Agenda Item 650-536

Title: Add Duplex Stainless Steels to Appendix X

Date: June 5, 2006

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Purpose: To add selected duplex stainless steel materials to new Appendix X.

Source: CB&I request at Fall 1999 meeting.

Revision: 1

Impact: Lower cost stainless steel tanks based on high strength of duplex

Reference: The below embedded excel file provided the allowable stress calculations that result in the proposed Tables X-2 and X-3.

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APPENDIX X—Duplex Stainless Steel Storage Tanks

X.1 Scope

X.1.1 This appendix 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), 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 not exceeding 260°C (500°F) and a minimum design metal temperature of -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).

X.1.3 This appendix is intended to provide the petroleum industry, chemical industry, and other users with tanks of safe design for containment of fluids within the design limits.

X.1.4 The minimum thicknesses in this appendix do not contain any allowance for corrosion.

X.1.5 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.

•**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 2 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 will 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**

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

a.) components named in 2.2.9.1 in all thicknesses, when the minimum design temperature is between-29°C and -40°C (-20°F and -40°F), and

b.) components named in 2.2.9.1 that have thickness greater than 10mm (3/8") for all temperatures.

ASTM A 923 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 minimum nominal thickness of 5 mm (3/16 in.), exclusive of any corrosion allowance. 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 minimum nominal width of 1200 mm (48 in.).

X.3.2 ANNULAR BOTTOM PLATES

Butt-welded annular bottom plates meeting the requirements of 3.5.2 through 3.5.5 are required when either the bottom shell course maximum product stress is greater than 160 MPa (23,200 lbf/in2) or the bottom shell course maximum test stress is greater than 172 MPa (24,900 lbf/in2).

X.3.3 SHELL DESIGN

X.3.3.1 Shell Minimum Thickness

The required minimum shell thickness shall be the greater of the design shell thickness plus corrosion allowance, test shell thickness, or the nominal plate thickness listed in 3.6.1.1

•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 3.6 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-2

X.3.3.3.2 Appendix 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:

$$td = (4.9D(H-0.3)G)/((Sd)(E)) + CA$$

$$tt = 4.9D(H-0.3))/((St)(E))$$

where

td	=	design shell thickness (mm),
tt	=	hydrostatic test shell thickness (mm),
D	=	nominal diameter of tank (m) (see 3.6.1.1),
H	=	design liquid level (m) (see 3.6.3.2),
•G	=	specific gravity of the liquid to be stored, as specified by the purchaser,
E	=	joint efficiency, 1.0, 0.85, or 0.70 (see Table X-3),
•CA	=	corrosion allowance (mm), as specified by the purchaser (see 3.3.2),
Sd	=	allowable stress for the design condition (MPa) (see Table X-2),
St	=	allowable stress for hydrostatic test condition (MPa) (see Table X-2).

In US Customary units:

$$td = (2.6D(H-1)G)/((Sd)(E)) + CA$$

$$tt = (2.6D(H-1))/((St)(E))$$

where

td	=	design shell thickness (in.),
tt	=	hydrostatic test shell thickness (in.),
D	=	nominal diameter of tank (ft) (see 3.6.1.1),
H	=	design liquid level (ft) (see 3.6.3.2),
•G	=	specific gravity of the liquid to be stored, as specified by the purchaser,
E	=	joint efficiency, 1.0, 0.85, or 0.70 (see Table X-3),
•CA	=	corrosion allowance (in.), as specified by the purchaser (see 3.3.2),
Sd	=	allowable stress for the design condition (lbf/in.2) (see Table X-2),
St	=	allowable stress for hydrostatic test condition (lbf/in.2) (see Table X-2).

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 3.7 must be maintained.

X.3.4.2 Thermal stress relief requirements of 3.7.4 are not applicable.

X.3.4.3 Shell manholes shall be in conformance with 3.7.5.

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

X.3.4.5 Allowable weld stresses for shell openings shall conform to 3.7.2.7 except Sd = the maximum allowable design stress (the lesser value of the base materials joined) permitted by Table X-2.

X.3.5 ROOF MANHOLES

All duplex stainless steel components of the roof manhole shall have a minimum thickness of 5 mm (3/16 in.).

X.3.6 APPENDIX F—MODIFICATIONS

In F.7.1, 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 APPENDIX M—MODIFICATIONS

X.3.7.1 Appendix 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.3.7.7.

X.3.7.2 Allowable shell stress shall be in accordance with Table X-2.

X.3.7.3 In M.3.5, the duplex stainless steel structural allowable stress shall be multiplied by the ratio of the material yield strength at the design temperature to the material yield strength at 40°C (100°F). (See Table X-4 for yield strength.)

X.3.7.4 In M.5.1, the requirements of 3.10.5 and 3.10.6 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 design temperature. (See Table X-5 for modulus of elasticity.)

X.3.7.5 In M.6 (the equation for the maximum height of unstiffened shell in 3.9.7.1), 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 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.

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-6

X.4.4.4 Forming at temperatures between 600°F (315°C) and the minimum temperature shown in Table X-6 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 5.3.5 apply to hydrostatic testing except that the penetrating oil test in 5.3.5(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 5.2.1.1. 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, 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 7 and by ASTM A923.

