Annex S
(normative)

Austenitic Stainless Steel Storage Tanks

S.1 Scope

S.1.1 This Annex covers materials, design, fabrication, erection, and testing requirements for vertical, cylindrical, aboveground, closed- and open-top, welded, austenitic stainless steel storage tanks constructed of material grades 201-1, 201LN, 304, 304L, 316, 316L, 317, and 317L. This Annex does not cover stainless steel clad plate or strip-lined construction.

- **S.1.2** This Annex applies only to tanks in nonrefrigerated services with a maximum design temperature not exceeding 260 °C (500 °F). Tanks designed to this Annex shall be assigned a maximum design temperature no less than 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 specified in this Annex are corroded thicknesses unless otherwise stated.

S.1.4 This Annex 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.1a and Table S.1b.

- **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 (see S.4.3.2 and S.4.4.3). The Purchaser shall specify the type/grade.

S.2.1.3 External structural attachments may be carbon steels meeting the requirements of Section 4 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. For stainless steel tanks subject to external fire impingement, the use of galvanizing on attachments, including ladders and platforms, is not recommended.

- ### 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)

Plates and Structural Members (Note 1)	Piping and Tubing—Seamless or Welded (Note 2)	Forgings (Notes 2, 3)	Bolting and Bars (Notes 4, 5)
A240M, Type 201-1	A213M, Grade TP 201	A182M, Grade F 304	A193M, Class 1, Grades B8, B8A, and B8M
A240M, Type 201LN	A213M, Grade TP 304	A182M, Grade F 304L	A194M, Grades B8, B8A, B8M, and B8MA
A240M, Type 304	A213M, Grade TP 304L	A182M, Grade F 316	A320M, Grades B8, B8A, B8M, and B8MA
A240M, Type 304L	A213M, Grade TP 316	A182M, Grade F 316L	A276, A479M, Type 304
A240M, Type 316	A213M, Grade TP 316L	A182M, Grade F 317	A276, A479M, Type 304L
A240M, Type 316L	A213M, Grade TP 317	A182M, Grade F 317L	A276, A479M, Type 316
A240M, Type 317	A213M, Grade TP 317L		A276, A479M, Type 316L
A240M, Type 317L	A312M, Grade TP 304		A276, A479M, Type 317
	A312M, Grade TP 304L		
	A312M, Grade TP 316		
	A312M, Grade TP 316L		
	A312M, Grade TP 317		
	A312M, Grade TP 317L		
	A358M, Grade 304		
	A358M, Grade 304L		
	A358M, Grade 316		
	A358M, Grade 316L		
	A403M, Class WP 304		
	A403M, Class WP 304L		
	A403M, Class WP 316		
	A403M, Class WP 316L		
	A403M, Class WP 317		
	A403M, Class WP 317L		

NOTE 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.

NOTE 2 Carbon steel flanges and/or stub ends may be used by agreement between the Purchaser and the Manufacturer, providing the design and details consider the dissimilar properties of the materials used and are suitable for the intended service.

NOTE 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 *Boiler and Pressure Vessel Code*, Section VIII, Division 1, Annex 7.

NOTE 4 All bars in contact with the product shall be furnished in the hot-rolled, annealed, and descaled condition.

NOTE 5 Other bolting materials may be used by agreement between the Purchaser and the Manufacturer.

Table S.1b—ASTM Materials for Stainless Steel Components (USC)

