Annex X
(normative)

Duplex Stainless Steel Storage Tanks

X.1 Scope

X.1.1 This Annex covers materials, design, fabrication, erection, and testing requirements for vertical, cylindrical, aboveground, closed- and open-top, welded, duplex stainless steel storage tanks constructed of material grades 2205 (UNS S31803), 2003 (UNS S32003), 2101 (UNS S32101), 2102 (UNS S82011), 2202 (UNS S32202), 2205 (UNS S32205), 2304 (UNS S32304), 255 (UNS S32550), 255+ (UNS S32520), 2507 (UNS S32750), and Z100 (UNS S32760). This Annex does not cover stainless steel clad plate or strip lined construction.

X.1.2 This Annex applies only to tanks in non-refrigerated services with a maximum design temperature not exceeding 260 °C (500 °F) and a design metal temperature of –40 °C (–40 °F) or warmer. 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).

X.1.3 The minimum thicknesses specified in this Annex are corroded thicknesses unless otherwise stated.

X.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.

X.2 Materials

X.2.1 Selection and Ordering

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

- **X.2.1.2** Selection of the type/grade of duplex stainless steel depends on the service and environment to which it will be exposed. The Purchaser shall specify 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 S32003	Method B[1]
UNS S32750	Method B[1] & C

Table X.1—ASTM Materials for Duplex Stainless Steel Components

	UNS S31803	UNS S32003	UNS S32101	UNS S82011	UNS S32202	UNS S32205	UNS S32304	UNS S32550	UNS S32520	UNS S32750	UNS S32760
	2205	2003	2101	2102	2202	2205	2304	255	255+	2507	Z100
Plates and Structural Members											
A240	X	X	X	X	X	X	X	X	X	X	X
A276	X		X		X	X	X	X			X
Tube or Pipe Seamless and Welded											
A789	X	X		X	X	X	X	X		X	X
A790	X	X		X	X	X	X	X		X	X
A928	X	X			X	X	X	X	X	X	X
Forgings and Fittings											
A182	X				X	X				X	X
A815	X				X	X					X
Bolting and Bars											
A479	X		X		X	X		X		X	X
A1082	X		X		X	X	X	X		X	X

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 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 A890 and shall be inspected in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix 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 manufacturer.

UNS S32550/S32520	Method B[1] & C
UNS S32760	Method B[1] & C[2]

[1]B test values to be agreed upon between Purchaser and Manufacturer but not less than 54J (40 ft-lbf).
[2]C test values to be agreed upon between Purchaser and Manufacturer.

X.2.3.2 Tests for detecting detrimental intermetallic phases per ASTM A1084 are required from one plate per heat treat lot as follows:

UNS S32304	Methods B & C
UNS S32202	Methods B & C
UNS S32101	Methods B & C
UNS S82011	Methods B & C

X.2.3.3 Charpy Impact Test Requirements

X.2.3.3.1 Charpy Impact testing at design metal temperature (DMT) in accordance with X.2.3.3.2 is required for plate components listed in 4.2.10.1 and for pipe and forgings used for shell nozzles/manways, for materials listed in Table X.1 and where either Item a) or Item b) below is true:

a) all thicknesses where the design metal temperature (DMT) is between –29 °C and –40° °C (–20 °F and –40 °F), or

b) all components where the nominal/governing thickness is greater than 10 mm ($^3/_8$ in.) for all temperatures.

For impact test evaluation of shell nozzles made from pipe or forgings, the governing thickness as defined in 4.5.4.3 shall be used instead of the nominal thickness of the pipe or forgings.

