2 Materials for liner plates, if required for liquid containment, in concrete *primary or secondary liquid containers*, loaded in compression under all design conditions shall be selected from materials explicitly listed in Table 4-1 excluding materials rated for design metal temperature 65°F and over.

R.2.1.2 Impact Test Requirements for Plates

R.2.1.2.1 Impact testing of plates, including structural members made of plate, shall comply with Table R-1.

09 < Notes moved to Figure R-2. >

R.2.1.2.2 Impact test specimens shall be taken transverse to the direction of final plate rolling.

R.2.1.2.3 The Charpy V-notch test shall be used, and the minimum impact value at the *design metal temperature* shall be as given in Table R-2. For subsize specimen acceptance criteria, see ASTM A20. An impact test temperature lower than the *design metal temperature* may be used by the Manufacturer, but in such a case the impact values at the test temperature must comply with Table R-2.

R.2.1.2.4 All other impact requirements of ASTM A20, Supplementary Requirement S5, shall apply for all materials listed in Table R-2, including specifications that do not refer to ASTM A20.

R.2.1.2.5 When as-rolled plate material complies with impact test requirements as specified here, the material need not be normalized. If, as with ASTM A516, the specification prohibits impact test without normalizing but otherwise permits as-rolled plates, the material may be ordered in accordance with the above provision and identified as "MOD" for this API modification.

Table R-1—Standards for Product Temperature Materials

Component	Materials	Notes	
Plate	Refer to R.2.1.2	1 and 2	
Pipe	ASTM A333 (seamless only)	2 and 3	
Pipe fittings	ASTM A420	2 and 3	
Structural members	Plate or pipe as listed above	4	
	Structural shapes	5	
	ASTM A36 Mod 1	6	
	ASTM A992		10
	ASTM A131 Grades D and E		
	ASTM A633 Grade A		
	CSA G40.21 Grades 38WT, 44WT and 50WT		
	ISO 630 E275 and E355 in Quality D	7, 8	
	EN 10025-2 S275 in Quality J2	7, 8	
	EN 10025-2 S355 in Quality J2 and K2	7, 8	
Forgings	ASTM A350	2 and 3	
Bolts	ASTM A320 Grade L7	3	

Notes:
1. See R.2.1.4.
2. Type 304, 304L, 316, or 316L stainless steel material, as permitted in Table Q-1 may be used at the maximum allowable stress values permitted by Table Q-3. Impact tests of this material are not required. Welding procedures shall be qualified in accordance with the more restrictive requirements of R.6.1 and Q.6.3 as applicable to the base materials and welding material.
3. See R.2.1.3.
4. Plate or pipe materials to be made into a structural member shall conform to the impact testing requirements of R.2.1.5.
5. Structural shapes shall be normalized, if necessary, to meet the required minimum Charpy V-notch impact values of R.2.1.5. 10
6. See 4.5 for a complete description of this material.
7. Minimum *Mn* to be 0.80%.
8. These grades require supplementary impact testing at the design metal temperature notwithstanding any impact testing at any other warmer temperature that may be mandated in the national specification.

R.2.1.3 Impact Requirements for Pipe, Bolting, and Forgings

The impact tests for pipe (including structural members made of pipe), bolting, and forgings, shall be in accordance with ASTM specifications referred to in Table R-1.

Piping materials made according to ASTM A333, A420, and A350 may be used at *design metal temperatures* no 10
lower than the impact test temperature required by the ASTM specification for the applicable material grade without additional impact tests. For temperatures below those allowed by the ASTM specification, the following paragraph shall apply.

For all other materials, the impact test temperature shall be at least 30°F colder than the *design metal temperature*. Alternately, materials impact tested at the *design metal temperature* or lower with Charpy impact test energy value of 25 ft-lb (average), 20 ft-lb (minimum) are acceptable for *design metal temperatures* above –40°F. Materials with an energy value of 30 ft-lb (average), 25 ft-lb (minimum) are acceptable for *design metal temperatures* of –40°F or lower.

• R.2.1.4 .Impact Requirements for Controlled-rolled or Thermo-mechanical Control Process (TMCP) Plates

Subject to the approval of the Purchaser, controlled-rolled or TMCP plates (material produced by a mechanical-thermal rolling process designed to enhance the notch toughness) may be used where normalized plates are 10
required. Each plate-as-rolled shall be Charpy V-notch tested to the requirements of R.2.1.2.

Table R-2—Minimum Charpy V-notch Impact[a] Requirements for Product Temperature Material
10 **Plate Specimens (Transverse) and Weld Specimens Including the Heat-affected Zone**

	Specification Number	Grade	Range in Thickness (in.)	Plate Impact Value[b] (ft–lb)		Weld Impact Value (ft-lb)	
				Average	Individual	Average	Individual
10	ASTM A516	55 and 60	3/16 – 2	25	20	20	15
	ASTM A516	65 and 70	3/16 – 2	25	20	20	15
	ASTM A516	65 and 70 Mod 1[d]	3/16 – 2	25	20	20	15
	ASTM A516	65 and 70 Mod 2[d]	3/16 – 2	25	20	20	15
	ASTM A841	1	3/16 – 2	25	20	20	15
	ASTM A537	1	3/16 – 2	25	20	20	15
	ASTM A537	2	3/16 – 2	30	25	25	20
	ASTM A662	B and C	3/16 – 2	25	20	20	15
	ASTM A678	A[c]	3/16 – 1 1/2	25	20	20	15
	ASTM A678	B[c]	3/16 – 2	30	25	25	20
	ASTM A737	B	3/16 – 2	25	20	20	15
	ASTM A841	1	3/16 – 2	25	20	20	15
	ISO 630	E 355 Quality D[c,d,e]	3/16 – 2	25	20	20	15
	EN 10028	P275 Qualities NH, NL1, and NL2	3/16 – 2	25	20	20	15
10	EN 10028	P355 Qualities N, NH, NL1, and NL2	3/16 – 2	25	20	20	15
	CSA G40.21	38WT[c,d,e]	3/16 – 2	25	20	20	15
	CSA G40.21	44WT[c,d,e]	3/16 – 2	25	20	20	15
	CSA G40.21	50wt[c,d,e]	3/16 – 2	25	20	20	15

Notes:

[a]See R.2.1.2.
[b]For *design metal temperatures* of –40°F and lower, the plate impact values shall be raised 5 ft-lb.
[c]The frequencies of testing for mechanical and chemical properties shall be at least equal to those of ASTM A20.
[d]See 4.2.3 for a complete description of this material.
[e]The steel shall be fully killed and made with fine-grain practice.

R.2.1.5 Impact Requirements for Structural Shapes

Impact test for structural shapes listed in Table R-1 shall be made in accordance with ASTM A673 on a piece-testing frequency. Impact values, in foot-pounds, shall be 25 minimum average of 3 and 20 minimum individual at a temperature no warmer than the *design metal temperature*.