Plates and Structural Members (Note 1)	Piping and Tubing—Seamless or Welded (Note 2)	Forgings (Notes 2, 3)	Bolting and Bars (Notes 4, 5)
A240, Type 201-1	A213, Grade TP 201	A182, Grade F 304	A193, Class 1, Grades B8, B8A, and B8M
A240, Type 201LN	A213, Grade TP 304	A182, Grade F 304L	A194, Grades 8, 8A, 8M, and 8MA
A240, Type 304	A213, Grade TP 304L	A182, Grade F 316	A320, Grades B8, B8A, B8M, and B8MA
A240, Type 304L	A213, Grade TP 316	A182, Grade F 316L	A276, A479, Type 304
A240, Type 316	A213, Grade TP 316L	A182, Grade F 317	A276, A479, Type 304L
A240, Type 316L	A213, Grade TP 317	A182, Grade F 317L	A276, A479, Type 316
A240, Type 317	A213, Grade TP 317L		A276, A479, Type 316L
A240, Type 317L	A312, Grade TP 304		A276, A479, Type 317
A276, Type 201	A312, Grade TP 304L		
A276, Type 304	A312, Grade TP 316		
A276, Type 304L	A312, Grade TP 316L		
A276, Type 316	A312, Grade TP 317		
A276, Type 316L	A312, Grade TP 317L		
A276, Type 317	A358, Grade 304		
	A358, Grade 304L		
	A358, Grade 316		
	A358, Grade 316L		
	A403, Class WP 304		
	A403, Class WP 304L		
	A403, Class WP 316		
	A403, Class WP 316L		
	A403, Class WP 317		
	A403, Class WP 317L		

NOTE 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.

NOTE 2 Carbon steel flanges and/or stub ends may be used by agreement between the Purchaser and the Manufacturer, providing the design and details consider the dissimilar properties of the materials used and are suitable for the intended service.

NOTE 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 *Boiler and Pressure Vessel Code*, Section VIII, Division 1, Annex 7.

NOTE 4 All bars in contact with the product shall be furnished in the hot-rolled, annealed, and descaled condition.

NOTE 5 Other bolting materials may be used by agreement between the Purchaser and the Manufacturer.

S.3 Design

• S.3.1 Tank Bottoms

S.3.1.1 Shell-to-Bottom Fillet Welds

The attachment weld between the bottom edge of the lowest course shell plate and the bottom plate shall comply with the following values:

Nominal Thickness of Shell Plate		Minimum Size of Fillet Weld	
(mm)	(in.)	(mm)	(in.)
5	0.1875	5	3/16
>5 to 25	>0.1875 to 1.0	6	1/4
>25 to 45	>1.0 to 1.75	8	5/16

S.3.1.2 Bottom Plates

All bottom plates shall have a corroded thickness of not less than 5 mm (3/16 in.). Bottom plates which weld to shell plates thicker than 25 mm (1.0 in.) shall have a corroded thickness of not less than 6 mm (1/4 in.). Unless otherwise agreed to by the Purchaser, all rectangular and sketch plates (bottom plates on which the shell rests that have one end rectangular) shall have a minimum nominal width of not less than 1200 mm (48 in.).

S.3.1.3 Annular Bottom Plates

Butt-welded annular bottom plates meeting the requirements of 5.5.2 through 5.5.5 are required when either the bottom shell course maximum product stress is greater than 160 MPa (23,200 lbf/in.^{2}) or the bottom shell course maximum test stress is greater than 172 MPa (24,900 lbf/in.^{2}).

• S.3.2 Shell Design

S.3.2.1 General

S.3.2.1.1 The required nominal shell thickness shall not be less than the greatest of the design shell thickness plus corrosion allowance, hydrostatic test shell thickness, or the nominal thickness listed in 5.6.1.1 (note 4 does not apply).

S.3.2.1.2 Unless otherwise agreed to by the Purchaser, the shell plates shall have a minimum width of 1200 mm (48 in.).

S.3.2.2 Shell Thickness Calculation

The requirements of 5.6 shall be followed, except as modified in S.3.2.2.1, S.3.2.2.2, and S.3.2.2.3.

S.3.2.2.1 Allowable stresses for all shell thickness calculation methods are provided in Table S.2a and Table S.2b.

S.3.2.2.2 Annex A is not applicable.

S.3.2.2.3 The following formulas for design shell thickness and test shell thickness may alternatively be used for tanks 60 m (200 ft) in diameter and smaller.

In SI units:

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

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

where

t_d = design shell thickness, in mm;

t_t = hydrostatic test shell thickness, in mm;

D = nominal diameter of tank, in m (see 5.6.1.1);

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

- G = design specific gravity;

E = joint efficiency, 1.0, 0.85, or 0.70 (see Table S.4);

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

S_d = allowable stress for the design condition, in MPa (see Table S.2a and Table S.2b);

S_t = allowable stress for hydrostatic test condition, in MPa (see Table S.2a and Table S.2b).

