Date: March 2012
Re: Addendum 3

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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
ADDENDUM 3, MARCH 2012
Design and Construction of Large, Welded, Low-pressure Storage Tanks

Downstream Segment

API STANDARD 620
ELEVENTH EDITION, FEBRUARY 2008

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ADDENDUM 2, AUGUST 2010
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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.

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.

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 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.

1.2.26 Appendix X covers materials, design, fabrication, erection, and testing requirements for aboveground, welded, duplex stainless steel storage tanks.
Section 2—References

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

Note: The reference below to ASCE 7-05 is not the latest version.

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, Aluminum Design Manual, Specifications for Aluminum Structures

ACI 318, Building Code Requirements for Reinforced Concrete (ANSI/ACI 318)

AISC, Manual of Steel Construction

ANSI H35.2, Dimensional Tolerances for Aluminum Mill Products

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

ASME B1.20.1, 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, Standard for Qualification and Certification of Nondestructive Testing Personnel

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3American Concrete Institute, P.O. Box 9094, Farmington Hills, Michigan 48333, www.aci-int.org.
8American Society for Nondestructive Testing, Inc., 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.
ASNT SNT-TC-IA, Personnel Qualification and Certification in Nondestructive Testing

ASTM A6\(^9\), General Requirements for Rolled Steel Plates, Shapes, Steel Piling, and Bars for Structural Use

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\(^{10}\), *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\(^{11}\), *Structural Quality Steel*

EN 10025\(^{12}\), *Hot Rolled Products of Structural Steels*

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

ISO 630\(^{13}\), *Structural Steels*

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\(^{12}\)European Commitee for Standardization, Management Centre: rue de Stassart, 36 B-1050 Brussels, Belgium.

\(^{13}\)International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.
Section 3—Definitions

3.1 Stress and Pressure Terms

3.1.1 design pressure: The maximum positive gauge pressure permissible at the top of a tank when the tank is in operation. It is the basis for the pressure setting of the safety-relieving devices on the tank. The design pressure is synonymous with the nominal pressure rating for the tank as referred to in this standard (see 5.3.1).

3.1.2 maximum allowable stress value: The maximum unit stress permitted to be used in the design formulas given or provided for in this standard for the specific kind of material, character of loading, and purpose for a tank member or element (see 5.5 and 5.6).

3.2 Capacity Terms

3.2.1 nominal liquid capacity: The total volumetric liquid capacity of a tank (excluding deadwood) between the plane of the high liquid design level and elevation of the tank grade immediately adjacent to the wall of the tank or such other low liquid design level as the Manufacturer shall stipulate.

3.2.2 total liquid capacity: The total volumetric liquid capacity of a tank (excluding deadwood) below the high liquid design level.

3.3 Tank Wall

The tank wall is any or all parts of the plates located in the surface of revolution that bounds the tank and serves to separate the interior of the tank from the surrounding atmosphere. Flat bottoms of cylindrical tanks are covered by the rules of 5.9.4. As such, the tank walls include the sidewalls (or shell), roof, and bottom of the tank but not any of the following elements located on or projecting from the walls:

a) Nozzles and manways or their reinforcement pads or cover plates.

b) Internal or external diaphragms, webs, trusses, structural columns, or other framing.

c) Those portions of a compression-ring angle, bar, or girder that project from the walls of the tank.

d) Miscellaneous appurtenances.

3.4 Welding Terms

The terms defined in 3.4.1 through 3.4.21 are commonly used welding terms mentioned in this standard. See 5.22 for descriptions of fusion-welded joints.

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

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

3.4.3 base metal: The metal or alloy to be welded or cut.

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

3.4.5 filler metal: Metal or alloy added in making a weld.

3.4.6 fusion: The melting together of filler metal and base metal, or the melting of base metal only, which results in coalescence.
3.4.7 **heat-affected zone:** The portion of the base metal that has not been melted but whose mechanical properties or microstructures have been altered by the heat of welding or cutting.

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

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

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

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

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

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

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

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

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

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

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

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

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

3.4.21 **welding operator:** One who operates machine welding equipment.

3.5 **Other Terms**

3.5.1 **Manufacturer:** The party having the primary responsibility for constructing the tank.

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

3.5.3 **Examiner:** A person who performs nondestructive examinations specified by this Standard and is qualified and certified as meeting the requirements of ASNT SNT-TC-1A and/or other requirements as determined by the Manufacturer or Purchaser for the method employed.

3.5.4 **Inspector:** The Inspector is the representative of the Purchaser who is qualified according to 7.2 and who ensures compliance with this standard as described in 7.1.
Section 5—Design

5.1 General

5.1.1 Scope of Rules

The rules presented in this standard are intended to establish approved engineering practices for low-pressure storage tanks constructed of any shape within the scope of 1.2 and to provide the fundamental rules for design and testing, which can serve as a sufficient basis for an inspector to judge the safety of any vessel and improve the application of the API 620 nameplate. Where these rules do not cover all details of design and construction, the Manufacturer, subject to the approval of the inspector, shall provide details of design and construction that will be as safe as those provided by this standard.

5.1.2 Pressure Chambers

For tanks that consist of two or more independent pressure chambers and have a roof, bottom, or other elements in common, each pressure part shall be designed for the most severe combination of pressure or vacuum that can be experienced under the specified operating conditions.

5.1.3 Avoidance of Pockets

Tank walls shall be shaped to avoid any pockets on the inside where gases may become trapped when the liquid level is being raised or on the outside where rainwater may collect.

5.1.4 Volume of Vapor Space

The volume of the vapor space above the high liquid design level upon which the nominal capacity is based shall be not less than 2% of the total liquid capacity (see 3.2.2).

5.1.5 Tests of New Design

When a tank is of a new design and has (a) an unusual shape or (b) large branches or openings that may make the stress system around these locations in the tank wall unsymmetrical to a degree that, in the judgment of the designer, does not permit computation with a satisfactory assurance of safety, the tank shall be subjected to a proof test, and strain-gauge surveys shall be made as provided in 7.24.

5.2 Operating Temperature

The temperature of the liquids, vapor, or gases stored in, or entering, these tanks shall not exceed 250°F (see 1.2.2).

5.3 Pressures Used in Design

5.3.1 Above Maximum Liquid Level

5.3.1.1 Tank components, including those above the maximum liquid level, subjected principally to gas pressure shall be designed for:

a) a pressure not less than the relief valves’ set pressure. The maximum positive gauge pressure shall be understood to be the nominal pressure rating for the tank (sometimes called the design pressure) and shall not exceed 15 lbf/in.²
gauge.

b) the maximum partial vacuum (also called the design vacuum) when the inflow of air (or another gas or vapor) through the vacuum relief valves is at the tank design maximum in-breathing flow rate.
5.3.1.2 If the maximum liquid level is below the top of the roof but the tank will be filled to the top of the roof during the hydrostatic test as provided in 7.18.4, the tank shall be designed for both maximum liquid-level conditions.

5.3.1.3 A suitable margin shall be provided between the operating pressure in the gas or vapor space and the relief valve’s set pressure. This margin allows for pressure increases caused by variations in temperature, atmospheric pressure, or other factors that affect the pressure in the gas or vapor space.

5.3.1.4 The set pressure of the vacuum relief valve shall limit the vacuum pressure accumulation in the tank to the design vacuum pressure.

5.3.2 Below Maximum Liquid Level

All pressure containing elements of the tank below the maximum liquid level shall be designed for the most severe combination of gas pressure (or partial vacuum) and static liquid head affecting the element.

5.3.3 Weight for Liquid Storage

The weight for liquid storage shall be assumed to be the weight per ft³ of the specified liquid contents at 60°F. When the minimum weight is less than 48 lb/ft³, the provisions of 5.5.7 shall be followed. This minimum weight does not apply to tanks used for gas storage only, or used for refrigerated liquid storage as discussed in Appendices Q and R.

5.4 Loads

5.4.1 Individual Loads

a) dead load \( (D_L) \): the weight of the tank or tank component, including any insulation, lining, or corrosion allowance unless otherwise noted.

b) hydrostatic and pneumatic tests \( (H_T) \): the load due to conducting the tests specified in 7.18.

c) loads from connected piping \( (L_p) \).

d) loads from platforms and stairways \( (L_s) \) (see Appendix E).

e) minimum roof live load \( (L_r) \): 20 lb/ft² on the horizontal projected area of the roof.

f) pressure \( (P_g) \): the maximum positive gauge pressure given in 5.3.1.

g) pressure \( (P_v) \): the maximum partial vacuum given in 5.3.1. The maximum partial vacuum shall be at least 1 in. \( w_c \).

h) seismic \( (E) \): seismic loads given in Appendix L.

i) snow \( (S) \): The ground snow load (lb/ft²) shall be determined from ASCE 7 Figure 7-1 or Table 7-1 unless the ground snow load is specified by the Purchaser. The design uniform roof snow load shall be 0.84 times the ground snow load. Alternately, the design uniform roof snow load shall be determined from the ground snow load in accordance with ASCE 7 or a national standard.

j) stored liquid \( (P_l) \): gauge pressure (lb/in.²) resulting from the liquid head of the liquid with the density given in 5.3.3. All liquid levels from empty to the maximum liquid level shall be considered.

k) wind \( (W) \): The design wind speed \( (V) \) shall be the 3-sec gust design wind speed (mph) determined from ASCE 7 Figure 6-1 or the 3-sec gust design wind speed specified by the Purchaser. When wind is specified as measured by fastest mile the speed shall be multiplied by 1.2. For tank components exposed to wind up to 80 ft above ground, the
and less than the nozzle wall thickness. This fillet may be machined to a radius of the same size, but in no case shall it be less than 3/16 in.

5.19.3.3 When a bolting flange is welded to the nozzle neck, but not for its entire thickness, it shall be designed and attached in accordance with 5.20 in this standard and the provisions of Figure 4-4, Appendix 2, in Section VIII of the ASME Code.

5.20 Bolted Flanged Connections

5.20.1 Bolted flanged connections conforming to ASME B16.5, Class 150, shall be used for connections to external piping and may be used for other flanged connections. Such flanges may be built up by fusion welding if the Manufacturer satisfies the inspector, by direct or comparative calculation, that the welded flanges are equivalent in strength to the one-piece flanges that they are intended to replace.