R.2.2 Atmospheric Temperature Materials

R.2.2.1 The following are considered *warm product vapor container* components:

a) Roofs over *suspended decks*;

10 b) Outer shells of double wall, *single containment tank systems* having open-top inner tanks;

c) Outer bottoms of double wall, *single containment tank systems* having open-top inner tanks;

d) Metallic liners for concrete *secondary liquid containers* where the liners are acting as *warm product vapor containers* but not required for secondary liquid containment.

R.2.2.2 Material for *warm product vapor containers* shall conform to one of the following:

a) Table 4-1 for design metal temperatures down to –35°F (lowest 1-day mean ambient temperature of –35°F) without impact test unless they are required by Table 4-1 or by the Purchaser.

b) Table R-3 for design metal temperatures down to –60°F without impact tests unless they are required by Table R-4 or by the Purchaser.

c) If approved by the Purchaser, the material may be selected by the requirements of 4.2.2. Where wall liner systems are composed of embedded plates with liner plates less than $^{3}/_{16}$ in. thick attached by lap welds, 4.2.2 shall not be applied to the liner or embedded plate material.

R.2.2.3 Material for *refrigerated temperature roofs* where combined membrane and primary bending tensile stress does not exceed 6000 $lb/in.^2$, may also satisfy the criteria of R.2.2.2 a, b, or c in lieu of the requirements of R.2.1.

R.2.2.4 The following are considered *purge gas container* components: 10

a) Outer roofs of double wall, double roof, *single containment tank systems*;

b) Outer shells of double wall, double roof, *single containment tank systems*;

c) Outer bottoms of double wall, double roof, *single containment tank systems*;

d) Metallic liner functioning with a concrete *secondary liquid container* as a moisture vapor barrier but not acting as a *warm product vapor container* and not required for secondary liquid containment.

R.2.2.5 Material for *purge gas containers* shall conform to one of the approved materials listed in Table 4-1. Consideration of the design metal temperature is not required if the actual stress does not exceed one-half the allowable tensile design stress for the material.

R.3 Design

R.3.1 General

Design considerations shall be as specified in API 625, Section 6, "Design and Performance Criteria," together with the additional provisions of this Section R.3.

Table R-3—Atmospheric Temperature Material Specifications

Material	Component Design Metal Temperature	
	–60°F to below –20°F	–20°F to +40°F
Plate	Materials as listed in Table R-4	Materials as listed in Table R-4
Pipe	ASTM A106	As listed in 4.3
Piping fittings	ASTM A420	As listed in 4.3
Structural members	Plate or pipe as listed above ASTM A36 Mod 1 structural shapes (see 4.5) ASTM A131 Grade D and E CSA G40.21 Grades 38W, 44W, and 50W (see Note) ISO 630 E275 and E355 in Quality D EN 10025-2 S275 in Quality J2 EN 10025-2 S355 in Quality J2 and K2	Plate or pipe as listed above Structural shapes as listed in 4.5 or as listed under the –60°F to –20°F temperature heading 10
Forgings	ASTM A105	As listed in 4.3
Bolts	ASTM A193 Grade B7 ASTM A320 Grade L7	As listed in 4.4

Note: The steel shall be fully killed and made to fine-grain practice.

Table R-4—Minimum Permissible Design Metal Temperature for Atmospheric Temperature Material Plates Used without Impact Testing

Group	Specification Number	Grade	Minimum Design Metal Temperature, °F			
			Plate Thickness Including Corrosion Allowance, in.			
			$^3/_{16}$ to $^3/_8$	> $^3/_8$ to $^1/_2$	> $^1/_2$ to 1	> 1 to $1^1/_2$
I (semikilled)	A 36	Mod 2[a]	–20	–10	+5	—
	A 131	B	–20	–10	+5	—
	CSA G40.21	38W	0	+10	+25	—
	ISO 630	E 275 Quality C[b]	–20	–10	+5	+5
	EN 10025	S 275 Quality J0[b]	–20	–10	+5	+5
II (fully killed)	A 573	58[b]	–30	–20	–10	0
	A 516	55 and 60	–30	–20	–10	0
	A 516	55 and 60[c]	–40	–30	—	—
	ISO 630	E 275 Quality D	–30	–20	–10	0
	EN 10025	S 275 Quality J2[b]	–30	–20	–10	0
	CSA G40.21	38W[b]	–40	–30	–15	0
III (fully killed and high strength)	A 573	65 and 70	–30	–20	–10	+5
	A 516	65 and 70	–30	–20	–10	+5
	A 516	65 and 70 Mod 1[a]	–40	–30	–15	0
	A 537	1 and 2	–60	–50	–35	–20
	A 662	B and C	–40	–30	–15	0
	A 633	C and D	–60	–50	–35	–20
	A 678	A and B	–60	–50	–35	–20
	A 737	B	–60	–50	–35	–20
	ISO 630	E 355 Quality D	–30	–20	–10	+5
	EN 10025	S 355 Quality J2 and K2[b]	–30	–20	–10	+5
	CSA G40.21	44W[b]	–40	–30	–15	0
	CSA G40.21	50W[b]	–30	–10	+5	+20

Notes:

When normalized, materials in this table may be used at temperatures 20°F below those shown (except for A 537 Classes 1 and 2, A 633 Grades C and D, A 678 Grades A and B, And A 737 Grade B). If impact tests are required for the materials listed in this table, they shall be in accordance with Table R-5.

[a]See 4.2.3 for a complete description of this material.

[b]The steel shall be fully killed and made with fine-grain practice, without normalizing, for thicknesses of $^3/_{16}$ in. through $1^1/_2$ in.

[c]The manganese content shall be in the range from 0.85% to 1.20% by ladle analysis.

R.3.2 Density of Liquid Stored

The density of the liquid stored shall be its maximum density within the range of design temperatures, but not less than 36 lbf/ft^3.

Text Deleted.

R.3.3 Design Allowable Stress

The maximum allowable tensile stress shall be taken from Table 5-1 or Table Q-3. For the maximum allowable stresses for design loadings combined with wind or earthquake loads, see 5.5.6 for carbon steel and Q.3.3.5 for stainless steel and aluminum.

R.3.4 Piping

All process piping within the limitations of R.1.2 (except pump columns as governed by API 625 7.3.3) shall fulfill the minimum design requirements of ASME B31.3 but using the allowable stresses of Table 5-1.