In USC units:

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

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

where

t_d = design shell thickness, in inches;

t_t = hydrostatic test shell thickness, in inches;

D = nominal diameter of tank, in ft (see 5.6.1.1);

H = design liquid level, in ft (see 5.6.3.2);

- G = design specific gravity;

E = joint efficiency, 1.0, 0.85, or 0.70 (see Table S.4);

- CA = corrosion allowance, in inches, as specified by the Purchaser (see 5.3.2);

Sd = allowable stress for the design condition, in lbf/in.^{2} (see Table S.2a and Table S.2b);

St = allowable stress for hydrostatic test condition, in lbf/in.^{2} (see Table S.2a and Table S.2b).

NOTE The allowable stresses recognize the increased toughness of stainless steels over carbon steels and the relatively low yield/tensile ratios of the stainless steels. The increased toughness permits designing to a higher proportion of the yield strength, however, the Manufacturer and Purchaser shall be aware that this may result in permanent strain (see Table S.2a and Table S.2b).

S.3.3 Shell Openings

S.3.3.1 The minimum nominal thickness of connections and openings shall be as follows:

Size of Nozzle	Minimum Nominal Neck Thickness
NPS 2 and less	Schedule 80S
NPS 3 and NPS 4	Schedule 40S
Over NPS 4	6 mm (0.25 in.)

NOTE Reinforcement requirements of 5.7 must be maintained.

S.3.3.2 Thermal stress relief requirements of 5.7.4 are not applicable.

S.3.3.3 Shell manholes shall be in conformance with 5.7.5 except that the corroded thickness requirements of the bolting flange and cover plate shall be multiplied by the greater of (a) the square root of the ratio of the material yield strength at 40 °C (100 °F) to the material yield strength at the maximum design temperature, or (b) the square root of the ratio of 205 MPa (30,000 psi) to the material yield strength at the maximum design temperature if this ratio is greater than 1.0.

S.3.3.4 As an alternative to S.3.3.3, plate ring flanges may be designed in accordance with API Standard 620 rules using the allowable stresses given in Table S.3a and Table S.3b.

S.3.3.5 Allowable weld stresses for shell openings shall conform to 5.7.2.8 except S_d = the maximum allowable design stress (the lesser value of the base materials joined) permitted by Table S.2a and Table S.2b.

S.3.4 Roof Design and Roof Manholes

S.3.4.1 The yield strength given in Table S.5a and Table S.5b shall be used for F_y in 5.10.4.4.

S.3.4.2 All stainless steel components of the roof manhole shall have a nominal thickness of not less than 5 mm ($^3/_{16}$ in.).

S.3.4.3 In 5.10.3.1 the stress limitations and safety factors of ANSI/AISC 360 shall be modified to those in ASCE 8. ASCE 8, Appendix D entitled, “Allowable Stress Design,” shall be used in determining allowable unit stresses.

S.3.4.4 For columns, ASCE 8 shall be used to determine allowable unit stresses. Modified allowable stress values for $l/r > 120$ are not applicable.

S.3.5 Annex F—Modifications

In F.2, the shell thickness shall be as specified in S.3.2 except that the pressure P (in kPa [in. of water]) divided by 9.8G (12G) shall be added to the design liquid height in meters (ft).

S.3.6 Annex M—Modifications

S.3.6.1 Annex M requirements shall be met for stainless steel tanks with a maximum design temperature over 40 °C (100 °F) as modified by S.3.6.2 through S.3.6.7.

S.3.6.2 Allowable shell stress shall be in accordance with Table S.2a and Table S.2b.

S.3.6.3 In M.3.5, the requirements of 5.7.7 for flush-type cleanout fittings and of 5.7.8 for flush-type shell connections shall be modified. The thickness of the bottom reinforcing plate, bolting flange, and cover plate shall be multiplied by the greater of (a) the ratio of the material yield strength at 40 °C (100 °F) to the material yield strength at the maximum design temperature, or (b) the ratio of 205 MPa (30,000 psi) to the material yield strength at the maximum design temperature. (See Table S.5a and Table S.5b for yield strength.)