X.2.3.3.2 Three specimens tested per ASTM A370 or equivalent ISO Standards shall have a lateral expansion opposite the notch not less than 0.38 mm (0.015 in.) at design metal temperature (DMT) or lower. In addition to lateral expansion, impact test energy values in Joules (ft-lbf) shall be measured and reported on test reports. If the value of lateral expansion for one specimen of a set is less than 0.38 mm (0.015 in.) but not less than 0.25 mm (0.01 in.) and the average value of the three specimens equals or exceeds 0.38 mm (0.015 in.), a retest of three additional specimens may be made, each of which must equal or exceed 0.38 mm (0.015 in.). If the required values are not obtained in the retest or if the values in the initial test are less than minimum required for retest, the material may be reheat treated. After reheat treatment, new sets of specimens shall be made and retested; all specimens must meet the lateral expansion value of 0.38 mm (0.015 in.) minimum.

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 Bottom Plates

All bottom plates shall have a nominal corroded thickness of not less than 5 mm ($^3/_{16}$ in.). Unless otherwise approved by the Purchaser, all rectangular and sketch plates (bottom plates on which the shell rests that have one end rectangular) shall have a nominal width of not less than1200 mm (48 in.).

X.3.2 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}).

X.3.3 Shell Design

X.3.3.1 Shell Minimum Thickness

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).

X.3.3.2 Minimum Plate Widths

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

X.3.3.3 Shell Thickness Calculation

The requirements of 5.6 shall be followed except as modified in X.3.3.3.1 through X.3.3.3.3.

X.3.3.3.1 Allowable stresses for all shell thickness calculation methods are provided in Table X.2a and Table X.2b.

X.3.3.3.2 Annex A is not applicable.

X.3.3.3.3 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:

$$t_d = (4.9D(H - 0.3)G)/((S_d)(E)) + CA$$

$$t_t = (4.9D(H - 0.3))/((S_t)(E))$$

where

t_d is the design shell thickness, in mm;

t_t is the hydrostatic test shell thickness, in mm;

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

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

G is the design specific gravity of the liquid to be stored, as specified by the Purchaser;

E is the joint efficiency, 1.0, 0.85, or 0.70 (see Table X.3);

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

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

S_t is the allowable stress for hydrostatic test condition, in MPa (see Table X.2a and Table X.2b).

In USC units:

$$t_d = (2.6D(H - 1)G)/((S_d)(E)) + CA$$

$$t_t = (2.6D(H - 1))/((S_t)(E))$$

where

t_d is the design shell thickness, in inches;

t_t is the hydrostatic test shell thickness, in inches;

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

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

G is the specific gravity of the liquid to be stored, as specified by the Purchaser;

E is the joint efficiency, 1.0, 0.85, or 0.70 (see Table X.3);

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

S_d is the allowable stress for the design condition, in lbf/in.^{2} (see Tables X.2a and X.2b);

S_t is the allowable stress for hydrostatic test condition, in lbf/in.^{2} (see Tables X.2a and X.2b).

X.3.4 Shell Openings

X.3.4.1 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	Schedule 40S but need not be greater than the shell thickness

NOTE Reinforcement requirements of 5.7 must be maintained.

X.3.4.2 Thermal stress relief requirements of 5.7.4 are not applicable.

X.3.4.3 Shell manholes shall be in conformance with 5.7.5.

X.3.4.4 As an alternative to X.3.4.3, plate ring flanges may be designed in accordance with API 620 rules using the allowable stresses given in Table X.2a and Table X.2b.

X.3.4.5 Allowable weld stresses for shell openings shall conform to 5.7.2.7 except S_d = the maximum allowable design stress (the lesser value of the base materials joined) permitted by Table X.2a and Table X.2b.

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

Alloy	Min Yield	Min Ten	Allowable Stress MPa for Design Temp Not Exceeding (*Sts*)					
	MPa	MPa	40 °C	90 °C	150 °C	200 °C	260 °C	*Si* ambient
S31803	450	620	248	248	239	230	225	266
S32003	450	655	262	231	218	215	212	281
S32101	450	650	260	234	223	215	212	278
S82011	450	655	262	257	232	216	206	281
S32202	450	650	262	258	226	214	209	281
S32205	450	655	262	234	225	208	191	281
S32304	400	600	240	229	213	205	200	257
S32550	550	760	303	302	285	279	272	325
S32520	550	770	308	270	265	256	251	331
S32750	550	795	318	319	298	279	268	343
S32760	550	750	298	314	259	256	256	319

NOTE 1 *Sts* may be interpolated between temperatures.