Table R-5—Minimum Charpy V-notch Impact Requirements for Atmospheric Temperature Material Plate Specimens (Transverse) 10

Group	Specification Number	Grade	Range in Thickness (in.)	Impact Value[a] (foot-lbs)	
				Average	Individual
I (semikilled)	A 36	Mod 2[b]	3/16 – 1	13	9
	A 131	B	3/16 – 1	13	9
	ISO 630	E 275 Quality C	3/16 – 1 1/2	13	9
	EN 10025	S 275 Quality J0	3/16 – 1 1/2	13	9
II (fully killed)	A 573	58[c]	3/16 – 1 1/2	15	10
	A 516	55 and 60	3/16 – 2	15	10
	A 516	55 and 60[d]	3/16 – 1/2	15	10
	ISO 630	E 275 Quality D	3/16 – 1 1/2	15	10
	EN 10025	S 275 Quality J2	3/16 – 1 1/2	15	10
	CSA G40.21	38WT	3/16 – 2	15	10
III (fully killed and high strength)	A 573	65 and 70	3/16 – 2	15	10
	A 516	65 and 70	3/16 – 2	15	10
	A 516	65 and 70 Mod 1[b]	3/16 – 2	15	10
	A 516	65 and 70 Mod 2[b]	3/16 – 2	15	10
	A 537	1	3/16 – 2	15	10
	A 537	2	3/16 – 2	20	15
	A 633	C and D	3/16 – 2	15	10
	A 662	B	3/16 – 2	15	10
	A 678	A	3/16 – 1 1/2	20	15
	A 678	B	3/16 – 2	20	15
	ISO 630	E 355 Quality D	3/16 – 2	15	10
	EN 10025	S 355 Quality J2 and K2	3/16 – 2	15	10
	CSA G40.21	44WT	3/16 – 2	15	10
	A 841	1	3/16 – 2	15	10

Notes:

[a]The stated values apply to full-sized specimens. For sub-size specimen acceptance criteria, see ASTM A20. An impact test temperature lower than the design metal temperature may be used by the Manufacturer, but the impact values at the test 09 temperature must comply with Table R-5. When plate is selected, consideration must be given to the possible degradation of the impact properties of the plate in the weld heat-affected zone.

[b]See 4.2.3 for a complete description of this material.

[c]The steel shall be fully killed and made with fine-grain practice, without normalizing, for thicknesses of 3/16 in. – 1 1/2 in.

[d]The manganese content shall be in the range from 0.85% to 1.20% by ladle analysis.

R.3.5 Bottom Plates for Primary and Secondary Liquid Containers 10

R.3.5.1 *Primary liquid containers* and *secondary liquid containers* shall have butt-welded annular bottom plates with a radial width that provides at least 24 in. between the inside of the shell and any lap-welded joint in the remainder of the bottom and at least a 2-in. projection outside the shell. A greater radial width (L_{min}) of annular plate is required when calculated by the following equation:

$$L_{min} = \frac{390 t_b}{\sqrt{(H)(G)}}$$

where

t_b = nominal thickness of the annular plate, in inches,

H = design height of the liquid, in ft,

10 G = design specific gravity of the liquid to be stored (see R.3.2).

R.3.5.2 The thickness of the annular bottom plates shall be not less than the thicknesses listed in Table R-6.

R.3.5.3 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
10 butt-welded in accordance with R.5.1.1, Item a.

R.3.5.4 The plates of the first shell course shall be attached to the annular bottom plates by welds as required by
10 5.9.5 except when a full penetration weld is used or required (see R.5.1.1).

R.3.5.5 Butt-welds in annular plates shall be not closer than 12 in. from any vertical weld in the tank shell.

10 **R.3.5.6** Three-plate laps or butt-weld junctions in the tank bottom shall be not closer than 12 in. from each other.

10 **Table R-6—Thickness Requirements[a] for the Annular Bottom Plate (in.)**

Nominal Thickness of First Shell Course (in.)	Design Stress[b] in First Shell Course (lbf/in.^{2})			
	≤ 20,000	22,000	24,000	26,000
≤ 0.75	1/4	1/4	1/4	1/4
> 0.75 – 1.00	1/4	1/4	1/4	5/16
> 1.00 – 1.25	1/4	1/4	5/16	3/8
> 1.25 – 1.50	1/4	9/32	3/8	7/16

Notes:

[a]The thicknesses and width (see R.3.4.1) are based on the foundation providing a uniform support under the full width of the annular plate. Unless the foundation is properly compacted, particularly at
10 the inside of a concrete ringwall, settlement will produce additional stresses in the annular plate.

[b]The stress shall be calculated using the formula (2.6*D*)(*HG*)/*t,* where *D* = nominal diameter of the tank, in ft; *H* = maximum filling height of the tank for design, in ft; *G* = design specific gravity; and *t* = design thickness of the first shell course, excluding corrosion allowance, in.

R.3.6 Shell Stiffening Rings for Primary and Secondary Liquid Containers

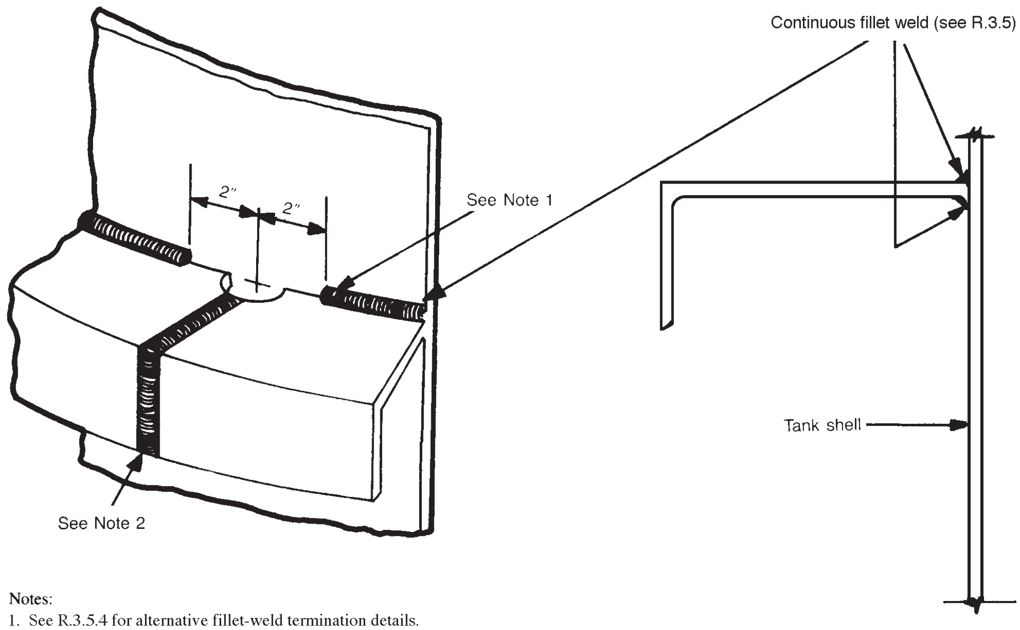
R.3.6.1 Internal or external shell stiffening rings may be required to maintain roundness when the tank is subjected to wind, vacuum, or other specified loads. When stiffening rings are required, the stiffener-to-shell weld details shall be in accordance with Figure R-1 and R.3.6.2 through R.3.6.5.

10 **R.3.6.2** The stiffener ring and backing strip, if used, shall comply with the requirements of R.2.1. The stiffener ring may be fabricated from plate using an intermittent weld on alternating sides between the web and the flange.