S.3.6.4 In M.3.5, the stainless steel structural allowable stress dependent on Yield Strength (F_y) or Modulus of Elasticity (E) or both Yield Strength (F_y) and Modulus of Elasticity (E) shall be based on Yield Strength (F_y) and Modulus of Elasticity (E) at the maximum design temperature. Refer to Table S.5a and Table S.5b for Yield Strength (F_y) and Table S.6a and Table S.6b for values of Modulus of Elasticity (E) at maximum design temperature.

S.3.6.5 In M.5.1, the requirements of 5.10.5 and 5.10.6 shall be multiplied by the ratio of the material modulus of elasticity at 40 °C (100 °F) to the material modulus of elasticity at the maximum design temperature. (See Table S.6a and Table S.6b for modulus of elasticity.)

S.3.6.6 In roof-to-shell-joint area calculation per 5.10.5.2 and 5.10.6.2, allowable stress F_a shall be calculated using 0.6 x Yield Strength (F_y) (least) at maximum design temperature. Refer to Table S.5a and Table S.5b for Yield Strength (F_y) at maximum design temperature.

S.3.6.7 In rafter spacing calculations per 5.10.4.4, Yield Strength (F_y) of roof plate material at maximum design temperature listed in Table S.5a and Table S.5b shall be used.

S.4 Fabrication and Construction

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 so as to minimize contact with iron or other types of steel during all phases of fabrication, shipping, and construction. The following sections describe the major precautions that should be observed during fabrication and handling.

S.4.2 Storage

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

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 noninjurious 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.

Table S.2a—Allowable Stresses for Tank Shells (SI)

Type	Min. Yield MPa	Min. Tensile MPa	Allowable Stress (S_d) (in MPa) for Maximum Design Temperature Not Exceeding					
			40 °C	90 °C	150 °C	200 °C	260 °C	S_t Ambient
201-1	260	515	155	136	125	121	—	234
201LN	310	655	197	172	153	145	143	279
304	205	515	155	155	140	128	121	186
304L	170	485	145	132	119	109	101	155
316	205	515	155	155	145	133	123	186
316L	170	485	145	131	117	107	99	155
317	205	515	155	155	145	133	123	186
317L	205	515	155	155	145	133	123	186

NOTE 1 S_d may be interpolated between temperatures.

NOTE 2 The design stress shall be the lesser of 0.3 of the minimum tensile strength or 0.9 of the minimum yield strength. The factor of 0.9 of yield corresponds to a permanent strain of 0.10 %. When a lower level of permanent strain is desired, the Purchaser shall specify a reduced yield factor in accordance with Table Y-2 of ASME Section II, Part D. The yield values at the different maximum design temperatures can be obtained from Table S.5a.

NOTE 3 For dual-certified materials (e.g. ASTM A182M/A182 Type 304L/304), use the allowable stress of the grade specified by the Purchaser.

Table S.2b—Allowable Stresses for Tank Shells (USC)

Type	Min. Yield psi	Min. Tensile psi	Allowable Stress (S_d) (in psi) for Maximum Design Temperature Not Exceeding					
			100 °F	200 °F	300 °F	400 °F	500 °F	S_t Ambient
201-1	38,000	75,000	22,500	19,700	18,100	17,500	--	34,200
201LN	45,000	95,000	28,500	24,900	22,200	21,100	20,700	40,500
304	30,000	75,000	22,500	22,500	20,300	18,600	17,500	27,000
304L	25,000	70,000	21,000	19,200	17,200	15,800	14,700	22,500
316	30,000	75,000	22,500	22,500	21,000	19,300	17,900	27,000
316L	25,000	70,000	21,000	19,000	17,000	15,500	14,300	22,500
317	30,000	75,000	22,500	22,500	21,000	19,300	17,900	27,000
317L	30,000	75,000	22,500	22,500	21,000	19,300	17,900	27,000

NOTE 1 S_d may be interpolated between temperatures.

NOTE 2 The design stress shall be the lesser of 0.3 of the minimum tensile strength or 0.9 of the minimum yield strength. The factor of 0.9 of yield corresponds to a permanent strain of 0.10 %. When a lower level of permanent strain is desired, the Purchaser shall specify a reduced yield factor in accordance with Table Y-2 of ASME Section II, Part D. The yield values at the different maximum design temperatures can be obtained from Table S.5b.