5.20.2 Bolted flanges for external piping connections other than those meeting the requirements of 5.20.1 shall be designed for a pressure of at least 50 lbf/in.$^2$ gauge in accordance with the applicable provisions of Section VIII, Appendix 2, of the ASME Code, using for values of $S_h$ and $S_r$ the applicable allowable design stress values given in Table 5-1 of this standard (instead of the allowable design stress values specified in Section VIII of the ASME Code) and limiting the values for $S_h$, $S_r$, and $S_t$ as follows:

\[
S_h = \text{longitudinal hub stress, not greater than } 1.5S_p \text{ except that for flanges of the types illustrated in Figures 4-4 (7), (8), (8a), (8b), and (9) in Section VIII, Appendix 2, of the ASME Code, } S_h \text{ shall not exceed the smaller of } 1.5S_p \text{ or } 1.5S_{in},
\]

\[
S_r = \text{radial flange stress, not greater than } S_h,
\]

\[
S_t = \text{tangential flange stress, not greater than } S_r.
\]

Also, $(S_h + S_r)/2$ shall not be greater than $S_h$ and $(S_h + s_t)/2$ shall not be greater than $S_r$. Design stress values for bolts shall not exceed the applicable values given in Table 5-1 in these rules, based on the area at the root of the thread.

5.20.3 Bolted flange connections, other than external piping connections, shall conform to ASME B16.5, Class 150 or shall be designed in accordance with the requirements of 5.20.2 except that they shall be designed for a pressure of at least 15 lbf/in.$^2$ gauge or the total pressure, $P$, on the wall of the tank and the level of the connection, whichever is greater.

5.20.4 Hubbed flanges may be welded to the ends of nozzle necks by any of the methods permitted for circumferential joints in the walls of the tank; the attachment shall conform to the requirement for circumferential joints of the type employed.

5.20.5 Flanges that do not exceed 12-in. pipe size for working pressures up to 50 lbf/in.$^2$ gauge or 4 in. pipe size for working pressures above 50 lbf/in.$^2$ gauge may be screwed to the end of a nozzle neck if the number of full threads engaged conforms to or exceeds the requirements of ASME B1.20.1.

5.20.6 Bolts and studs shall be at least $1/2$ in. in diameter. If smaller bolts are used, they shall be of alloy steel.

5.21 Cover Plates

5.21.1 Flat Cover Plates and Blind Flanges

5.21.1.1 The thickness of flat, unstayed cover plates and blind flanges shall be determined by one of the following methods, but shall not be less than $1/2$ in. plus corrosion allowance.
a) Blind flanges that conform to ASME B16.5 and are of the appropriate pressure-temperature ratings and diameters given in the standard, or their equivalent, shall be used when attached by bolting as shown in Figure 5-10, Panels b and c.

b) For sizes and designs not covered by ASME B16.5, the required thickness of flat steel cover plates or blind flanges shall be computed by the following formula using the appropriate value for $C$:

$$ t = \frac{d}{4} \left( \frac{CP}{s} + c \right) \quad \text{or} \quad P = \frac{s(t-c)^2}{Cd^2} $$

where

- $t$ = minimum required thickness, in in.,
- $d$ = diameter, in in., measured as indicated in Figure 5-10,
- $C = 0.25$ for plates rigidly riveted or bolted to flanges as shown in Figure 5-10, Panel a (this applies in these rules to any kind of gasket material),
- $= 0.30$ for plates inserted into the ends of nozzles and held in place by some suitable positive mechanical locking arrangement such as those shown in Figure 5-10, Panel d, e, or f if the design of all holding parts against failure by shear, tension, or compression resulting from the end force produced by the pressure is based on a factor of safety of at least four and that threaded joints, if any, in the nozzle wall are at least as strong as they are for standard pipe of the same diameter,
- $= 0.30 + (1.49 \frac{W h_G}{H G})$ for plates bolted to flanges in such a manner that the setting of the bolts tends to dish the plate, where the pressure is on the same side of the plate as the bolting flange, as shown in Figure 5-10, Panels b and c,
- $W$ = flange design bolt load, in lb [see ASME Section VIII, Appendix 2, Paragraph 2-5(e)],
- $h_G$ = radial distance from the bolt-circle diameter to diameter $G$, in in.,
- $H$ = total hydrostatic end force, in lb, as defined in ASME Section VIII, Appendix 2, Paragraph 2-3,
- $G$ = diameter, in in., at the location of the gasket load reaction, as defined in ASME Section VIII, Appendix 2, Paragraph 2-3,
- $P$ = design pressure, in lbf/in.2 gauge (this shall be at least equal to the total pressure $P$ on the wall of the tank at the level where the cover plate is located or shall be 15 lbf/in.2 gauge, whichever is greater),
- $s$ = maximum allowable stress value, $S_{ls}$, in lbf/in.2, as given in Table 5-1,
- $c$ = corrosion allowance, in in.

5.21.1.2 Unreinforced openings up to and including 2-in. pipe size are permissible in flat cover plates without increasing the plate thickness if the edges of these openings are not closer to the center of the plate than one-fourth the diameter $d$ in Figure 5-10. When this condition is not met, the plate thickness shall be increased by 40% of the thickness required in a solid plate after the loss of corrosion metal. The solid-plate thickness shall be determined by deducting the corrosion allowance from the thickness computed using Equation 33.

5.21.1.3 Openings that do not exceed 50% of dimension $d$ shown in Figure 5-10 may be made in flat cover plates if these openings are reinforced in accordance with 5.16 as though the cover plates were dished to the form of a spherical segment having a radius equal to diameter $d$. However, the reinforcement added to the cover plate shall compensate for not less than 50% of the cross section of the metal removed for the opening in the cover plate. When the maximum diameter of the opening in the flat cover plate exceeds 50% of dimension $d$ shown in Figure 5-10, the cover plate shall be designed as a flange in accordance with the rules for bolted flanges given in 5.20 of this standard and in ASME Section VIII, Appendix 2.
6.16 Matching Plates of Unequal Thickness

For plates over $\frac{1}{2}$-in. thick in the sidewalls, roof, or bottom of a tank, if the thickness of two adjacent plates that are to be butt-welded together differ by more than $\frac{1}{8}$ in., the thicker plate shall be trimmed to a smooth taper that extends for a distance at least four times the offset between the abutting surfaces so that the adjoining edges will be of approximately the same thickness. The length of the required taper may include the width of the weld (see Figure 6-3).

<table>
<thead>
<tr>
<th>Plate Thickness (in.)</th>
<th>Vertical Joints</th>
<th>Horizontal Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq \frac{1}{2}$</td>
<td>$\frac{3}{32}$</td>
<td>$\frac{1}{8}$</td>
</tr>
<tr>
<td>$&gt; \frac{1}{2}$ thru 1</td>
<td>$\frac{1}{8}$</td>
<td>$\frac{3}{16}$</td>
</tr>
<tr>
<td>$&gt; 1$</td>
<td>$\frac{3}{16}$</td>
<td>$\frac{1}{4}$</td>
</tr>
</tbody>
</table>

6.17 Fitting Up of Closure Plates

For the closure of the final joints, plates of extra width and length—not narrow strips or filler bars—shall be used. The fitting up of the closure plates used and the proposed method of installation shall be subject to the inspector’s approval before the work is started, and the inspector shall ensure that the closure plates meet all applicable requirements.

6.18 Thermal Stress Relief

6.18.1 General thermal stress relief of an entire tank is not visualized for tanks of this type, but sections of tanks shall be stress relieved before erection where required by the provisions of 5.25.

6.18.2 Parts of a tank that require stress relief according to the rules in 5.25 shall be stress relieved in an enclosed furnace before shipment from the fabricators’ shops. The procedure used shall be as outlined in 6.18.2.1 through 6.18.2.5.

6.18.2.1 The temperature of the furnace shall not exceed 600°F at the time the part or section of the tank is placed in it.

6.18.2.2 The rate of heating in excess of 600°F shall be not more than 400°F per hour divided by the maximum metal thickness, in in., of the wall plate being heated, but in no case shall it be more than 400°F per hour.

6.18.2.3 During the heating period, the temperature throughout the portion of the tank being heated shall not vary more than 250°F within any 15-ft interval of length and when at the hold temperature not more than 150°F throughout the portion of the tank being heated. A minimum temperature of 1100°F (except as permitted in 6.18.2.5) shall be maintained for a period of one hour per in. of metal thickness (maximum metal thickness of the tank wall plates affected). During the heating and holding periods, the furnace atmosphere shall be controlled to avoid excessive oxidation of the surface of the material being treated. The furnace shall be designed to prevent direct impingement of the flame on the material.

6.18.2.4 At temperatures over 600°F, cooling shall be done in a closed furnace or cooling chamber at a rate not greater than 500°F per hour divided by the maximum metal thickness, in in., of the plates affected; in no case shall the rate be more than 500°F per hour. At temperatures of 600°F and below, the material may be cooled in still air.

6.18.2.5 When stress relieving at a temperature of 1100°F is impracticable, it is permissible to carry out the stress-relieving operation at lower temperatures for longer time periods in accordance with Table 6-4.

6.19 Peening Field Welds

6.19.1 A tank fabricated according to these rules that is too large to be completely assembled and welded in a shop may be transported in sections and assembled in the field. Welds made after assembly in the field may require a spe-

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33Gaps of this kind may require removal of part of the adjoining plate to give proper widths. Full consideration should be given to radiographic and magnetic-particle methods of examination as well as to the thermal stress relief or peening of these welds.
cial welding procedure in accordance with 5.25, and mechanical peening as described in Appendix I may then be used on the field welds.

6.19.2 Peening of welds is not considered as effective as thermal stress relief and is not to be substituted for thermal stress relief where the thermal stress relief is mandatory under the provision of 5.25.

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**Figure 6-3—Butt Welding of Plates of Unequal Thickness**

**Table 6-4—Stress-relieving Temperatures and Holding Times**

<table>
<thead>
<tr>
<th>Metal Temperature (° Fahrenheit)</th>
<th>Holding Time (hours per in. of thickness)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100</td>
<td>1</td>
</tr>
<tr>
<td>1050</td>
<td>2</td>
</tr>
<tr>
<td>1000</td>
<td>3</td>
</tr>
<tr>
<td>950</td>
<td>5</td>
</tr>
<tr>
<td>900 (minimum)</td>
<td>10</td>
</tr>
</tbody>
</table>

*Note: For intermediate temperatures, the heating time shall be determined by straight line interpolation.*
Section 7—Inspection, Examination and Testing

7.1 Responsibility of Examiner

7.1.1 The inspector\textsuperscript{34} shall ensure that all materials used in tanks constructed according to the rules in this standard comply in all respects with the requirements of these rules. This shall be done either by witnessing mill tests or verifying that the materials to be used are properly identified in the certified mill test reports supplied by the Manufacturer.

7.1.2 Tanks constructed according to the rules in this standard shall be inspected and tested in accordance with the sections that follow. The inspector shall carefully follow the fabrication and testing of each tank and shall make sure that they comply in all details with the design, fabrication, and tests specified in these rules.