R.3.6.3 One rat hole with a minimum radius of 3/4 in. shall be provided at each longitudinal shell joint and ring juncture weld (see Figure R-1).

R.3.6.4 All fillet welds shall consist of a minimum of two passes. The ends of the fillet welds shall be 2 in. from the rat hole (see Figure R-1), and these welds shall be deposited by starting 2 in. from the rat hole and welding away from the rat hole. An acceptable alternative to stopping fillet welds 2 in. short of the rat hole would be to weld continuously
09 through the rat hole from one side of the stiffener to the opposite side. All craters in fillet welds shall be repaired by back welding.

R.3.6.5 Any joints between the adjacent sections of stiffening rings, as shown in Figure R-1, shall be made so that the required moment of inertia of the combined ring-shell section is provided. Weld joints between adjacent sections shall be made with full-thickness and full-penetration butt-welds. Stiffening-ring butt-welds may employ metal backing strips. Backing strips and the associated welding shall be made in a manner that provides a smooth contour in the rat hole and all other weld joints ends. All weld passes shall be started at the rat hole and other weld joint ends and shall be completed by moving away from these ends. Passes shall be overlapped away from the edge to provide a smooth continuous weld.



Notes:
1. See R.3.5.4 for alternative fillet-weld termination details.
2. Backing strips are permitted for stiffening-ring junction welds.

Figure R-1—Typical Stiffening-ring Weld Details

R.3.7 Tank Anchorage for Primary and Secondary Liquid Containers

R.3.7.1 In addition to the loads in R.3.8, the anchorage for the *primary liquid container* and any *secondary liquid container* shall be designed to meet the requirements of R.3.7.2 through R.3.7.5. 10

R.3.7.2 The anchorage shall accommodate movement of the tank wall and bottom caused by thermal changes.

R.3.7.3 The Manufacturer and the Purchaser shall either use stainless steel anchorage materials, or provide for corrosion allowance when carbon steels are used. Material for tank anchorage shall meet the requirements for primary components given in R.2.1. 10

R.3.7.4 Anchorage subject to load from internal pressure shall be designed as described in R.3.7.4.1 through R.3.7.4.3.

R.3.7.4.1 When the topshell course is the minimum thickness indicated in Table 5-6, the minimum anchorage shall be designed for normal loads as specified by the Purchaser and by this standard. See 5.11.2.3 for the allowable stress.

R.3.7.4.2 When the topshell course is thickened beyond minimum thickness provided in Table 5-6 or as in Figure 5-6, details f and g, or when a knuckle is used, the minimum anchorage shall be designed for three times the internal design pressure. The allowable stress for this loading is 90% of the minimum specified yield strength of the anchorage material.

R.3.7.4.3 As an alternative to R.3.7.4.2, the Purchaser may specify a combination of normal anchorage design (see R.3.7.4.1) and emergency venting. The Purchaser shall specify required emergency venting discharge rates considering upset conditions including those addressed in API 2000 (see 9.2 and K.1).

R.3.7.5 The foundation design loading for R.3.7.4 is described in R.8.

R.3.8 Combination of Design Loads for Double-wall Tanks

The inner and outer containers shall be designed for the most critical load combinations per 5.4.2 and per R.3.8.1 through R.3.8.5 as applicable.

R.3.8.1 Inner Tank

The *primary liquid container* (inner tank) shall also be designed for the static insulation pressure, the insulation pressure as the inner tank expands during warming after an in-service period, and the purging or operating pressure of the space between the inner and outer tank shells, unless the pressure is equalized on both sides of the inner tank.

R.3.8.2 Single Containment Outer Wall

A metallic *warm vapor, or purge gas container* for a double wall, *single containment tank system* shall also be designed for the purging and operating pressure of the space between the inner and outer tank shells and for the loading from the insulation.

10 R.3.8.3 Double Containment Outer Wall

A metallic *warm vapor, purge gas,* or *secondary liquid container* for a *double containment tank system* shall be designed for the load combinations specified for the outer wall of a *single containment tank system*. A metallic *secondary liquid container* shall also be designed for the following upset conditions:

a) Dead load and liquid head [$D_L + P_L$]

b) Dead load, liquid head, and seismic [$D_L + P_L + E$]

where

D_L, P_L, and E are defined in R.3.8.5.

R.3.8.4 Full Containment Outer Wall

A metallic outer wall for a *full containment tank system* shall be designed for the load combinations specified for the outer wall of a *single containment tank system*. The metallic outer wall shall also be designed for the following upset conditions:

a) Dead load, design pressure, and liquid head [$D_L + P_g + P_L$]

b) Dead load, design pressure, liquid head, and seismic [$D_L + P_g + P_L + E$]

where

D_L, P_g, P_L, and E are defined in R.3.8.5.

R.3.8.5 Nomenclature

D_L = Dead load,

P_g = Design pressure of the *secondary liquid container*,

P_L = Liquid head in the *secondary liquid container* determined from the maximum normal operating capacity of the *primary liquid container*,

E = ALE seismic as required by L.4. including 10% snow load.

R.3.9 Warm Product Vapor and Purge Gas Containers

R.3.9.1 Design of *warm vapor and purge gas containers* shall be in accordance with Section 5 of this standard together with the additional provisions of this Section R.3.9.

R.3.9.2 *Warm vapor* and *purge gas containers* shall have a minimum nominal thickness of $3/16$ in. except for metallic wall liners for concrete containers which shall have a minimum nominal thickness of 0.12 in.

R.3.9.3 *Purge gas containers* may be of single-welded lap or of single-welded partial penetration butt construction
when the thickness does not exceed $3/8$ in. Such single side welds shall be made from the outside to prevent 10
corrosion and the entrance of moisture. At any thickness, it may be of single-welded butt construction from either side with full penetration and fusion or double-welded butt construction without necessarily having full fusion and penetration.

R.3.9.4 *Warm product vapor containers* shall conform to the lap- or butt-welded construction described elsewhere in this standard.

Text deleted.

R.4 Welding Procedures

These rules shall apply to *primary* and *secondary liquid containers*, *refrigerated temperature roofs*, and *suspended insulation decks* of the tank. *Warm vapor and purge gas containers* shall be welded in accordance with the basic rules of this standard.

R.4.1 Welding Procedure Qualification

R.4.1.1 The qualification of welding procedures shall conform to 6.7. For product temperature materials (see R.2.1), impact tests are also required for each welding procedure (with exceptions for Type 304 or 304L stainless steel described in Table R-1, Note 2). Charpy V-notch specimens that conform to ASTM E23 shall be taken from the weld metal and from the heat-affected zone of the welding procedure qualification test plates or duplicate test plates.

R.4.1.2 Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. The specimen shall be oriented so that the notch is normal to the surface of the material. One face of the specimen shall be substantially parallel to and within $1/16$ in. of the surface.