NOTE 2 The design stress shall be the lesser of 2/5 of the minimum tensile strength or 2/3 of the minimum yield strength.

NOTE 3 The hydrotest stress shall be the lesser of 3/7 of the minimum tensile strength or 3/4 of the minimum yield strength.

NOTE 4 For dual certified materials, S31803/S32205 and S32550/S32520, use the allowable stress of the grade specified by the Purchaser.

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

Alloy	Min Yld	Min Ten	Allowable Stress PSI for Design Temp Not Exceeding (*Sts*)					
	lbf/in^2	lbf/in^2	100 °F	200 °F	300 °F	400 °F	500 °F	*Si* ambient
S31803	65,000	90,000	36,000	36,000	34,700	33,400	32,600	38,600
S32003	65,000	95,000	38,000	33,600	33,600	31,200	30,700	40,800
S32101	65,000	94,000	37,600	34,000	32,400	31,200	30,700	40,300
S82011	65,000	95,000	38,000	37,300	33,600	31,300	30,000	40,700
S32202	65,000	94,000	38,000	37,000	32,900	31,000	30,300	40,800
S32205	65,000	95,000	38,000	34,000	32,700	30,000	28,700	40,800
S32304	58,000	87,000	34,800	33,200	30,900	29,700	29,000	37,300
S32550	80,000	110,000	44,000	43,800	41,400	40,400	39,400	47,200
S32520	80,000	112,000	44,800	39,200	38,400	37,200	36,400	48,000
S32750	80,000	116,000	46,400	46,200	43,200	40,500	38,900	49,800
S32760	80,000	108,000	43,200	39,200	37,600	37,200	37,200	46,300

NOTE 1 *Sts* may be interpolated between temperatures.

NOTE 2 The design stress shall be the lesser of 2/5 of the minimum tensile strength or 2/3 of the minimum yield strength.

NOTE 3 The hydrotest stress shall be the lesser of 3/7 of the minimum tensile strength or 3/4 of the minimum yield strength.

NOTE 4 For dual certified materials, S31803/S32205 and S32550/S32520, use the allowable stress of the grade specified by the Purchaser.

Table X.3—Joint Efficiencies

Joint Efficiency	Radiographic Requirements
1	Radiograph per 8.1.2
0.85	Radiograph per X.4.14.1.1
0.7	No radiography required

X.3.5 Roof Design

X.3.5.1 All duplex stainless steel components of the roof manhole shall have a nominal thickness of not less than 5 mm ($^3/_{16}$ in.).

X.3.5.2 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 X.4a and Table X.4b for Yield Strength (F_y) at maximum design temperature.

X.3.5.3 In rafter spacing calculations per 5.10.4.4, Yield Strength (F_y) of roof plate material at maximum design temperature as listed in Table X.4a and Table X.4b shall be used.

X.3.6 Annex F—Modifications

In F.2, the shell thickness shall be as specified in X.3.3 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).

X.3.7 Annex M—Modifications

X.3.7.1 Annex M requirements shall be met for duplex stainless steel tanks with design temperatures over 40 °C (100 °F) as modified by X.3.7.2 through X.3.7.5.

X.3.7.2 Allowable shell stress shall be in accordance with Table X.2a and Table X.2b.

X.3.7.3 In M.3.6, the duplex 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 X.4a and Table X.4b for Yield Strength (F_y) and Table X.5a and Table X.5b for values of Modulus of Elasticity (E) at maximum design temperature.