7.1.3 All nondestructive examination shall be reviewed and approved by the Inspector.

7.2 Qualifications of Inspectors

7.2.1 Inspectors for tanks constructed according to the rules in this standard shall have had not less than 5 years experience in design, construction, maintenance and/or repair, or in the responsible supervision of the construction, maintenance and/or repair of various types of unfired pressure vessels and/or tanks, including at least 1 year of experience in the construction or supervision of the construction of vessels or tanks by fusion welding. Satisfactory completion of a suitable course of training approved by the Purchaser or the Purchaser’s agent may be substituted for 3 of the 5 years experience. However, training cannot replace more than 6 months of the required experience on fusion-welding construction.

7.2.2 Inspectors shall be employed by the Purchaser or by an organization regularly engaged in making inspections. The Inspector is the representative of the Purchaser.

7.2.3 The Manufacturer shall also provide inspection to help ensure that all requirements of these rules have been met before signing the certificate and Manufacturer’s report (see 8.3).

7.3 Access for Inspector

The inspector shall be permitted free access to all parts of the plant concerned with the manufacture of the tank during fabrication and to all parts of the plants of material suppliers who are concerned with the manufacture of materials to be used in the tank.

7.4 Facilities for Inspector

The Manufacturer shall afford the Inspector all reasonable facilities for testing and inspection and shall provide mutually agreeable advance notification to permit the Inspector to witness all tests of the equipment and materials during fabrication, including all laboratory tests of the material to be used and all hydrostatic and pneumatic tests at the site of erection.

7.5 Approval of Repairs

Approval by the inspector shall be required before and after any defects are repaired. Defective material that cannot be satisfactorily repaired shall be rejected (see 6.16 for repair of defects in welds).

7.6 Inspection of Materials

The plates and other material for parts that will be subjected to pressure-imposed loads shall be inspected before being incorporated in the tank. Particular attention shall be given to all cut edges to ensure that the material is free from serious laminations and other defects.

\textsuperscript{34}Footnote Deleted
7.7 **Stamping of Plates**

Before plates required to be stamped by the steel mill are used, the inspector shall see that they bear the stamp. In laying out and cutting the plates, at least one set of the original material identification markings should, if possible, be left where it will be plainly visible when the tank is completed. Should the identifying marks be obliterated, one set shall be accurately transferred by the tank Manufacturer to a location that will be visible on the completed tank, or a coded marking shall be used to ensure identification of each piece of material during fabrication and subsequent identification of the markings on the completed tank. These latter markings shall be readily distinguishable from the mill markings. The inspector need not witness the transfer of the markings but shall be satisfied that the transfer of the markings has been made correctly. Care should be taken not to damage the plate by stamping the figures too deeply. To guard against incipient cracks in plates less than $\frac{1}{4}$ in. thick, the mill markings shall be transferred in some manner other than by die stamping.

7.8 **Measuring Thickness of Material**

All material shall be gauged or measured to determine whether the thickness meets the requirements.

7.9 **Inspection of Surfaces Exposed during Fabrication**

7.9.1 The edges of plates, openings and fittings exposed during fabrication shall be inspected carefully to make sure that any defects have been uncovered, as well as to determine that the work has been performed properly.

7.9.2 Minor defects found may be repaired only after the inspector approves the method and extent of repairs. Materials that have more than minor defects that cannot be satisfactorily repaired shall be rejected.

7.10 **Surface Inspection of Component Parts**

Before assembly, all sidewall plates or sections and roof and bottom plates shall be inspected for thickness, freedom from injurious defects, and soundness of any welded joints.

7.11 **Check of Dimensions of Component Parts**

All formed plates and curved sections shall be checked for conformance with the planned dimensions and cross section. For unusual repairs the inspector should keep a record of measurements taken at sufficient intervals to constitute a satisfactory record.

7.12 **Check of Chemical and Physical Property Data**

The Inspector shall check the material being assembled by the lists of the plates from the mill, their heat numbers, chemical analyses, and mechanical properties as given on mill reports and shall see that copies are available to be attached to the Manufacturer’s report (see 8.3).

7.13 **Data Required from Manufacturer on Completed Tanks**

If specified in the purchase order, the Manufacturer shall supply marked copies of plans (or a separate sketch) showing the location of all plates, with a means of identifying each plate with the heat numbers. These markings shall be checked by the inspector. A copy shall be attached to the Manufacturer’s report.

7.14 **Check of Stress-relieving Operation**

The inspector shall check any thermal stress-relieving operation and shall be satisfied that the temperature readings are accurate and that the procedure conforms to the applicable requirements of these rules.
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.

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 $\frac{3}{32}$ 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:

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 Examination 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 examination requirements for work covered by this document. The specific requirements as listed in Sections 1 through 9, and Appendices Q, R, S, and X 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 examined 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 examination 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 examined 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 (½ 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 examination 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
7.18.2.5 Tanks with anchors shall be grouted (if required by design) and anchor retainers shall be attached.

7.18.2.6 After all the welding has been examined and tested and all defective welding disclosed by such examination and testing has been repaired and retested, the tank shall be filled with air to a pressure of 2 lbf/in.² gauge or one-half the pressure \( P_g \) for which the vapor space at the top of the tank is designed, whichever pressure is smaller. A solution film shall be applied to all joints in the tank wall above the high liquid (capacity) design level. If any leaks appear, the defects shall be removed and rewelded, and the applicable preliminary tightness tests specified shall be repeated. When anchors are not provided near the boundary of contact to hold down a dished tank bottom resting directly on the tank grade, the bottom at this boundary may be rise slightly off the foundation during the tightness test when air pressure is in the tank. In this case, sand shall be tamped firmly under the bottom to fill the gap formed while the tank is under pressure (see 7.18.8).

7.18.3 Combination Hydrostatic-pneumatic Tests

7.18.3.1 Tanks that have not been designed to be filled with liquid to a test level higher than their specified capacity level (see 5.3.1.2) shall be subjected to combination hydrostatic-pneumatic pressure tests in accordance with the procedure described in 7.18.3.2 through 7.18.3.5.

7.18.3.2 After the preliminary tightness tests specified in 7.18.4 have been completed, the pressure-vacuum relief valve or valves shall be blinded off. With the top vented to the atmosphere to prevent accumulation of pressure, the tank shall be filled with water to its high liquid (capacity) design level (see 7.18.7). Tank anchor retainers shall be adjusted to a uniform tightness after the tank is filled with water. If the pressure-vacuum valve or valves are not available at the time of the test, the tank connections may be blinded off and the test procedure continued by agreement between the Purchaser and the Manufacturer. With the vents at the top of the tank closed, air shall be injected slowly into the top of the tank until the pressure in the vapor space is about one-half the pressure \( P_g \), for which this space is designed. The air pressure shall be increased slowly until the pressure in the vapor space is 1.25 times the pressure, \( P_g \), for which the space is designed.

7.18.3.3 An air test introduces some hazard. In view of the large amount of air that will be present in the tank during this test, no one should be permitted to go near the tank while pressure is being applied for the first time during this test. While the pressure in the tank exceeds the pressure for which the vapor space is designed, the inspections should be made at a reasonable distance from the tank using field glasses as required for close-up observation of particular areas.

7.18.3.4 As the pressure is being increased, the tank shall be inspected for signs of distress. The maximum test pressure of 1.25 times the vapor space design pressure shall be held for at least one hour, after which the pressure shall be released slowly and the blinds shall be removed from the pressure-vacuum relief valves. The operation of the relief valves shall then be checked by injecting air into the top of the tank until the pressure in the vapor space equals the pressure, \( P_g \), for which this space is designed, at which time the relief valves shall start to release air.

7.18.3.5 While this latter pressure is held, a solution film shall be applied to all of the welding involved above the high liquid (capacity) design level for which the tank is designed. A prior vacuum box check may be substituted for the close visual with solution-film examination. The solution-film examination shall still be made, above the liquid level, on all welds around openings, all piping joints, and the compression ring welds to the roof and shell, except the prior vacuum box is permitted for any listed below.

— 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 \( \frac{1}{2} \) of the conical compression ring thickness and greater than two times the adjacent shell ring thickness.

— Full fusion butt-welded connections.
7.18.4 Complete Hydrostatic Tests

7.18.4.1 Tanks that have been designed and constructed to be filled with liquid to the top of the roof (see 5.3.1.2) shall be subjected to full hydrostatic tests in accordance with the procedure prescribed in 7.18.4.2 and 7.18.4.4, in lieu of the procedure specified in 7.18.3.

7.18.4.2 Following the test preliminaries called for in 7.18.2, the pressure-vacuum relief valve or valves shall be blinded off; with the top of the tank vented to the atmosphere, the tank shall be filled with water to the top of the roof (see 7.18.7) while allowing all air to escape to prevent the accumulation of pressure. If the pressure-vacuum relief valve or valves are not available at the time of the test, the tank connections may be blinded off and the test procedure continued by agreement between the Purchaser and the Manufacturer. The vents used during water filling of the tank shall then be closed, and the pressure in the tank shall be increased slowly until the hydrostatic pressure under the topmost point in the roof is 1.25 times the pressure, \( P_g \), which the vapor space is designed to withstand when in operation with the tank filled to its specified high liquid (capacity) level.

7.18.4.3 This test procedure shall be held for at least one hour. The hydrostatic pressure under the topmost point in the roof shall then be reduced to the pressure, \( P_g \), for which the vapor space is designed and shall be held at this level for a sufficient time to permit close visual inspection of all joints in the walls of the tank and all welding around manways, nozzles and other connections.

7.18.4.4 The tank shall then be vented to atmosphere, the water level shall be lowered below the inlets to the pressure-relief valves, and the blinds shall be removed from the relief valves. The operation of the relief valves shall then be checked by injecting air into the top of the tank until the pressure in the vapor space equals the pressure, \( P_g \), for which this space is designed, at which time the relief valves shall start to release air.

7.18.5 Partial-vacuum Tests

7.18.5.1 Following the tests specified in 7.18.3 (or in 7.18.4) where this latter procedure has been used), the pressure in the vapor space of the tank shall be released and a manometer shall be connected to this space. The ability of the upper part of the tank to withstand the partial vacuum for which it is designed and the operation of the vacuum-relief valve or valves on the tank shall then be checked by withdrawing water from the tank, with all vents closed, until the design partial vacuum is developed at the top of the tank and by observing the differential pressure at which the valve or valves start to open. The vacuum-relief valve or valves must be of a size and be set to open at a partial vacuum closer to the external atmospheric pressure than the partial vacuum for which the tank is designed. The partial vacuum in the tank should never exceed the design value (see Appendix K).