R.4.1.3 Heat-affected-zone impact specimens shall be taken across the weld and as near the surface of the material as is practicable. The specimens shall be of sufficient length to locate, after etching, the notch in the heat-affected zone. The notch shall be cut approximately normal to the material surface to include as much heat-affected zone material as possible in the resulting fracture.

R.4.1.4 Impact test specimens shall be tested at the design metal temperature or at a lower temperature, as agreed upon by the Purchaser and the Manufacturer.

R.4.1.5 The required impact values of the weld and heat-affected zone shall be as given in Table R-2.

R.4.2 Production Welding Procedures

The production welding procedures and the production welding shall conform to the requirements of the procedure qualification tests within the following limitations:

a) Individual weld layer thickness shall not be substantially greater than that used in the procedure qualification test.

b) Electrodes shall be of the same size and American Welding Society (AWS) classification.

c) The nominal preheat and interpass temperatures shall be the same.

R.4.3 Production Weld Tests

10 **R.4.3.1** Production weld test plates shall be welded and tested for *primary* and *secondary liquid container*, butt-welded shell plates when welding procedure qualifications are required to be impact tested per paragraph R.6.1.1. The number of production weld tests shall be based on the requirements of R.6.3.3 and R.6.3.4. Weld testing shall be in accordance with R.6.3.5. Test plates shall be made from plates produced only from the heats used to produce the shell plates for the tank.

R.4.3.2 Test plates shall be welded using the same qualified welding procedure and electrodes as required for the tank shell plate joints. The test plates need not be welded as an extension of the tank shell joint but shall be welded in the required qualifying positions.

R.4.3.3 One test weld shall be made on a set of plates from each specification and grade of plate material, using a thickness that would qualify for all thicknesses in the shell. Each test welded of thickness t shall qualify for plate thicknesses from $2t$ down to $t/2$, but not less than $5/8$ in. For plate thicknesses less than $5/8$ in., a test weld shall be made for the thinnest shell plate to be welded; this test weld will qualify the plate thickness from t up to $2t$.

10 **R.4.3.4** Test welds shall be made for each position and for each process used in welding *primary* and *secondary liquid containers'* shell plates except for the following:

a) A manual or semi-automatic vertical test weld will qualify manual or semi-automatic welding using the same weld process in all positions.

b) A semi-automatic vertical test weld will qualify machine welding using the same weld process in all positions.

c) Test welds are not required for machine welded circumferential joints in cylindrical shells.

10 **R.4.3.5** The impact specimens and testing procedure shall conform to R.4.1.2 through R.4.1.5.

R.4.3.6 By agreement between the Purchaser and the Manufacturer, production weld test plates for the first tank shall satisfy the requirements of this paragraph for similar tanks at the same location if the tanks are fabricated within six months of the time the impact tests were made and found satisfactory and the same weld procedure specifications are used.

R.4.4 Impact Tests for Warm Product Vapor Container Components

10 When impact tests are required by R.2.2.2 for *warm product vapor container* components, they shall conform to the requirements of ASTM A20, Supplementary Requirement, paragraph S 5, or this appendix, whichever is applicable. Weld material for lap welded wall liners shall meet requirements for design metal temperature without exception, (i.e., including cases where 4.2.2 is applied for liner selection).

R.5 Requirements for Fabrication, Openings, Examination, and Testing

R.5.1 Miscellaneous Requirements for Primary and Secondary Liquid Containers and Refrigerated Temperature Roofs 10

R.5.1.1 The following shall be joined with double butt-welds that have complete penetration and complete fusion except as noted:

a) Longitudinal and circumferential shell joints and joints that connect the annular bottom plates together. When approved by Purchaser, these may be welded from a single side provided temporary non-fusible backing is used with complete penetration and complete fusion. Both sides of the joint shall be 100% visually examined as specified in 7.15.5. 09

b) Joints that connect sections of compression rings and sections of shell stiffeners together. Backup bars may be used for these joints with complete penetration and complete fusion details.

c) Joints around the periphery of a shell insert plate. 09

d) Joints that connect the shell to the bottom, unless a method of leak checking is used (see R.6.2.3); in that case, double fillet welds are acceptable. 10

e) Joints that connect nozzle necks to flanges. 10

f) Butt-welds in piping nozzles, manway necks, and pipe fittings, including weld neck flanges, shall be made using double butt-welded joints. When accessibility does not permit the use of double butt-welded joints, single butt-welded joints that ensure full penetration through the root of the joint are permitted.

R.5.1.2 All fillet welds shall have a minimum of two passes.

R.5.1.3 Connections:

R.5.1.3.1 Slip-on flanges may be used where specifically approved by the Purchaser.

R.5.1.3.2 All connections shall have complete penetration and complete fusion.

R.5.1.3.3 Acceptable types of welded opening connections are shown in Figure 5-8, panels a, b, c, g, h, m, and o.

R.5.1.3.4 Flanges for nozzles shall be in accordance with this standard; however, the material shall comply with the requirements of R.2.1. 10

R.5.1.3.5 Manways shall have welded closures rather than depending on gaskets.

R.5.2 Warm Product Vapor Container Welds

Metallic wall liners for concrete *secondary liquid containers* where the liners are acting as *warm product vapor containers* but not required for secondary liquid containment shall be butt welded together or lap welded to embedment plates. Fillet welds for lap welded wall liners shall be two pass minimum except that wall liners less than $^{3}/_{16}$ in. may be single pass.

R.5.3 Postweld Heat Treatment

10 **R.5.3.1** All *primary* and *secondary liquid container* opening connections shall be welded into the shell plate or a thickened insert plate, and the welded assembly shall be stress relieved prior to installation in the tank unless one of the following exceptions is fulfilled:

a) The stress level in the plate, under the design conditions, does not exceed 10% of the minimum tensile strength of the plate material. The opening shall be reinforced for the low stress.

b) The impact tests on the material and welding fulfill the requirements of R.2.1.2 and Table R-2, and the thickness of the material is less than $^{5}/_{8}$ in. for any diameter of connection or less than $1^{1}/_{4}$ in. for connections that have a nominal diameter less than 12 in. The thickness of the nozzle neck without stress relief shall be limited to the value of (D + 50)/ 120, as described in 5.25.3.

c) Opening reinforcement is made from forgings similar in configuration to Figure 5-8, Panels o-1, o-2, o-3, and o-4.

R.5.3.2 The stress-relieving requirements of 5.25 shall still be mandatory for both primary and secondary components.

R.5.3.3 When used in stress relieved assemblies, the material 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.

R.5.4 Spacing of Connections and Welds

10 **R.5.4.1** In *primary* and *secondary liquid containers*, all opening connections in a shell plate shall conform to the requirements of R.5.4.2 through R.5.4.4 for the spacing of butt and fillet welds.