X.3.7.4 In M.6 (the equation for the maximum height of unstiffened shell in 5.9.6.1), the maximum height shall be multiplied by the ratio of the material modulus of elasticity at the design temperature to the material modulus of elasticity at 40 °C (100 °F).

X.4 Fabrication and Construction

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 iron or other types of steel 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 should be observed during fabrication, and handling.

X.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. Duplex stainless steel should not be stored in contact with carbon steel. Materials containing chlorides, including foods, beverages, oils, cleaners and greases, should not come in contact with duplex stainless steel.

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.

Table X.4a—Yield Strength Values in MPa

Alloy	Yield Strength MPa for Design Temp Not Exceeding				
	40 °C	90 °C	150 °C	200 °C	260 °C
S31803	450	396	370	353	342
S32003	450	386	352	331	317
S32101	450	379	351	324	317
S82011	450	385	347	323	310
S32202	448	387	339	321	314
S32205	450	358	338	319	286
S32304	400	343	319	307	299
S32550	550	484	443	421	407
S32520	550	448	421	400	379
S32750	550	486	446	418	402
S32760	550	455	428	414	400

NOTE 1 Interpolate between temperatures.

NOTE 2 Reference: Table Y-1 of ASME Section II, Part D. or manufacturers' data sheets.

Table X.4b—Yield Strength Values in PSI

Alloy	Yield Strength lbf/in^2 for Design Temp Not Exceeding				
	100 °F	200 °F	300 °F	400 °F	500 °F
S31803	65,000	57,500	51,000	48,000	46,000
S32003	65,000	56,000	51,000	47,000	46,000
S32101	65,000	55,000	49,000	45,000	43,000
S82011	65,000	55,900	50,400	46,900	45,000
S32202	65,000	55,500	49,300	46,500	45,500
S32205	65,000	52,000	49,000	45,000	43,000
S32304	58,000	49,800	46,300	44,500	43,400
S32550	80,000	70,200	64,300	61,000	59,000
S32520	80,000	65,000	61,000	58,000	55,000
S32750	80,000	70,500	64,700	60,700	58,300
S32760	80,000	66,000	62,000	60,000	58,000

NOTE 1 Interpolate between temperatures.

NOTE 2 Reference: Table Y-1 of ASME Section II, Part D. or manufacturers' data sheets.

Table X.5a—Modulus of Elasticity at the Maximum Design Temperature (SI)

Alloy	Modulus of Elasticity in MPa for Design Temperatures Not Exceeding				
	40 °C	90 °C	150 °C	200 °C	260 °C
S31803	198,000	190,000	185,000	180,000	174,000
S32003	209,000	205,000	201,000	197,000	192,000
S32101	198,000	194,000	190,000	185,000	182,000
S82011	209,600	204,000	200,600	195,800	191,000
S32202	198,000	195,000	190,000	186,000	182,000
S32205	198,000	190,000	185,000	180,000	174,000
S32304	198,000	190,000	185,000	180,000	174,000
S32550	209,000	206,000	202,000	198,000	194,000
S32520	209,000	206,000	202,000	198,000	180,000
S32750	202,000	194,000	188,000	180,000	175,000
S32760	199,000	193,000	190,000	185,000	182,000

NOTE 1 Interpolate between temperatures.

Table X.5b—Modulus of Elasticity at the Maximum Design Temperature (USC)

Alloy	Modulus of Elasticity (x 10^6 PSI) for Design Temperatures Not Exceeding				
	100 °F	200 °F	300 °F	400 °F	500 °F
S31803	28.7	27.6	26.8	26.1	25.3
S32300	30.3	29.8	29.2	28.6	27.9
S32101	28.7	28.1	27.5	26.9	26.4
S82011	30.4	29.6	29.1	28.4	27.7
S32202	28.2	28.2	27.5	26.4	26.0
S32205	28.7	27.6	26.8	26.1	25.3
S32304	28.7	27.6	26.8	26.1	25.3
S32550	30.3	29.9	29.3	28.7	28.1
S32520	30.3	29.9	29.3	28.7	26.1
S32750	29.3	28.1	27.2	26.2	25.4
S32760	28.8	28.0	27.6	26.9	26.4

NOTE 1 Interpolate between temperatures.