7.18.5.2 After completing 7.18.5.1, the withdrawal of water from the tank shall be continued, with the vents closed and without exceeding the specified maximum partial vacuum in the top of the tank, until the level in the tank reaches one-half the high liquid (capacity) level for which the tank is designed. Alternatively, to speed up the withdrawal of water to the degree thought expedient, the vents may either be kept closed and air pressure not exceeding \( P_g \) at the top of the tank applied, or the vents may be opened during most of this interval if in either procedure they are closed long enough before the level in the tank reaches half height for the specified partial vacuum to be developed by the time the level of the water reaches half height\(^{36}\). Air shall then be again injected into the tank until the pressure above the water level equals the pressure, \( P_g \), for which the vapor space at the top of the tank is designed.

7.18.5.3 Careful observation shall be made under all of the specified conditions of loading, as well as with atmospheric pressure above the surface of the water when the level is at half height, to determine whether any appreciable changes occur in the shape of the tank (see 7.18.8). In the case of a vertical tank with cylindrical sidewalls, no tests are required with the water level at half height; in this case, the tests specified in 7.18.5.4 shall be applied immediately after the first vacuum test specified in 7.18.5.

\(^{36}\)These provisions presuppose that an ejector or vacuum pump is not available for drawing a partial vacuum on the tank. However, if such equipment is available, it may be used; vents may be opened during the entire period while the water level is being lowered; and the sequence of the vacuum and pressure test may be reversed if either the tank Manufacturer or the Purchaser so selects.
7.18.5.4 The water remaining in the tank shall then be withdrawn and when the tank is substantially empty, a vacuum test comparable to that specified in 7.18.5.1, except with regard to the level of water in tank, shall be applied to the tank. After this, air shall again be injected into the tank until the pressure in the tank equals the pressure, \( P_g \), for which the vapor space at the top of the tank is designed. Observations shall be made, both with the specified partial vacuum and with the vapor space design pressure above the surface of the water, to determine whether any appreciable changes in the shape of the tank occur under either condition of loading. In the case of a tank whose dished bottom rests directly on the tank grade, if the bottom rises slightly off the foundation during the pressure test, sand shall be tamped firmly under the bottom to fill the gap formed while the tank is under pressure (see 7.18.2.6 and 7.18.8).

7.18.6 Visual Inspection

Upon completion of all the foregoing tests, the pressure in the tank shall be released and a thorough visual inspection shall be made of both the inside and outside of the tank, giving particular attention to all internal ties, braces, trusses, and their attachments to the walls of the tank. Anchors shall be checked for snug tightness and adjusted if required. Anchor threads shall be fouled by peening or tack welding to prevent loosening. In lieu of thread fouling, double nuts may be used.

7.18.7 Rate of Water Filling and Water Temperature

The rate at which water is introduced into a tank for a hydrostatic test shall not exceed 3 ft of depth per hour. The foundation, venting equipment, or other conditions may limit the water filling to a lower rate. Pressure shall not be applied above the surface of the water before the tank and its contents are at about the same temperature. The temperature of the water used in the tests should be not less than 60°F whenever practicable.

7.18.8 Changes in Tank Shape

If in any of the foregoing tests there is an excessive rise of the bottom of the tank around the boundary of contact with grade, or off its foundations, or if any of the specified conditions of test loading cause other appreciable changes in the shape of the tank, the design shall be reviewed and means shall be provided in the tank for holding the shape within permissible limits under all conditions of loading.

7.18.9 Additional Tests

The tests prescribed in 7.18 are believed to be sufficient for most tanks constructed according to these rules; if, in the opinion of the designer, additional tests are needed to investigate the safety of a tank under certain other conditions of loading, as determined from the design computations, these tests shall be made on the tank involved in addition to the tests specified in this standard.

7.18.10 Tanks Subject to Corrosion

In the case of tanks that are subject to corrosion on some or all of their wall plates or on internal ties, braces, or other members that carry pressure-imposed loads, the test specified in 7.18.3 (or the test specified in 7.18.4, if applicable) should be repeated periodically during the lives of the tanks as the metal added for corrosion allowance disappears.

7.19 Proof Tests for Establishing Allowable Working Pressures

7.19.1 General

Because pressures in liquid storage tanks built according to these rules vary quite markedly from the tops to the bottoms of the tanks, proof testing of these tanks presents problems not usually encountered in the construction of unfired pressure vessels—especially where the parts under investigation are located near the bottoms of the tanks. The principal difficulty is devising a test or series of tests that will reliably establish the working pressure that can be permitted on the part of the unproven design without, at the same time, imposing hazardous conditions on other parts located at higher levels in the tank. Another possible complication is that, because of the large volumetric capacities of these tanks, it may not be practicable to completely remove all pressure loading from the part under investigation in order to obtain strain-gauge readings under no-load conditions after successive increments of pressure have been
applied in the test procedure. Also, in the case of tanks designed for storing only gases or vapors, water cannot be used as a testing medium.

7.19.2 Use of Design Rules

The design rules and formulas given in the design section of these rules will be found to cover all of the more common designs of vertical tanks, shapes of openings, and so forth. The absence of a standard proof-test procedure will not greatly affect the usefulness of these rules. Whether a standard proof-test procedure can be devised that will be applicable to all shapes, sizes and types of tanks that might be constructed under these rules is not known, but it is recognized that in special cases a Manufacturer may be able to propose a proof-test procedure that would be satisfactory for a particular tank (see 7.19.3).

7.19.3 Developing Proof Tests

7.19.3.1 Pending development of an approved standard proof-test procedure, whenever a Manufacturer desires to construct a tank that will be marked as specified in 8.1 and embodies any features that should be proof-tested because of the provisions of 5.1.5 and 5.13.5.3 or any other provisions of these rules that call for proof test or strain-gauge surveys, the Manufacturer shall develop specifications for an appropriate proof-test procedure for the tank and obtain approval from the Purchaser or the Purchaser’s agent, preferably before starting fabrication of the tank. Such specifications shall cover all important details of the proposed proof-test procedure, including but not necessarily limited to a description of how the tank would be prepared for the test, how the test loadings would be applied, what medium would be used for the test, the increments in which the loadings would be applied, what kind of data would be taken, how the test results would be interpreted, and the basis upon which allowable working pressures would be established for the part or parts under investigation. In seeking approval of such a test, the Manufacturer shall furnish full information concerning the general construction of the proposed tank, the design and location of the part or parts of uncertain strength, the conditions of loading to which the tank would be subjected in service, and other pertinent matters.

7.19.3.2 In case the Purchaser or the Purchaser’s agent does not approve a special proof-test procedure, the tank in question shall not be marked as specified in 8.1, nor shall a tank be so marked after failing to satisfactorily pass a special proof test that has been so approved, unless the tank is strengthened in a manner acceptable to the inspector and is then retested and satisfactorily passes the second proof test.

7.20 Test Gauges

7.20.1 An indicating gauge shall be connected directly to the topmost part of the roof on the tank under test. In the case of a tank which is designed for the storage of gases or vapors alone and is to be tested only with air, the gauge may be connected to the tank at some lower level. If the indicating gauge is not readily visible to the operator who is controlling the pressure applied, an additional indicating gauge shall be provided where it will be visible to the operator throughout the test. Means shall be provided to ensure that the required test pressure will not be exceeded.

7.20.2 A recording gauge shall also be used on each tank, and a record shall be kept of the pressures during all stages of the tests. This gauge shall be connected either to the piping that leads to the indicating gauge or directly to the tank at a point near the indicating gauge connection.

7.20.3 Indicating gauges used during the tests shall be calibrated against a standard deadweight tester before the tests are started.

7.20.4 If at any time during a test there is reason to believe that a gauge is in error, its calibration shall be checked. If the gauge is in error, it should preferably be adjusted to read correctly, or a calibration curve may be made to indicate the correct pressures for the readings indicated by the gauge.

7.20.5 In all cases in which a gauge is mounted at a level lower than its connection to the tank or lower than some part of the piping that leads to the gauge, suitable precautions shall be taken to prevent accumulation of any static head of condensed moisture (or water from other sources) in the piping leads above the level of the gauge. Not preventing this would result in erroneous readings.


Section 8—Marking

8.1 Nameplates

8.1.1 A tank made in accordance with this standard shall be identified by a nameplate similar to that shown in Figure 8-1. The nameplate shall indicate, by means of letters and numerals not less than 5/32 in. high, the following information:

a) API Standard 620.

b) Applicable appendix.

c) Year completed.

d) Applicable edition and revision number of this publication.

e) Nominal diameter and nominal height, in ft and in.\(^{37}\)

f) Nominal capacity, in barrels of 42 gallons per barrel.\(^{37}\)

g) Design liquid level, in ft and in.\(^{37}\)

h) Design specific gravity of liquid.

i) Maximum test level for hydrostatic test with water, in ft and in.\(^{37}\)

j) Design pressure for gas or vapor space at the top of the tank, in lbf/in.\(^2\) gauge.\(^{37}\)

k) Design metal temperature, in °F.\(^{37}\) Use the lower of the following temperatures:

1) The temperature described in 4.2.1, or

2) The minimum design temperature of product storage given by the Purchaser for refrigerated product tanks.

l) Purchaser’s tank number.

m) Maximum operating temperature, which shall not exceed 250°F.\(^{37}\)

n) The name of the Manufacturer with a serial number or contract number to identify the specific tank.

o) If thermal stress relief is applied to a part in accordance with 5.25 or R.7.3, the nameplate shall be marked “SR,” and the part shall be identified on the Manufacturer’s certificate.

p) The material specification number for each shell course.

8.1.2 On request by the Purchaser or at the discretion of the Manufacturer, additional pertinent information may be shown on the nameplate. The size of the nameplate may be increased accordingly.

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

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

8.1.5 When a tank is fabricated by one organization and erected by another, the names of both organizations shall appear on the nameplate, or separate nameplates shall be applied by each.

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\(^{37}\)Unless other units are specified by the Purchaser.
8.2 Division of Responsibility

Unless otherwise agreed upon, when a tank is fabricated by one organization and erected by another, the erection Manufacturer shall be considered as having the primary responsibility. The Manufacturer shall make certain that the materials used in the fabrication of the components and in the construction of the tank are in accordance with all applicable requirements.

8.3 Manufacturer's Report and Certificate

8.3.1 Upon completion of all tests, examinations, and inspections on each tank, the Manufacturer shall prepare a report summarizing all the data on the tank, including foundations (if they are within the Manufacturer’s scope of responsibility) and shall attach to the report all drawings and charts as required by other paragraphs in this section of the rules (see 7.13 and Appendix M).