R.5.4.2 The butt-weld around the periphery of a thickened insert plate or the fillet weld around the periphery of a reinforcing plate shall be at least the greater of 10 times the shell thickness or 12 in. from any butt-welded shell seams except where the completed periphery weld has been stress relieved prior to the welding of the adjacent butt-welded shell seams. Where stress relief has been performed, the spacing from the periphery weld to a shell butt-weld shall be at least 6 in. from the longitudinal or meridional joints or 3 in. from the circumferential or latitudinal joints if in either case the spacing is not less than 3 times the shell thickness. These rules shall also apply to the bottom-to-shell joint; however, as an alternative, the insert plate or reinforcing plate may extend to and intersect the bottom-to-shell joint at approximately 90°. The stress-relieving requirements do not apply to the weld to the bottom or annular plate.

R.5.4.3 In cylindrical tank walls, the longitudinal weld joints in adjacent shell courses, including compression ring welds, shall be offset from each other a minimum distance of 12 in.

R.5.4.4 Radial weld joints in a compression ring shall not be closer than 12 in. from any vertical weld.

R.5.5 Examination of Welds by Magnetic-particle or Liquid-penetrant Methods

R.5.5.1 The following *primary* and *secondary liquid container* welds shall be examined, using the magnetic-particle
10 method (see 7.15) for carbon steel and the liquid-penetrant method (see 7.15) for stainless steel, after stress relieving, if any, and before the hydrostatic test of the tank.

a) All longitudinal and circumferential butt-welds that are not completely radiographed. Examination shall be on both sides of the joint.

b) The welded joint that joins the cylindrical wall of the tank to the bottom annular plates.

c) All welds of opening connections that are not completely radiographed, including nozzle and manhole neck welds and neck-to-flange welds. Examination shall also include the root pass and every $^{1}/_{2}$ in. of thickness of deposited weld metal (see 5.27.11) as welding progresses.

d) All welds of attachments such as stiffeners, compression rings, clips, and other nonpressure parts.

e) All welded joints on which backing strips are to remain shall also be examined after the first complete layer (normally two beads) of weld metal have been deposited. 10

R.5.5.2 All longitudinal and circumferential butt-welds in thermal distance pieces connecting cold piping to *warm product vapor* or *purge gas containers* shall also be examined by the liquid-penetrant method.

R.5.6 Radiographic Examination of Butt-welds in Plates

Primary and *secondary liquid container* butt-welds shall be examined by radiographic methods as listed in R.5.6.1 through R.5.6.6.

R.5.6.1 Butt-welds in all tank wall courses subjected to a maximum actual operating membrane tensile stress perpendicular to the welded joint that is greater than 0.1 times the specified minimum tensile strength of the plate material shall be completely examined.

R.5.6.2 Butt-welds in all tank wall courses subjected to a maximum actual operating membrane tensile stress perpendicular to the welded joint that is less than or equal to 0.1 times the specified minimum tensile strength of the plate material shall be examined in accordance with Figure R-2.

R.5.6.3 Butt-welds around the periphery of a thickened insert plate shall be completely examined. This does not include the weld that joins the insert plate with the bottom plate of a flat-bottom tank.

R.5.6.4 Butt-welds at all three-plate junctions in the tank wall shall be examined except in the case of a flat bottom (wall) supported uniformly by the foundation. This does not include the shell-to-bottom weld of a flat-bottom tank. See Figure R-2 for minimum examination dimensions.

R.5.6.5 Twenty-five percent of the butt-welded annular plate radial joints shall be spot examined for a minimum length of 6 in. The location shall be under the tank shell at the outer edge of the joint.

R.5.6.6 Twenty-five percent of the butt-welded compression bar radial joints shall be spot examined for a minimum length of 6 in. except as required by 5.26.4.3.

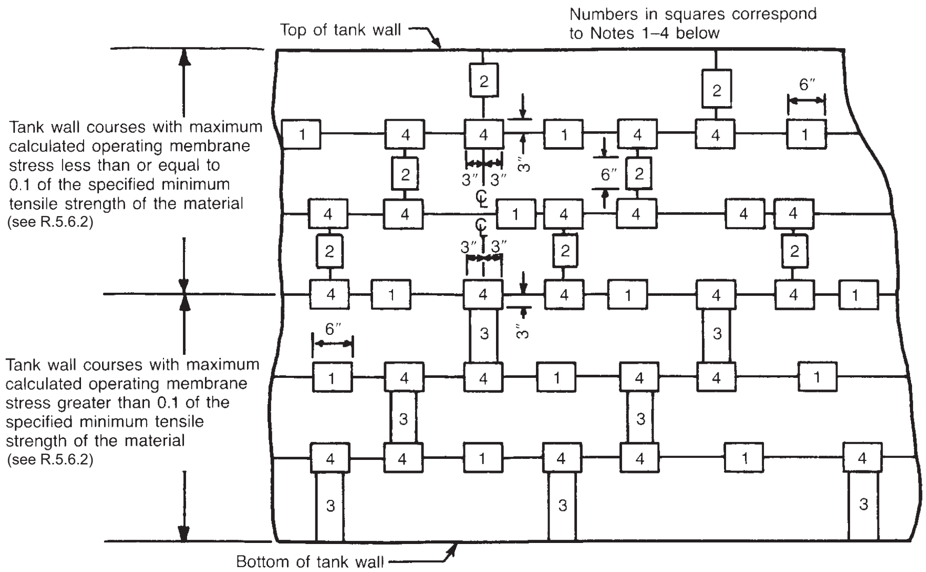
R.5.7 Examination of Butt-welds in Piping

R.5.7.1 Butt-welds in piping and in pipe fittings within the limitations of API 625, Section 1.6, shall be examined in conformance with R.5.7.2 through R.5.7.9.

R.5.7.2 Longitudinal welded joints in piping carrying liquid shall be completely radiographed except for welds in manufactured pipe welded without filler metal, 12 in. or less in diameter, which is tested hydrostatically or by eddy current to ASTM requirements. 10

R.5.7.3 Longitudinal welded joints in piping carrying vapor shall be completely radiographed except for welds in manufactured pipe welded without filler metal, 18 in. or less in diameter, which is tested hydrostatically or by eddy current to ASTM requirements.

R.5.7.4 Ten percent of the circumferential welded joints (including weld neck flange to pipe joints) in liquid and vapor carrying piping shall be completely radiographed.



Notes:

1) One circumferential spot examination shall be performed in the first 10 ft for each welding operator of each type and thickness. After the first 10 ft, without regard to the number of welders, one circumferential spot examination shall be performed between each longitudinal joint on the course below.

09 2) One longitudinal spot examination shall be performed in the first 10 ft for each welder or welding operator of each type and thickness. After the first 10 ft, without regard to the number of welders, one longitudinal spot examination shall be performed in each longitudinal joint.

3) Longitudinal joints shall be 100% examined.

4) All intersections of joints shall be examined.

10 **Figure R-2—Radiographic/Ultrasonic Examination Requirements for Butt-welded Shell Joints in Primary and Secondary Liquid Containers**

R.5.7.5 Butt-welded joints used to fabricate liquid and vapor carrying built-up pipe fittings shall be completely radiographed.