NOTE 3 For dual-certified materials (e.g. ASTM A182M/A182 Type 304L/304), use the allowable stress of the grade specified by the Purchaser.

Table S.3a—Allowable Stresses for Plate Ring Flanges (SI)

	Allowable Stress (S_t) (in MPa) for Maximum Design Temperature Not Exceeding				
Type	**40 °C**	**90 °C**	**150 °C**	**200 °C**	**260 °C**
201-1	155	133	115	104	--
201LN	197	167	151	143	138
304	140	115	103	95	89
304L	117	99	88	81	75
316	140	119	107	99	92
316L	117	97	87	79	73
317	140	119	108	99	92
317L	140	119	108	99	92

NOTE 1 Allowable stresses may be interpolated between temperatures.

NOTE 2 The allowable stresses are based on a lower level of permanent strain.

NOTE 3 The design stress shall be the lesser of 0.3 of the minimum tensile strength or $^2/_3$ of the minimum yield strength.

• NOTE 4 For dual-certified materials (e.g. ASTM A182M/A182 Type 304L/304), use the allowable stress of the grade specified by the Purchaser.

Table S.3b—Allowable Stresses for Plate Ring Flanges (USC)

	Allowable Stress (S_t) (in psi) for Maximum Design Temperature Not Exceeding				
Type	**100 °F**	**200 °F**	**300 °F**	**400 °F**	**500 °F**
201-1	22,500	19,300	16,700	15,100	--
201LN	28,500	24,200	21,900	20,700	20,000
304	20,000	16,700	15,000	13,800	12,900
304L	16,700	14,300	12,800	11,700	10,900
316	20,000	17,200	15,500	14,300	13,300
316L	16,700	14,100	12,600	11,500	10,600
317	20,000	17,300	15,600	14,300	13,300
317L	20,000	17,300	15,600	14,300	13,300

NOTE 1 Allowable stresses may be interpolated between temperatures.

NOTE 2 The allowable stresses are based on a lower level of permanent strain.

NOTE 3 The design stress shall be the lesser of 0.3 of the minimum tensile strength or $^2/_3$ of the minimum yield strength.

• NOTE 4 For dual-certified materials (e.g. ASTM A182M/A182 Type 304L/304), use the allowable stress of the grade specified by the Purchaser.

Table S.4—Joint Efficiencies

Joint Efficiency	Radiograph Requirements
1.0	Radiograph per 8.1.2
0.85	Radiograph per A.5.3
0.70	No radiography required

Table S.5a—Yield Strength Values in MPa (SI)

Type	Yield Strength (in MPa) for Maximum Design Temperature Not Exceeding				
	40 °C	90 °C	150 °C	200 °C	260 °C
201-1	260	199	172	157	—
201LN	310	250	227	214	207
304	205	170	155	143	134
304L	170	148	132	121	113
316	205	178	161	148	137
316L	170	145	130	119	110
317	205	179	161	148	138
317L	205	179	161	148	138

NOTE 1 Interpolate between temperatures.

NOTE 2 Reference: Table Y-1 of ASME Section II, Part D.

Table S.5b—Yield Strength Values in psi (USC)

Type	Yield Strength (in psi) for Maximum Design Temperature Not Exceeding				
	100 °F	200 °F	300 °F	400 °F	500 °F
201-1	38,000	28,900	25,000	22,700	—
201LN	45,000	36,300	32,900	31,100	30,000
304	30,000	25,000	22,500	20,700	19,400
304L	25,000	21,400	19,200	17,500	16,400
316	30,000	25,800	23,300	21,400	19,900
316L	25,000	21,100	18,900	17,200	15,900
317	30,000	25,900	23,400	21,400	20,000
317L	30,000	25,900	23,400	21,400	20,000

NOTE 1 Interpolate between temperatures.

NOTE 2 Reference: Table Y-1 of ASME Section II, Part D.