8.3.2 The Manufacturer shall furnish and fill out a certificate for each tank (such as that shown in Appendix M), attesting that the tank has been constructed according to the rules in this standard. This certificate shall be signed by the Manufacturer and the Purchaser’s inspector. This certificate, together with the nameplate or markings placed on the tank, shall guarantee that the Manufacturer has complied with all applicable requirements of these rules.

8.3.3 If the Purchaser so requests, the Manufacturer shall attach to the report copies of the records of the qualification test of welding procedures, of welders, and/or of welding operators (see 6.7 and 6.8).

8.4 Multiple Assemblies

In the case of assemblies that consist of two or more tanks or compartments designed and built according to the rules of this standard, each tank or compartment in the assembly shall be marked separately, or the markings may be grouped at one location and arranged so that the data for the separate compartments can be identified. Removable pressure parts shall be marked to identify them with the tank to which they belong.

Figure 8-1—Nameplate
Appendix S
Austenitic Stainless Steel Storage Tanks

S.1 Scope

S.1.1 This appendix covers materials, design, fabrication, erection, and testing requirements for aboveground, welded, austenitic stainless steel storage tanks constructed of material grades 304, 304L, 316, 316L, 317, and 317L. This appendix does not cover stainless steel clad plate or strip lined construction.

S.1.2 This appendix applies only to tanks in non-refrigerated service. For stainless steel tanks in refrigerated service, refer to Appendix Q of this standard. Minimum design metal temperature of the non-refrigerated tanks in the scope of the appendix is not limited. Maximum design metal temperature shall be limited as given in 1.2.2. For the purposes of this appendix, the design temperature shall be the maximum operating temperature as specified by the Purchaser. Ambient temperature tanks (non-heated) shall have a design temperature of 40°C (100°F). It is cautioned that exothermic reactions occurring inside unheated storage tanks can produce temperatures exceeding 40°C (100°F).

S.1.3 The minimum thicknesses in this appendix do not contain any allowance for corrosion.

S.1.4 This appendix states only the requirements that differ from the basic rules in this standard. For requirements not stated, the basic rules must be followed.

S.2 Materials

S.2.1 Selection and Ordering

S.2.1.1 Materials shall be in accordance with Table S-1.

S.2.1.2 Selection of the type/grade of stainless steel depends on the service and environment to which it will be exposed and the effects of fabrication processes. The Purchaser shall specify the type/grade.

S.2.1.3 External structural attachments may be carbon steels meeting the requirements of Section 2 of this standard, providing they are protected from corrosion and the design and details consider the dissimilar properties of the materials used. (This does not include shell, roof, or bottom openings and their reinforcement.) Carbon steel attachments (e.g., clips for scaffolding) shall not be welded directly to any internal surface of the tank.

S.2.2 Packaging

Packaging stainless steel for shipment is important to its corrosion resistance. Precautions to protect the surface of the material depend on the surface finish supplied and may vary among manufacturers. Normal packaging methods may not be sufficient to protect the material from normal shipping damage. If the intended service requires special precautions, special instructions shall be specified by the Purchaser.

S.2.3 Impact Testing

Impact tests are not required for austenitic stainless steel base metals.
Table S-1a—ASTM Materials for Stainless Steel Components (SI Units)

<table>
<thead>
<tr>
<th>Plates and Structural Members (Note 1)</th>
<th>Piping and Tubing Seamless or Welded (Note 2)</th>
<th>Forgings (Notes 2, 3)</th>
<th>Bolting and Bars (Notes 4, 5)</th>
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<td>A182M, Grade F 304</td>
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<td></td>
<td>A312M, Grade TP 317L</td>
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<td>A479M, Type 317</td>
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</table>

Notes:
1. Unless otherwise specified by the Purchaser, plate, sheet, or strip shall be furnished with a No. 1 finish and shall be hot-rolled, annealed, and descaled.
2. Carbon steel flanges and/or stub ends may be used by agreement between the Purchaser and Manufacturer, providing the design and details consider the dissimilar properties of the materials used and are suitable for the intended service.
3. Castings shall not be used unless specified by the Purchaser. If specified, castings shall meet ASTM A351 and shall be inspected in accordance with ASME Section VIII, Division 1, Appendix 7.
4. All bars in contact with the product shall be furnished in the hot-rolled, annealed, and descaled condition.
5. Other bolting materials may be used by agreement between the Purchaser and Manufacturer.

S.3 Design
S.3.1 Operating Temperature

S.3.1.1 The Purchaser shall specify the maximum operating temperature of the tank, not to exceed 120°C (250°F) given in 5.2.

S.3.2 Maximum Tensile Stress

S.3.2.1 The maximum tensile stress shall be in accordance with 5.5.3 except Table S-2 shall be used to determine $S_{ts}$.

S.3.3 Maximum Compressive Stress

S.3.3.1 Allowable compressive stresses shall be in accordance with 5.5.4, except the allowable compressive stress shall be reduced by the ratio material modulus of elasticity at the design temperature to 200,000 Mpa (29,000,000 lbf/in.$^2$) for values $(t – c)/R$ less than 0.0175 and by the ratio of the materials minimum yield strength at the design temperature to 205 Mpa (30,000 lbf/in.$^2$) for values of $(t – c)/R$ equal to or greater than 0.0175.
S.3.4 Maximum Allowable Stress for Structural Members and Bolts

S.3.4.1 The maximum allowable stress values for structural members shall be in accordance with Table 3-3 except the allowable stresses for compression shall be reduced by the ratio of the materials yield strength at the design temperature to 205 Mpa (30,000 lbf/in.²).

S.3.5 Flat Bottoms of Cylindrical Tanks

S.3.5.1 The minimum thickness for bottom plates shall be 5 mm (3/16 in.), exclusive of any corrosion allowance specified by the Purchaser.

S.3.6 Intermediate Wind Girders for Cylindrical Sidewalls

S.3.6.1 The value $H_1$ in 5.10.6.1 shall be reduced by the ratio of the materials modulus of elasticity at the design temperature to 200,000 Mpa (29,000,000 lbf/in.²).

S.3.6.2 The value $W_{tr}$ in 5.10.6.2 shall be reduced by the ratio of the materials modulus of elasticity at the design temperature to 200,000 Mpa (29,000,000 lbf/in.²).

S.3.7 Compression Rings

S.3.7.1 The value of 15,000 in equation (27) in 5.12.4.3 shall be reduced by the ratio of the material yield strength at the design temperature to 205 Mpa (30,000 lbf/in.²).
S.3.8 Flat Cover Plates and Blind Flanges

S.3.8.1 The value $s$ in 5.21 shall be in accordance with Table S-3.

S.3.9 Stress Relieving

S.3.9.1 The stress relieving requirements of 5.25 need not be performed unless specified by the Purchaser.

S.3.10 Flush-type Shell Connection

S.3.10.1 The value $t_b$ in 5.27.4.5 shall be reduced by the ratio of the materials yield stress at the design temperature to 205 Mpa (30,000 lbf/in.$^2$).

S.4 Fabrication

S.4.1 General

Special precautions must be observed to minimize the risk of damage to the corrosion resistance of stainless steel. Stainless steel shall be handled in a manner that minimizes contact with iron or other types of steel during all phases of fabrication, shipping, and construction. The following sections describe the major precautions that shall be observed during fabrication and handling.

S.4.2 Storage

Storage should be under cover and removed from shop dirt, fumes, and pickling operations. If outside storage is necessary, provisions shall be made for rainwater to drain and allow the material to dry. Stainless steel shall not be stored in contact with carbon steel. Materials containing chlorides, including foods, beverages, oils, and greases, shall not come in contact with stainless steel. Inadvertent contamination shall be removed by methods described in S.4.5.

### Table S-2—Maximum Allowable Stress Values for Simple Tension

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Min Yield</th>
<th>Min Tensile</th>
<th>Allowable Stress for Design Temperature Not Exceeding ($S_{ts}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MPa</td>
<td>lbf/in.$^2$</td>
<td>MPa</td>
</tr>
<tr>
<td>304</td>
<td>205</td>
<td>30,000</td>
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<td>515</td>
</tr>
<tr>
<td>317L</td>
<td>205</td>
<td>30,000</td>
<td>515</td>
</tr>
</tbody>
</table>

Notes:
1. $S_{ts}$ may be interpolated between temperatures.
2. The design stress corresponds to the lesser of 0.33 of the minimum tensile strength or 0.75 of the minimum yield strength.
3. For dual certified materials (e.g., ASTM A182M/A182 Type 304L/304), use the allowable stress of the grade specified by the Purchaser.

S.4.3 Thermal Cutting

S.4.3.1 Thermal cutting of stainless steel shall be by the iron powder burning carbon arc or the plasma-arc method.

S.4.3.2 Thermal cutting of stainless steel may leave a heat-affected zone and intergranular carbide precipitates. This heat-affected zone may have reduced corrosion resistance unless removed by machining, grinding, or solution annealing and quenching. The Purchaser shall specify if the heat-affected zone is to be removed.
S.4.4 Forming

S.4.4.1 Stainless steels shall be formed by a cold, warm, or hot forming procedure that is non-injurious to the material.

S.4.4.2 Stainless steels may be cold formed, providing the maximum strain produced by such forming does not exceed 10% and control of forming spring-back is provided in the forming procedure.

S.4.4.3 Warm forming at 540°C (1000°F) to 650°C (1200°F) may cause intergranular carbide precipitation in 304, 316, and 317 grades of stainless steel. Unless stainless steel in this sensitized condition is acceptable for the service of the equipment, it will be necessary to use 304L, 316L, or 317L grades or to solution anneal and quench after forming. Warm forming shall be performed only with agreement of the Purchaser.

S.4.4.4 Hot forming, if required, may be performed within a temperature range of 900°C (1650°F) to 1200°C (2200°F).
S.4.4.5  Forming at temperatures between 650°C (1200°F) and 900°C (1650°F) is not permitted.

S.4.5  Cleaning

S.4.5.1  When the Purchaser requires cleaning to remove surface contaminants that may impair the normal corrosion resistance, it shall be done in accordance with ASTM A380, unless otherwise specified. Any additional cleanliness requirements for the intended service shall be specified by the Purchaser.

S.4.5.2  When welding is completed, flux residues and weld spatter shall be removed mechanically using stainless steel tools.

S.4.5.3  Removal of excess weld metal, if required, shall be done with a grinding wheel or belt that has not been previously used on other metals.

S.4.5.4  Chemical cleaners used shall not have a detrimental effect on the stainless steel and welded joints and shall be disposed of in accordance with laws and regulations governing the disposal of such chemicals. The use of chemical cleaners shall always be followed by thorough rinsing with water and drying (see S.4.9).