R.5.7.6 Lines carrying liquid located outside the primary liquid container in double wall tanks shall be hydrostatically or pneumatically pressurized at a minimum pressure of 35 lbf/in.^{2} and butt welded joints shall be simultaneously visually examined (hydrostatic) or solution film tested (pneumatic) for tightness. If manufactured pipe has been hydrostatically tested previously to ASTM requirements, then only circumferential welds need to be examined.

10

R.5.7.7 Lines carrying product vapor within a *purge gas container's* annular space shall be pneumatically pressurized at a minimum pressure of 5 lbf/in.^{2} and circumferential butt-welded joints shall be simultaneously solution film tested for tightness.

R.5.7.8 For piping that does not carry liquid or product vapor (e.g., instrument conduit and purge lines) examination needs to satisfy only the applicable requirements of R.2.

R.5.7.9 Radiography of butt-welds in piping shall comply with ASME B31.3, *Process Piping* rules, Normal Fluid Service conditions.

R.5.8 Nonpressure Parts

Welds for pads, lifting lugs, and other nonpressure parts, as well as temporary lugs for alignment and scaffolding attached to *primary* and *secondary liquid containers*, shall be made in full compliance with a welding procedure
10 qualified in accordance with R.4.1. Lugs attached for erection purposes shall be removed by the grinding of all remaining welds followed by magnetic-particle examination. Plate that is gouged or torn in removing the lugs shall be

repaired using a qualified procedure, followed by grinding. Where such repairs are made in *primary* and *secondary liquid containers*, the area shall be examined using the magnetic-particle method. A visual examination is adequate for repaired areas in *warm product vapor* and *purge gas containers*.

R.6 Testing the Primary Liquid and Primary Vapor Containers 10

The provisions stated in R.6.1 through R.6.3 are testing requirements for the *primary liquid container*. Provisions stated in R.6.4 cover the pneumatic testing of the *warm product vapor container* (or when inner tank is not open top, the *refrigerated temperature roof*).

R.6.1 General Procedure

A thorough check for tightness and structural adequacy is essential for the *primary liquid container*. Except as 10
permitted by R.6.5, the test shall be conducted after the entire tank is complete, but before the insulation is applied. The hydrostatic test shall be performed by filling the tank with water to the design liquid level and applying an overload air pressure of 1.25 times the pressure for which the vapor space is designed. The hydrostatic test shall not produce a membrane tensile stress in any part of the tank exceeding 85% of the minimum specified yield strength or 55% of the minimum specified tensile strength of the material.

R.6.2 Test Preliminaries

Before the tank is filled with water, the procedures described in R.6.2.1 through R.6.2.5 shall be completed.

R.6.2.1 All welded joints in the bottom of the tank shall be examined by applying a solution film to the welds and 10
pulling a partial vacuum of at least 3 lbf/in.^{2} gauge above the welds by means of a vacuum box with a transparent top.

R.6.2.2 Complete penetration and complete fusion welds that join the cylindrical wall to the tank bottom shall be examined by applying a solution film to the welds and pulling a partial vacuum of at least 3 lbf/in.^{2} gauge above the 10
welds by means of a vacuum box with a transparent top.

R.6.2.3 When the weld in R.6.2.2 does not have complete penetration and complete fusion, the initial weld passes, inside and outside of the shell, shall have all slag and non-metals removed from the surface of the welds and the welds examined visually. After completion of the inside and outside fillet or partial penetration welds, the welds shall be tested by pressurizing the volume between the inside and outside welds with air pressure to 15 lbf/in.^{2} gauge and applying a solution film to both welds. To assure that the air pressure reaches all parts of the welds, a sealed blockage in the annular passage between the inside and outside welds must be provided by welding at one or more points. Additionally, a small pipe coupling communicating with the volume between the welds must be welded on each side of and adjacent to the blockages. The air supply must be connected at one end and a pressure gauge connected to a coupling on the other end of the segment under test.

R.6.2.4 The attachment welding around all openings and their reinforcements in the bottom, shell, and roof shall be examined by magnetic particle method and solution film test in accordance with 7.18.2.2 and 7.18.2.3.

R.6.2.5 The attachment fillet welds around bottom openings, which do not permit the application of air pressure behind the reinforcing plate, shall be examined by applying a solution film and by a vacuum box examination. 10

R.6.2.6 All welds of bottom, wall, and roof metallic liners of concrete containers shall be examined by applying a solution film to the welds and applying a partial vacuum of between 3 lbf/in.^{2} and 5 lbf/in.^{2} gauge above the welds by means of a vacuum box with transparent top. Where single pass lap welds less than $^3/_{16}$ in. are used for wall liners, a second partial vacuum of at least 8 lbf/in.^{2} shall be applied.

R.6.3 Hydrostatic Test

The provisions described in R.6.3.1 through R.6.3.5 shall apply during and after water filling for the hydrostatic test.

R.6.3.1 The tank shall be vented to the atmosphere when it is filled with or emptied of water.

10 **R.6.3.2** During water filling, the elevations of at least eight equidistant points at the bottom of the tank shell and on top of the ringwall or slab shall be checked. Differential settlement, or uniform settlement of substantial magnitude, requires an immediate stop to water filling. Any further filling with water will depend on an evaluation of the measured settlement.

10 **R.6.3.3** The tank shall be filled with water to the design liquid level. In the case of settlement, as stated in R.6.3.2, an appropriate corrective action shall be taken before further filling or, alternatively the design liquid level shall be reduced to the actual maximum test water level.

R.6.3.4 After the tank is filled with water and before the pneumatic test pressure is applied, anchor bolts or anchor straps, if provided, shall be tightened against the hold-down brackets.

R.6.3.5 All welds in the shell, including the corner weld between the shell and the bottom, shall be visually checked for tightness.

R.6.4 Pneumatic Pressure

R.6.4.1 An air pressure equal to 1.25 times the pressure for which the vapor space is designed shall be applied to the enclosed space above the water level. In the case of a double-wall tank with an open-top inner tank, where the air pressure acts against the outer tank and the inner tank is thus not stressed by the air pressure, the inner tank may be emptied of water before the pneumatic pressure testing begins.

R.6.4.2 The test pressure shall be held for 1 hour.

R.6.4.3 The air pressure shall be reduced until the design pressure is reached.

R.6.4.4 Above the water level, all welded joints shall be checked with a solution film. A prior vacuum box check may be substituted for the solution-film examination of the welded joints. Above the water level, the solution-film examination shall be made, of all welds around openings, all piping joints, and the compression ring welds to the roof and shell except any listed below:

10

— Continuous double lap roof to compression ring welds.

— Shell to compression ring welds, continuous inside and outside, and applying a thickened upper shell ring detail similar to Figure 5-6, details f or f-1. The thickened upper shell ring shall be greater than half of the conical compression ring thickness and greater than two times the adjacent shell ring thickness.

— Full fusion butt welded connections.