Table X.6a—Hot Forming Temperatures (SI)

Alloy	°C Max	°C Min	°C Min Soaking
S31803	1230	950	1040
S32003	1100	950	1010
S32101	1100	900	980
S82011	1100	950	1010
S32202	1100	1000	1080
S32205	1230	950	1040
S32304	1100	950	980
S32550	1230	1000	1080
S32520	1230	1000	1080
S32750	1230	1025	1050
S32760	1230	1000	1100

Table X.6b—Hot Forming Temperatures (USC)

Alloy	°F Max	°F Min	°F Min Soaking
S31803	2250	1740	1900
S32003	2010	1740	1850
S32101	2010	1650	1800
S82011	2010	1740	1850
S32202	2010	1830	1975
S32205	2250	1740	1900
S32304	2010	1740	1800
S32550	2250	1830	1975
S32520	2250	1830	1975
S32750	2250	1875	1920
S32760	2250	1830	2010

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 is provided in the forming procedure.

X.4.4.3 Hot forming, if required, may be performed within a temperature range shown in Table X.6a and Table X.6b.

Forming at temperatures between 600 °F (315 °C) and the minimum temperature shown in Table X.6a and Table X.6b is not permitted.

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, 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, 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).

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 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 may 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. Pickling solutions may require a neutralization treatment before rinsing.

- **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), unless specifically allowed by the Purchaser.

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

X.4.10 Hydrostatic Testing

X.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 penetrant dwell time must be at least one hour.

• **X.4.10.2** 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, unless otherwise allowed by the Purchaser.

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

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

X.4.10.5 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.4.11 Welding

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

• **X.4.11.2** 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.4.12 Welding Procedure and Welder Qualifications

• **X.4.12.1** Welding Procedure and Welder Qualification requirements shall be as specified in Section 7. In addition, welding procedures used for welding components listed in X.2.3.3.1 shall also meet the requirements of ASTM A923 Method B and Method C as required in X.2.3.1 or ASTM A1084 Method B and Method C as required in X.2.3.2 with test values to be agreed upon between Purchaser and Manufacturer. Weld metal and heat affected zone test specimens tested per ASTM A370, or equivalent ISO Standards, shall meet the lateral expansion requirements described in X.2.3.3.2. Welding Procedure Qualification Records shall document the results of tests required both by Section 7, ASTM A923 and X.2.3.3.2.

X.4.12.2 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.4.13 Postweld Heat Treatment

Post weld heat treatment of duplex stainless steel materials shall not be performed.

X.4.14 Examination of Welds

X.4.14.1 Radiographic Examination of Butt-Welds

X.4.14.1.1 Radiographic examination of butt-welds shall be in accordance with 8.1 and Table X.3.

X.4.14.1.2 When shell designs use joint efficiency = 0.85, spot radiographs of vertical joints shall conform to 8.1.2.2, Item a, excluding the 10 mm ($^3/_8$ in.) shell-thickness limitation in Item a and excluding the additional random spot radiograph required by Item a.

X.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.

X.5 Marking

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

• X.6 Annexes

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

a) Annex A is not applicable to tanks built to this Annex.

b) Annex C may be used; however, the Purchaser shall identify all materials of construction. The nominal deck thickness using duplex stainless steel shall not be less than 2.5 mm (0.094 in.).

c) Annex F is modified as outlined in X.3.6 of this Annex.

d) Annex H may be used: however the Purchaser shall identify all materials of construction. The nominal deck thickness using duplex stainless steel shall not be less than 2.5 mm (0.094 in.).

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

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

g) Annex M is modified as outlined in X.3.7 of this Annex.

h) Annex N is not applicable.

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

j) All other Annexes may be used without modifications.