S.4.6  Blast Cleaning

If blast cleaning is necessary, it shall be done with sharp acicular grains of sand or grit containing not more than 2% by weight iron as free iron or iron oxide. Steel shot or sand used previously to clean nonstainless steel is not permitted.

S.4.7  Pickling

If pickling of a sensitized stainless steel is necessary, an acid mixture of nitric and hydrofluoric acids shall not be used. After pickling, the stainless steel shall be thoroughly rinsed with water and dried.

S.4.8  Passivation or Iron Freeing

When passivation or iron freeing is specified by the Purchaser, it may be achieved by treatment with nitric or citric acid. The use of hydrofluoric acid mixtures for passivation purposes is prohibited for sensitized stainless.

S.4.9  Rinsing

S.4.9.1  When cleaning and pickling or passivation is required, these operations shall be followed immediately by rinsing, not allowing the surfaces to dry between operations.

S.4.9.2  Rinse water shall be potable and shall not contain more than 200 parts per million chloride at temperatures below 40°C (100°F), or no more than 100 parts per million chloride at temperatures above 40°C (100°F) and below 65°C (150°F), unless specified otherwise by the Purchaser.

S.4.9.3  Following final rinsing, the material shall be completely dried.

S.4.10  Welding

S.4.10.1  Welding shall be by any of the processes permitted in 6.6.2. Galvanized components or components with zinc-bearing coatings shall not be welded to austenitic stainless steel.

S.4.10.2  Filler metal chemistry shall match the type of base metals joined. Dissimilar welds to carbon steels shall use filler metals of E 309 or higher alloy content.
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 $\frac{1}{16}$ in. of each other with the maximum plate thickness being $\frac{1}{2}$ 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.

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 Examination

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

Ultrasonic Examination in Lieu of Radiography

U.1 Purpose and Scope

This appendix provides detailed rules for the use of the ultrasonic examination (UT) method for the examination of tank seams as permitted by 5.26, R.7.6, and Q.7.6. This alternative is limited to joints where the thickness of the thinner of the two members joined is greater than or equal to 10 mm (3/8 in.).

U.2 Definitions

U.2.1 documenting: Preparation of text and/or and figures.

U.2.2 evaluation: All activities required in U.6.3 through U.6.6 to determine the acceptability of a flaw.

U.2.3 flaw: A reflector that is not geometric or metallurgical in origin that may be detectable by nondestructive testing but is not necessarily rejectable.

U.2.4 flaw categorization: Whether a flaw is a surface flaw or is a subsurface flaw (see U.6.4). Note that a flaw need not be surface breaking to be categorized as a surface flaw.

U.2.5 flaw characterization: The process of quantifying the size, location, and shape of a flaw. See U.6.3 for size and location. The only shape characterization required by this appendix is applied to the results of supplemental surface examination by MT or PT (see U.6.6.2).

U.2.6 indication: That which marks or denotes the presence of a reflector.

U.2.7 interpretation: The determination of whether an indication is relevant or nonrelevant, i.e., whether it originates from a geometric or metallurgical feature or conversely originates from a flaw (see U.6.2).

U.2.8 investigation: Activities required to determine the interpretation of an indication (see U.6.1 and U.6.2).

U.2.9 recording: The writing of ultrasonic data onto an appropriate electronic medium.

U.2.10 reflector: An interface at which an ultrasonic beam encounters a change in acoustic impedance and at which at least part of the energy is reflected.

U.3 Technique

U.3.1 The ultrasonic examination volume shall include the weld metal, plus the lesser of 25 mm (1 in.) or\( t \) of adjoining base metal on each side of the weld unless otherwise agreed upon by the Purchaser and the Manufacturer.

U.3.2 Ultrasonic examination for the detection of flaws shall be performed using automated, computer-based data acquisition except that scanning of adjacent base metal for flaws that can interfere with the examination may be performed manually. Ultrasonic examination for sizing of flaws shall be performed as described in U.6.3.1.

U.3.3 A documented examination strategy or scan plan shall be provided showing transducer placement, movement, and component coverage that provides a standardized and repeatable methodology for weld acceptance. The scan plan shall also include ultrasonic beam angle to be used, beam directions with respect to weld centerline, and tank material volume examined for each weld. The documentation shall be made available to the Owner upon request.
U.3.4 Data from the examination volume, per U.3.1, shall be recorded and/or documented as follows:

a) For automated computer-based scans, data shall be recorded using the same system essential variables, specified value or range of values, used for the demonstration of the procedure per U.4.3 below.

b) For manual scans, results shall be documented in a written report.

U.3.5 The ultrasonic examination shall be performed in accordance with a written procedure which has been reviewed and approved by the Purchaser and conforms to the requirements of Section V, Article 4, except that:

a) The calibration block shown in Figure T-434.2.1 of Section V, Article 4 shall be used, and;

b) For examination techniques that provide plate quality information (e.g., time of flight diffraction), the initial base material straight-beam examination need not be performed.

U.3.6 The examination methodology (including U.6.6) shall be demonstrated to be effective over the full weld volume. It is recognized that time of flight diffraction (TOFD) may have limitations in detection of flaws at the surface such that it may be necessary to supplement TOFD with pulse-echo techniques suitable for the detection of near-field and far-field flaws. The variety of surface and sub-surface category flaws in the test plate mandated by U.4.3.a are intended to ensure that any such limitations are adequately addressed.

U.3.7 It is recognized that in the ultrasonic examination of joints with austenitic weld metals, initial screening for defects may be done by methods that determine flaw lengths but give only limited information on flaw height. In these cases a length and upper bound height acceptance criteria is applied (see Table U-2).

U.4 Personnel Qualifications and Training

U.4.1 Personnel Qualifications

Personnel performing and evaluating UT examinations shall be qualified and certified in accordance with their employer's written practice. ASNT SNT-TC-IA or CP-189 shall be used as a guideline. Only Level II or III personnel shall perform UT examinations, analyze the data, or interpret the results.

U.4.2 Qualification Records

Qualification records of certified personnel shall be approved by the Manufacturer and maintained by their employer.

U.4.3 Personnel Testing

Personnel who acquire and analyze UT data shall be trained using the equipment of U.3.2, and the procedure of U.3.5 above. Additionally, they shall pass a practical examination based on the technique on a blind test plate. The testing program details shall be by agreement between the Purchaser and the inspection company, but shall in any case include the following elements as a minimum:

a) The test plate shall contain a variety of surface and sub-surface category flaws including multiple flaws described in section U.6.5. Some of the flaws shall be acceptable and others unacceptable per the applicable criteria of Tables U-1 or U-2.

b) The practical examination should cover detection, interpretation, sizing, plotting, categorization, grouping, and characterization that is sufficient to cover the cases outlined in U.6.
Appendix X

Duplex Stainless Steel Storage Tanks

X.1 Scope

X.1.1 This appendix covers materials, design, fabrication, erection, and testing requirements for aboveground, welded, duplex stainless steel storage tanks constructed of material grades 2205 (UNS S31803), 2003 (UNS S32003), 2101 (UNS S32101), 2205 (UNS S32205), 2304 (UNS S32304), 255 (UNS S32550), 255+ (UNS S32520), 2507 (UNS S32750), and Z100 (UNS S32760). This appendix does not cover stainless steel clad plate or strip lined construction.

X.1.2 This appendix applies only to tanks in non-refrigerated services with a maximum design temperature limited as given in 1.2.2 and a minimum design metal temperature equal to or higher than –40 °C (–40 °F). Ambient temperature tanks (non-heated) shall have a design temperature of 40 °C (100 °F). It is cautioned that exothermic reactions occurring inside unheated storage tanks can produce temperatures exceeding 40 °C (100 °F). For the purposes of this appendix, the design temperature shall be the maximum operating temperature as specified by the Purchaser.

X.1.3 The minimum thicknesses in this appendix do not contain any allowance for corrosion.

X.1.4 This appendix states only the requirements that differ from the basic rules in this standard. For requirements not stated, the basic rules must be followed.

X.2 Materials

X.2.1 Selection and Ordering

X.2.1.1 Materials shall be in accordance with Table X-1.

<table>
<thead>
<tr>
<th>Table X-1—ASTM Materials for Duplex Stainless Steel Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Plates &amp; Structural Members</td>
</tr>
<tr>
<td>A240</td>
</tr>
<tr>
<td>A276</td>
</tr>
<tr>
<td>Tube or Pipe Seamless &amp; Welded</td>
</tr>
<tr>
<td>A789</td>
</tr>
<tr>
<td>A790</td>
</tr>
<tr>
<td>A928</td>
</tr>
<tr>
<td>forgings &amp; Fittings</td>
</tr>
<tr>
<td>A182</td>
</tr>
<tr>
<td>A815</td>
</tr>
<tr>
<td>Bolting and Bars</td>
</tr>
<tr>
<td>A479</td>
</tr>
</tbody>
</table>

Notes:
1. Unless otherwise specified by the Purchaser, plate, sheet, or strip shall be furnished with a No. 1 finish and shall be hot-rolled, annealed, and descaled.
2. Carbon steel flanges and/or stub ends may be used by agreement between the Purchaser and Manufacturer, providing the design and details consider the dissimilar properties of the materials used and are suitable for the intended service.
3. Castings shall not be used unless specified by the Purchaser. If specified, castings shall meet ASTM A890 and shall be inspected in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 7.
4. All bars in contact with the product shall be furnished in the hot-rolled, annealed, and descaled condition.
5. Other bolting materials may be used by agreement between the Purchaser and Manufacturer.
X.2.1.2 Specification of the type/grade of duplex stainless steel depends on the service and environment to which it will be exposed and the effects of fabrication processes. The Purchaser shall select the type/grade.

X.2.1.3 External structural attachments may be carbon steels meeting the requirements of Section 4 of this standard, providing any permanent attachments are protected from corrosion. (This does not include shell, roof, or bottom openings and their reinforcement.) Carbon steel attachments (e.g., clips for scaffolding) shall not be welded directly to any internal surface of the tank.

X.2.2 Packaging

Packaging duplex stainless steel for shipment is important to maintain its corrosion resistance. Precautions to protect the surface of the material depend on the surface finish supplied and may vary among manufacturers. Standard packaging methods may not be sufficient to protect the material from normal shipping damage. If the intended service requires special precautions, the Purchaser shall specify special instructions.

X.2.3 Qualification Testing

X.2.3.1 Tests for detecting detrimental intermetallic phases for ASTM A923 are required from one plate per heat treat lot as follows:

- UNS S32205/S31803 Methods B & C**
- UNS S32304 Method B*
- UNS S32101 Method B*
- UNS S32003 Method B*
- UNS S32750 Method B* & C**
- UNS S32550/S32520 Method B* & C**
- UNS S32760 Method B* & C**

*B test values to be agreed upon between Purchaser and manufacturer but not less than 54 J (40 ft-lbf).