Table S.6a—Modulus of Elasticity at the Maximum Design Temperature (SI)

Maximum Design Temperature (°C) Not Exceeding	Modulus of Elasticity (MPa)
40	194,000
90	190,000
150	186,000
200	182,000
260	179,000
NOTE Note: Interpolate between temperatures.	

Table S.6b—Modulus of Elasticity at the Maximum Design Temperature (USC)

Maximum Design Temperature (°F) Not Exceeding	Modulus of Elasticity (psi)
100	28,100,000
200	27,500,000
300	27,000,000
400	26,400,000
500	25,900,000
NOTE Interpolate between temperatures.	

- **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 residue 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 equipment shall be completely dried.

S.4.10 Hydrostatic Testing

S.4.10.1 The rules of 7.3.6 apply to hydrostatic testing except that the penetrating oil test in 7.3.6, Item 2) shall be replaced with liquid penetrant examination conducted by applying the penetrant on one side and developer on the opposite side of the welds. The dwell time must be at least one hour.

- **S.4.10.2** 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.4.10.3 When testing with potable water, the exposure time shall not exceed 21 days, unless specified otherwise by the Purchaser.

S.4.10.4 When testing with other fresh waters, the exposure time shall not exceed 7 days.

S.4.10.5 Upon completion of the hydrostatic test, water shall be completely drained. Wetted surfaces shall be washed with potable water when nonpotable 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.4.11 Welding

S.4.11.1 Tanks and their structural attachments shall be welded by any of the processes permitted in 7.2.1.1 or by the plasma arc process. Galvanized components or components coated with zinc-rich coating shall not be welded directly to stainless steel.

S.4.11.2 Weld procedure qualifications for stainless steel alloys shall demonstrate strength matching the base metals joined (i.e. 3XX stainless shall be welded with a matching E3XX or ER3XX filler metal).

S.4.11.3 For the 300 series stainless steel materials, the filler metal mechanical properties and chemistry shall both match the type of base metals joined (i.e. 3XX stainless shall be welded with a matching E3XX or ER3XX filler metal).

S.4.11.4 For the 200 series stainless steel materials, filler metals of matching composition are not available. The Manufacturer, with approval of the Purchaser, shall select the appropriate filler metal, taking into account the corrosion resistance and mechanical properties required for the joint.

S.4.11.5 Dissimilar material welds (stainless steels to carbon steels) shall use filler metals of E309/ER309 or higher alloy content.

S.4.11.6 Two stainless steel plates identical in material type may be welded together prior to erection in order to form a single shell plate subassembly. Plates welded together shall have thicknesses within 1.6 mm ($^1/_{16}$ in.) of each other with the maximum plate thickness being 13 mm ($^1/_2$ 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 vertical joint offset requirement of 5.1.5.2 (b) shall be applied only between the subassembly and plates above and below it. The subassembly shall conform to the dimensional tolerances contained in Section 7 and shall be subjected to inspection requirements contained in Section 8. 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 9.

S.4.12 Welding Procedure and Welder Qualifications

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

S.4.13 Postweld Heat Treatment

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

S.4.14 Examination of Welds

S.4.14.1 Radiographic Examination of Butt-Welds

Radiographic examination of butt-welds shall be in accordance with 8.1 and Table S.4.

S.4.14.2 Examination 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.

S.5 Marking

Marking shall be in accordance with Section 10, except that nameplates shall not be attached by brazing.

S.6 Annexes

The following Annexes are modified for use with austenitic stainless steel storage tanks.

a) Annex A is not applicable to tanks built to this Annex, except for the radiography requirements of A.5.3 subject to the joint efficiency used.

• b) Annex C may be used; however, the Purchaser shall identify all materials of construction.

c) Annex F is modified as outlined in S.3.5 of this Annex.

d) Annex J may be used, except the nominal shell thickness for all tank diameters shall not be less than 5 mm ($^3/_{16}$ in.).

e) Annex K is not applicable to tanks built to this Annex.

f) Annex M is modified as outlined in S.3.6 of this Annex.

g) Annex N is not applicable.

h) Annex O may be used; however, the structural members of Table O.1a and Table O.1b shall be of an acceptable grade of material.

i) All other Annexes may be used without modifications.