R.6.4.5 The opening pressure or vacuum of the pressure relief and vacuum relief valves shall be checked by pumping air above the water level and releasing the pressure, then partially withdrawing water from the tank.

R.6.4.6 After the tank has been emptied of water and is at atmospheric pressure, the anchorage, if provided, shall
10 be rechecked for tightness.

R.6.4.7 Air pressure equal to the design pressure shall be applied to the empty tank, and the anchorage, if provided, and the foundation shall be checked for uplift.

R.6.5 Temporary Openings after Hydrostatic Test

When approved by the Purchaser in writing, and only in the case of tanks which when complete have no shell penetrations, it is permitted to restore by welding up to four temporary shell openings after the hydrostatic test in accordance with the provisions of this section.

R.6.5.1 Each temporary opening shall be restored by the insertion of a shell plate that matches the thickness and specification of adjacent shell material, and is welded into place with full fusion butt-welds. The insert plate shall be round with diameter no less than 24 in. and no greater than 42 in.

R.6.5.2 The insert plate weld shall not cross any shell seams and shall be at least the greater of 10 times the shell thickness or 12 in. from any other weld in the shell including shell seams, shell-to-bottom weld or attachment welds.

R.6.5.3 The butt weld around the periphery of the plate shall be examined over 100% of its length by the magnetic particle method, by the radiographic method and by the ultrasonic method. Ultrasonic examination acceptance criteria shall be as given in Table U-1. The magnetic particle examination is required on the root pass, on the back-gouged surface, and on the inside and outside finished weld surfaces. Additionally, the weld shall be vacuum box leak tested.

R.7 Testing a Purge Gas Container

R.7.1 The tightness test shall be made before insulation is installed.

R.7.2 The inner tank shall be opened to the atmosphere, and a sufficient amount of water shall be added to the inner tank to balance the upward pressure against the inner tank bottom produced by the pneumatic test of the outer tank; as an alternative, the pressure between the inner and outer tanks can be equalized. 10

R.7.3 Air pressure shall be applied to the space enclosed by the outer tank equal to at least the design gas pressure but not exceeding a pressure that would overstress either the inner or outer tank.

R.7.4 While the test pressure is being held, all lap welded seams and all welds in connections in the outer shell and roof shall be thoroughly examined with solution film unless they were previously checked with a vacuum box.

R.7.5 The air pressure shall be released.

R.7.6 Pressure relief and vacuum relief valves shall be checked by applying the design gas pressure to the outer tank, followed by evacuation of the outer space to the vacuum setting of the relief valve.

R.8 Foundations

R.8.1 Foundations shall be in accordance with API 625, Section 6.7. 10

R.8.2 Uplift on Foundation

R.8.2.1 The increased uplift described in R.8.2.2 and R.8.2.3 is intended to apply to the size of the ringwall and foundation but not to the anchorage. 10

R.8.2.2 For tanks with an internal design pressure less than 1 lbf/in.^{2} gauge, the uplift shall be taken as the smaller of the maximum uplift values computed under the following conditions:

a) The internal design pressure times 1.5 plus the design wind load on the shell and roof.

b) The internal design pressure plus 0.25 lbf/in.^{2} gauge plus the design wind load on the shell and roof.

R.8.2.3 For tanks with an internal design pressure of 1 lbf/in.^{2} gauge and over, the uplift, if any, shall be calculated under the combined conditions of 1.25 times the internal design condition plus the design wind load on the shell and roof.

R.8.2.4 When the anchorage is designed to meet the requirements of R.3.7.4.2, the foundation should be designed to resist the uplift that results from three times the design pressure with the tank full to the design liquid level. When designing to any of the conditions of this paragraph, it is permissible to utilize friction between the soil and the vertical face of the ringwall and all of the effective liquid weight. 10

R.9 Marking

Except for 8.2 on Division of Responsibility, marking requirements of Section 8 are superseded by the requirements of API 625, Section 11. 10

S.4.10.3 Two stainless steel plates identical in material type may be welded together prior to erection in order to form a single shell plate subassembly. Plates welded together shall have thicknesses within $^1/_{16}$ in. of each other with the maximum plate thickness being $^1/_2$ in. No more than two plates shall be used to form one subassembly. Vertical edges of the pair of plates comprising a subassembly shall be aligned. The subassembly shall conform to the dimensional tolerances contained in Section 6 and shall be subjected to inspection requirements contained in Section 7. At least 25% of vertical spot radiographs shall be made at the subassembly horizontal weld to field vertical weld intersection. All welding procedure specifications shall be in accordance with Section 6. 10

S.4.11 Welding Procedure and Welder Qualifications

Impact tests are not required for austenitic stainless steel weld metal and heat-affected zones.

S.4.12 Postweld Heat Treatment

Postweld heat treatment of austenitic stainless steel materials need not be performed unless specified by the Purchaser.

S.5 Inspection and Testing

S.5.1 Weld Inspection

Where specified, the magnetic-particle method of examination shall be replaced by the liquid-penetrate examination method.

S.5.2 Hydrostatic Test Considerations—Quality of Test Water

S.5.2.1 The materials used in the construction of stainless steel tanks may be subject to severe pitting, cracking, or rusting if they are exposed to contaminated test water for extended periods of time. The Purchaser shall specify a minimum quality of test water that conforms to the following requirements:

a) Unless otherwise specified by the Purchaser, water used for hydrostatic testing of tanks shall be potable and treated, containing at least 0.2 parts per million free chlorine.

b) Water shall be substantially clean and clear.

c) Water shall have no objectionable odor (that is, no hydrogen sulfide).

d) Water pH shall be between 6 and 8.3.

e) Water temperature shall be below 50°C (120°F).

f) The chloride content of the water shall be below 50 parts per million, unless specified otherwise by the Purchaser.

S.5.2.2 When testing with potable water, the exposure time shall not exceed 21 days, unless specified otherwise by the Purchaser.

S.5.2.3 When testing with other fresh waters, the exposure time shall not exceed seven days.

S.5.2.4 Upon completion of hydrostatic test, water shall be completely drained. Wetted surfaces shall be washed with potable water when non-potable water is used for the test and completely dried. Particular attention shall be given to low spots, crevices, and similar areas. Hot air drying is not permitted.

S.6 Marking

S.6.1 Brazing shall be deleted from 6.1.3

S.7 Appendices

The appendices are applicable for use with austenitic stainless steels as follows:

a) Appendix D is applicable; however see S.2.1.3 for special requirements when attaching to carbon steel supports.

b) Appendix E is applicable; however see S.2.13 for special requirements when attaching external carbon steel supports. Internal supports shall meet the material requirements of Appendix S.

c) Appendix H is not applicable; stress relieving is only required when specified by the Purchaser and must be performed with care and in such a manner that does not damage or alter the properties of the stainless steel.

d) Appendix Q is not applicable.

e) Appendix R is not applicable.

f) All other appendices are applicable without modifications.

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