**C test values to be agreed upon between Purchaser and manufacturer.

X.2.3.2 Charpy Impact testing per ASME UHA-51 at minimum design metal temperature is required for shell plates, shell reinforcing plates, shell insert plates, bottom plates welded to the shell, plates used for manhole and nozzle necks, plate-ring shell-nozzle flanges, blind flanges, and manhole cover plates:

a) in all thicknesses, when the minimum design temperature is between –29 °C and –40 °C (–20 °F and –40 °F), and

b) for those that have thickness greater than 10 mm (3/8 in.) for all temperatures.

ASTM A923 Practice B test results may be used to fulfill these requirements provided the lateral expansion is measured and reported.

X.3 Design

X.3.1 Operating Temperature

X.3.1.1 The Purchaser shall specify the maximum operating temperature of the tank, not to exceed 120 °C (250 °F) given in 5.2.
X.3.2 Maximum Tensile Stress

X.3.2.1 The maximum tensile stress shall be in accordance with 5.5.3, except Table X-2 shall be used to determine \( S_{ts} \).

X.3.3 Maximum Compressive Stress

X.3.3.1 Allowable compressive stresses shall be in accordance with 5.5.4, except the allowable compressive stress shall be modified by the ratio of the material’s modulus of elasticity at the design temperature to 200,000 MPa (29,000,000 lbf/in.\(^2\)) for values \((t – c)/R\) less than 0.0175 and by the ratio of the material’s minimum yield strength at the design temperature to 205 MPa (30,000 lbf/in.\(^2\)) for values \((t – c)/R\) equal to or greater than 0.0175.

X.3.4 Maximum Allowable Stress for Structural Members and Bolts

X.3.4.1 The maximum allowable stress values for structural members shall be in accordance with Table 5-3 except the allowable stresses for compression shall be modified by the ratio of the material’s yield strength at design temperature to 205 MPa (30,000 lbf/in.\(^2\)).

X.3.5 Flat Bottoms of Cylindrical Tanks

X.3.5.1 The minimum thickness for bottom plates shall be 5 mm (\(3/16\) in.), exclusive of any corrosion allowance specified by the Purchaser.

X.3.6 Intermediate Wind Girders for Cylindrical Sidewalls

X.3.6.1 The value \( H/1 \) in 5.10.6.1 shall be modified by the ratio of the material’s modulus of elasticity at the design temperature to 200,000 MPa (29,000,000 lbf/in.\(^2\)).

X.3.6.2 The value \( W^{tr} \) in 5.10.6.2 shall be modified by the ratio of the material’s modulus of elasticity at the design temperature to 200,000 MPa (29,000,000 lbf/in.\(^2\)).

X.3.7 Compression Rings

X.3.7.1 The value of 15,000 in equation (27) in 5.12.4.3 shall be modified by the ratio of the material’s yield strength at the design temperature to 205 MPa (30,000 lbf/in.\(^2\)).

X.3.8 Flat Cover Plates and Blind Flanges

X.3.8.1 The value \( s \) in 5.21 shall be in accordance with Table X-2.

X.3.9 Stress Relieving

X.3.9.1 The stress relieving requirements of 5.25 shall not be performed unless specified by the Purchaser.

X.3.10 Flush-type Shell Connection

X.3.10.1 The value \( th \) in 5.27.4.5 shall be modified by the ratio of the material’s yield stress at the design temperature to 205 MPa (30,000 lbf/in.\(^2\)).
### Table X-2a—Allowable Stresses for Tank Shells (SI)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Min Yld</th>
<th>Min Ten</th>
<th>Allowable Stress MPa for Design Temp Not Exceeding (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MPa</td>
<td>MPa</td>
<td>40 °C</td>
</tr>
<tr>
<td>S31803</td>
<td>450</td>
<td>620</td>
<td>186</td>
</tr>
<tr>
<td>S32003</td>
<td>450</td>
<td>655</td>
<td>197</td>
</tr>
<tr>
<td>S32101</td>
<td>450</td>
<td>650</td>
<td>194</td>
</tr>
<tr>
<td>S32205</td>
<td>450</td>
<td>655</td>
<td>197</td>
</tr>
<tr>
<td>S32304</td>
<td>400</td>
<td>600</td>
<td>180</td>
</tr>
<tr>
<td>S32550</td>
<td>550</td>
<td>760</td>
<td>228</td>
</tr>
<tr>
<td>S32520</td>
<td>550</td>
<td>770</td>
<td>232</td>
</tr>
<tr>
<td>S32750</td>
<td>550</td>
<td>795</td>
<td>240</td>
</tr>
<tr>
<td>S32760</td>
<td>550</td>
<td>750</td>
<td>223</td>
</tr>
</tbody>
</table>

**Notes**
1. Sts may be interpolated between temperatures.
2. The design stress shall be the lesser of 0.3 of the minimum tensile strength or 0.6 of the minimum yield strength.
3. For dual certified materials, S31803/S32205 and S32550/S32520, use the allowable stress of the grade specified by the Purchaser.
4. The hydrotest stress allowable shall be as shown in 5.5.7.

### Table X-2b—Allowable Stresses for Tank Shells (USC)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Min Yld</th>
<th>Min Ten</th>
<th>Allowable Stress lbf/in.² for Design Temp Not Exceeding (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbf/in.²</td>
<td>lbf/in.²</td>
<td>100 °F</td>
</tr>
<tr>
<td>S31803</td>
<td>65,000</td>
<td>90,000</td>
<td>27,000</td>
</tr>
<tr>
<td>S32003</td>
<td>65,000</td>
<td>95,000</td>
<td>28,500</td>
</tr>
<tr>
<td>S32101</td>
<td>65,000</td>
<td>94,000</td>
<td>28,200</td>
</tr>
<tr>
<td>S32205</td>
<td>65,000</td>
<td>95,000</td>
<td>28,500</td>
</tr>
<tr>
<td>S32304</td>
<td>58,000</td>
<td>87,000</td>
<td>26,100</td>
</tr>
<tr>
<td>S32550</td>
<td>80,000</td>
<td>110,000</td>
<td>33,000</td>
</tr>
<tr>
<td>S32520</td>
<td>80,000</td>
<td>112,000</td>
<td>33,600</td>
</tr>
<tr>
<td>S32750</td>
<td>80,000</td>
<td>116,000</td>
<td>34,800</td>
</tr>
<tr>
<td>S32760</td>
<td>80,000</td>
<td>108,000</td>
<td>32,400</td>
</tr>
</tbody>
</table>

**Notes**
1. Sts may be interpolated between temperatures.
2. The design stress shall be the lesser of 0.3 of the minimum tensile strength or 0.6 of the minimum yield strength.
3. For dual certified materials, S31803/S32205 and S32550/S32520, use the allowable stress of the grade specified by the Purchaser.
4. The hydrotest stress allowable shall be as shown in 5.5.7.
### Table X-3a—Yield Strength Values (SI)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>40 °C</th>
<th>90 °C</th>
<th>120 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>S31803</td>
<td>450</td>
<td>396</td>
<td>383</td>
</tr>
<tr>
<td>S32003</td>
<td>450</td>
<td>386</td>
<td>369</td>
</tr>
<tr>
<td>S32101</td>
<td>450</td>
<td>379</td>
<td>365</td>
</tr>
<tr>
<td>S32205</td>
<td>450</td>
<td>358</td>
<td>348</td>
</tr>
<tr>
<td>S32304</td>
<td>400</td>
<td>343</td>
<td>331</td>
</tr>
<tr>
<td>S32550</td>
<td>550</td>
<td>484</td>
<td>464</td>
</tr>
<tr>
<td>S32520</td>
<td>550</td>
<td>448</td>
<td>434</td>
</tr>
<tr>
<td>S32750</td>
<td>550</td>
<td>486</td>
<td>466</td>
</tr>
<tr>
<td>S32760</td>
<td>550</td>
<td>455</td>
<td>441</td>
</tr>
</tbody>
</table>

Notes
1. Interpolate between temperatures.
2. Reference: Table Y-1 of ASME Section II, Part D, or manufacturer’s data sheets.

### Table X-3b—Yield Strength Values (USC)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>100 °F</th>
<th>200 °F</th>
<th>250 °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>S31803</td>
<td>65,000</td>
<td>57,500</td>
<td>55,600</td>
</tr>
<tr>
<td>S32003</td>
<td>65,000</td>
<td>56,000</td>
<td>53,500</td>
</tr>
<tr>
<td>S32101</td>
<td>65,000</td>
<td>55,000</td>
<td>53,000</td>
</tr>
<tr>
<td>S32205</td>
<td>65,000</td>
<td>52,000</td>
<td>50,500</td>
</tr>
<tr>
<td>S32304</td>
<td>58,000</td>
<td>49,800</td>
<td>48,050</td>
</tr>
<tr>
<td>S32550</td>
<td>80,000</td>
<td>70,200</td>
<td>67,250</td>
</tr>
<tr>
<td>S32520</td>
<td>80,000</td>
<td>65,000</td>
<td>63,000</td>
</tr>
<tr>
<td>S32750</td>
<td>80,000</td>
<td>70,500</td>
<td>67,600</td>
</tr>
<tr>
<td>S32760</td>
<td>80,000</td>
<td>66,000</td>
<td>64,000</td>
</tr>
</tbody>
</table>

Notes
1. Interpolate between temperatures.
2. Reference: Table Y-1 of ASME Section II, Part D, or manufacturer’s data sheets.
## Table X-4a—Modulus of Elasticity at the Maximum Operating Temperature (SI)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Modulus of Elasticity in MPa for Design Temp Not Exceeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 °C</td>
</tr>
<tr>
<td>S31803</td>
<td>198,000</td>
</tr>
<tr>
<td>S32003</td>
<td>209,000</td>
</tr>
<tr>
<td>S32101</td>
<td>198,000</td>
</tr>
<tr>
<td>S32205</td>
<td>198,000</td>
</tr>
<tr>
<td>S32304</td>
<td>198,000</td>
</tr>
<tr>
<td>S32550</td>
<td>209,000</td>
</tr>
<tr>
<td>S32520</td>
<td>209,000</td>
</tr>
<tr>
<td>S32750</td>
<td>202,000</td>
</tr>
<tr>
<td>S32760</td>
<td>199,000</td>
</tr>
</tbody>
</table>

**Note**
1. Interpolate between temperatures.

## Table X-4b—Modulus of Elasticity at the Maximum Operating Temperature (USC)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Modulus of Elasticity in lbf/in.² for Design Temp Not Exceeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 °F</td>
</tr>
<tr>
<td>S31803</td>
<td>28,700,000</td>
</tr>
<tr>
<td>S32003</td>
<td>30,300,000</td>
</tr>
<tr>
<td>S32101</td>
<td>28,700,000</td>
</tr>
<tr>
<td>S32205</td>
<td>28,700,000</td>
</tr>
<tr>
<td>S32304</td>
<td>28,700,000</td>
</tr>
<tr>
<td>S32550</td>
<td>30,300,000</td>
</tr>
<tr>
<td>S32520</td>
<td>30,300,000</td>
</tr>
<tr>
<td>S32750</td>
<td>29,300,000</td>
</tr>
<tr>
<td>S32760</td>
<td>28,800,000</td>
</tr>
</tbody>
</table>

**Note**
1. Interpolate between temperatures.
X.4 Fabrication

X.4.1 General

Special precautions must be observed to minimize the risk of loss of the corrosion resistance and toughness of duplex stainless steel. Duplex stainless steel shall be handled so as to minimize contact with free iron or other types of carbon steels during all phases of fabrication, shipping and construction. The thermal history of the material must also be controlled. The following sections describe the major precautions that shall be observed during handling.

X.4.2 Storage

Storage shall be under cover and well removed from shop dirt and fumes from pickling operations. If outside storage is necessary, provisions shall be made for rainwater to drain and allow the material to dry. Duplex stainless steel shall not be stored in contact with carbon steel. Materials containing chlorides, including foods, beverages, oils, cleaners, and greases, shall not come in contact with duplex stainless steel. Inadvertent contamination shall be removed by methods described in X.4.5.

X.4.3 Thermal Cutting

X.4.3.1 Thermal cutting of duplex stainless steel shall be by the plasma-arc method or by laser cutting.

• X.4.3.2 Thermal cutting of duplex stainless steel may leave a heat-affected zone with intermetallic precipitates. This heat-affected zone may have reduced corrosion resistance and toughness unless removed by machining or grinding. Normally the HAZ from thermal cutting is thin enough to be removed by edge preparation machining and adjacent base metal melting during welding. The Purchaser shall specify if the heat-affected zone is to be removed.

X.4.4 Forming

X.4.4.1 Duplex stainless steels shall be formed by a cold or hot forming procedure that is not injurious to the material.

X.4.4.2 Duplex stainless steels may be cold formed. The maximum strain produced by such cold forming shall not exceed 10% and control of forming spring-back shall be provided in the forming procedure.

X.4.4.3 Hot forming, shall be performed within a temperature range shown in Table X-5.

X.4.4.4 The minimum soaking temperature shall be achieved before commencing any hot forming.

X.4.4.5 Forming at temperatures between 315°C (600°F) and the minimum temperature shown in Table X-5 is not permitted.

X.4.4.6 Following hot forming an anneal and water quench shall be performed.

X.4.5 Cleaning

• X.4.5.1 When the Purchaser requires cleaning to remove surface contaminants that may impair the normal corrosion resistance, it shall be done in accordance with ASTM A380, unless otherwise specified. The Purchaser shall specify any additional cleanliness requirements for the intended service.

X.4.5.2 When welding is completed, flux residues and weld spatter shall be removed mechanically using stainless steel tools.
X.4.5.3 Removal of excess weld metal, if required by Purchaser, shall be done with a grinding wheel or belt that has not been previously used on other metals.

X.4.5.4 Removal of weld heat tint, if required by Purchaser, shall be done using an appropriate pickling product and pickling procedure.

X.4.5.5 Chemical cleaners and pickling solutions used shall not have a detrimental effect on the duplex stainless steel or welded joints and shall be disposed of in accordance with laws and regulations governing the disposal of such chemicals. Thorough rinsing with water and drying shall always follow the use of any chemical cleaners or pickling solutions (see X.4.9).

Table X-5a—Minimum and Maximum Hot Forming Temperatures and Minimum Soaking Temperature (SI)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>°C Max</th>
<th>°C Min</th>
<th>°C Min Soaking Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>S31803</td>
<td>1230</td>
<td>950</td>
<td>1040</td>
</tr>
<tr>
<td>S32003</td>
<td>1100</td>
<td>950</td>
<td>1010</td>
</tr>
<tr>
<td>S32101</td>
<td>1100</td>
<td>900</td>
<td>980</td>
</tr>
<tr>
<td>S32205</td>
<td>1230</td>
<td>950</td>
<td>1040</td>
</tr>
<tr>
<td>S32304</td>
<td>1100</td>
<td>950</td>
<td>980</td>
</tr>
<tr>
<td>S32550</td>
<td>1230</td>
<td>1000</td>
<td>1080</td>
</tr>
<tr>
<td>S32520</td>
<td>1230</td>
<td>1000</td>
<td>1080</td>
</tr>
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<td>S32750</td>
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<td>1050</td>
</tr>
<tr>
<td>S32760</td>
<td>1230</td>
<td>1000</td>
<td>1100</td>
</tr>
</tbody>
</table>

Table X-5b—Minimum and Maximum Hot Forming Temperatures and Minimum Soaking Temperature (USC)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>°F Max</th>
<th>°F Min</th>
<th>°F Min Soaking Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>S31803</td>
<td>2250</td>
<td>1740</td>
<td>1900</td>
</tr>
<tr>
<td>S32003</td>
<td>2010</td>
<td>1740</td>
<td>1850</td>
</tr>
<tr>
<td>S32101</td>
<td>2010</td>
<td>1650</td>
<td>1800</td>
</tr>
<tr>
<td>S32205</td>
<td>2250</td>
<td>1740</td>
<td>1900</td>
</tr>
<tr>
<td>S32304</td>
<td>2010</td>
<td>1740</td>
<td>1800</td>
</tr>
<tr>
<td>S32550</td>
<td>2250</td>
<td>1830</td>
<td>1975</td>
</tr>
<tr>
<td>S32520</td>
<td>2250</td>
<td>1830</td>
<td>1975</td>
</tr>
<tr>
<td>S32750</td>
<td>2250</td>
<td>1875</td>
<td>1920</td>
</tr>
<tr>
<td>S32760</td>
<td>2250</td>
<td>1830</td>
<td>2010</td>
</tr>
</tbody>
</table>
X.4.6 Blast Cleaning

If blast cleaning is necessary, it shall be done with sharp acicular grains of sand or grit containing not more than 1% by weight iron as free iron or iron oxide. Steel shot or sand previously used to clean non stainless steel materials is not permitted.

X.4.7 Pickling

If pickling of a duplex stainless steel is necessary, an acid mixture of nitric and hydrofluoric acids shall be used. After pickling, the duplex stainless steel shall be thoroughly rinsed with water and dried.

X.4.8 Passivation or Surface Iron Removal

When the Purchaser specifies passivation or surface iron removal, cleaning shall be achieved by treatment with nitric or citric acid. Nitric hydrofluoric acid shall be used to remove embedded iron.

X.4.9 Rinsing

X.4.9.1 When cleaning, pickling or passivation is required, these operations shall be followed immediately by rinsing, not allowing the surfaces to dry between operations. Manufacturer’s instructions will require a neutralization treatment before rinsing for some pickling products.

X.4.9.2 Rinse water shall be potable and shall not contain more than 200 parts per million chloride at temperatures below 40 °C (100 °F), or no more than 100 parts per million chloride at temperatures above 40 °C (100 °F) and below 65 °C (150 °F).

X.4.9.3 Following final rinsing, the equipment shall be completely dried.

X.4.10 Welding

X.4.10.1 Welding shall be by any of the processes permitted in 6.6.2. Galvanized components or components with zinc-bearing coatings shall not be welded to duplex stainless steel.

X.4.10.2 Filler metal chemistry shall be as specified by the Purchaser. Proper filler metal selection may be discussed with the materials manufacturer. Dissimilar welds to carbon steels shall use filler metals of E309L or higher alloy content.

X.4.11 Welding Procedure and Welder Qualifications

X.4.11.1 Welding Procedure and Welder Qualification requirements shall be as specified in Section 6.7 and 6.8. In addition, procedures shall meet the requirements of ASTM A923 Method B and when specified by Purchaser also Method C. Welding Procedure Qualification Records shall document the results of tests required both by Section 6.7 and by ASTM A923.

X.4.11.2 For any material that has not been assigned a P-number in Table QW-422 of Section IX of the ASME code the Welding Procedure and the Welder Qualification shall be developed for that specific material.

X.4.12 Postweld Heat Treatment

Post weld heat treatment of duplex stainless steel materials shall not be performed.
X.5 Inspection and Testing

X.5.1 Inspection of Welds

X.5.1.1 Radiographic Inspection of Butt-Welds

X.5.1.1.1 Radiographic examination of butt-welds shall be in accordance with 7.15.1 and 7.17.1.1.

X.5.1.1.2 When shell designs use joint efficiency = 0.85, spot radiographs of vertical joints shall conform to 7.17.2, 7.17.3, and 7.17.4.

X.5.1.2 Inspection of Welds by Liquid Penetrant Method

The following component welds shall be examined by the liquid penetrant method before the hydrostatic test of the tank:

a) The shell-to-bottom inside attachment weld.

b) All welds of opening connections in tank shell that are not completely radiographed, including nozzle and manhole neck welds and neck-to-flange welds.

c) All welds of attachments to shells, such as stiffeners, compression rings, clips, and other nonpressure parts for which the thickness of both parts joined is greater than 19 mm (3/4 in.).

d) All butt-welded joints in tank annular plates on which backing strips are to remain.

X.5.2 Hydrostatic Testing

X.5.2.1 The rules of 7.18.3 and 7.18.4 apply to hydrostatic testing.

• X.5.2.2 The materials used in the construction of duplex stainless steel tanks may be subject to pitting, or general corrosion 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.

• X.5.2.3 When testing with potable water, the exposure time shall not exceed 21 days unless otherwise specified by the Purchaser.

X.5.2.4 When testing with other fresh waters, the exposure time shall not exceed 7 days.

X.5.2.5 Upon completion of the 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.
X.6 **Marking**

Brazing shall be deleted from 8.1.3.

X.7 **Appendices**

The appendices are applicable for use with duplex stainless steels as follows:

— Appendix D is applicable; however see X.2.1.3 for special requirements when attaching to carbon steel supports.

— Appendix E is applicable; however see X.2.1.3 for special requirements when attaching external carbon steel supports. Internal supports shall meet the material requirements of Appendix X.

— 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. (Ref X.3.9.1.)

— Appendix Q is not applicable.

— Appendix R is not applicable.

**All other appendices are applicable**