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 INSPECTION OF WELDS

X.4.14.1 Radiographic Inspection of Butt-Welds

X.4.14.1.1 Radiographic examination of butt-welds shall be in accordance with 6.1 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 6.1.2.2, Item a, excluding the 10 mm (3/8”) shell-thickness limitation in Item a and excluding the additional random spot radiograph required by Item a.

X.4.14.2 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 Marking

Brazing shall be deleted from 8.1.2.

- ## X.6 Appendices

The following appendices are modified for use with duplex stainless steel storage tanks:

a. Appendix C is applicable; however, the purchaser shall identify all materials of construction. The minimum deck thickness using duplex stainless steel shall be 2.5mm (0.094 in.).
b. Appendix F is modified as outlined in X.3.5 of this appendix.
c. Appendix H is applicable: however the purchaser shall identify all materials of construction. The minimum deck thickness using duplex stainless steel shall be 2.5mm (0.094 in.)."
d. Appendix J is applicable, except the minimum shell thickness for all tank diameters is 5 mm (3/16 in.).
e. Appendix K is not applicable to tanks built to this appendix.
f. Appendix M is modified as outlined in X.3.6 of this appendix.
g. Appendix N is not applicable.
h. Appendix O is applicable; however, the structural members of Table O-1 shall be of an acceptable grade of material.
i. All other appendices are applicable without modifications.

API Ballot Comments and Resolution			
Ballot: 69-06-650-536 appendix X	Proposal:	Ballot ID: 813	Date: June 5, 2006

1	2	3	4	5	6
Voter Name (Vote)	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Type of Comment**	**Comment (justification for change) by the Voting Member**	**Proposed change by the Voting Member**	**Comment Resolution**
Jerry Boldra (Affirmative)	X.2.1.3	Editorial	Suggest that Paragraph X.2.1.3 is in the wrong section of the document. It appears that this paragraph should be split with part moved to Section 3.0 and the remainder moved to Section 4.0.		**
Manfred Lengsfeld (Abstain)		Technical	Not familiar with this steel		OK
Nelson Acosta HMT Inspection (Affirmative)	X.4.13	Technical	API 650, Para. 3.7.4 establishes requirements for "thermal stress relief" as used throughout the document. Proposed X.4.13 references "postweld heat treatment" and this is the common industry term but not the term used in 3.7.4. The title of X.4.13 and the first three words of the added sentence within should be changed to read "thermal stress relief".	X.4.13 Thermal Stress Relief Thermal stress relief of duplex stainless stell materials shall not be performed.	PWHT is an anneal and quench treatment for properties – not for stress relief No Change Required
James McBride Petrex, Inc. (Negative)	X.3.7.4	Technical	References Table X-6. There is no such table.	Add Table X-6	Corrected
James McBride Petrex, Inc. (Negative)	X.4.4.4	Technical	References a Table X-7. There is no Table X-7.	Add Table X-7.	Corrected
James McBride Petrex, Inc. (Negative)	Appendix X	Technical	This appendix seems to parallel Appendix S rather closely. There are many sections that are indentical to both. Since the duplex stainless steels are basically lower cost stainless steels, I believe that it should be possible to incorporate the pertinent information from Appendix X into Appendix S.	Incorporate the duplex stainless steel information into Appendix S.	While an effort was made to mirror S editorially - there are technical differences between the alloy systems that could give rise to confusion or misuse if S and X were combined.
John Legge Sunoco Logistics, L.P. (Affirmative)		Technical	Assuming ballot 814 passes, would it be prudent to allow the variable design point method in this Appendix?		It is allowed per 3.3.3 No change required.

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John Lieb Tank Industry Consultants, Inc. (Negative)	X.1.1	Editorial	Delete "." between "(UNS S35250)," and "2507".	See above.	Corrected
John Lieb Tank Industry Consultants, Inc. (Negative)	X.1.4	Editorial		Change "thickness" to "thicknesses".	Corrected
John Lieb Tank Industry Consultants, Inc. (Negative)	X.2.1.2	Editorial		Change "select" to "specify" in the second sentence.	**
John Lieb Tank Industry Consultants, Inc. (Negative)	X.2.2	Other	I suggest 3 changes, as described below, to improve the editorial and technical content of this section.	1) In the 1st sentence, add "protect" between "...important to" and "its corrosion resistance." 2) In the 3rd sentence, delete the second "normal". [i.e., Normal packaging should protect against normal shipping damage.] 3) In the last sentence, change "should" to "shall".	Changed Changed ** / Changed
John Lieb Tank Industry Consultants, Inc. (Negative)	X.2.3.1	Technical	Proposed wording is unclear. Change as described below.	Change 1st sentence to read: "ASTM A923 tests are required from one plate from each heat treat lot number as follows:"	No change Heat treat lots are controlled with plate/heat tracing but not necessarily assigned a separate number.
John Lieb Tank Industry Consultants, Inc.	X.4.1	Editorial		In 2nd sentence, add ", shipping" between "...all phases of fabrication" and "and construction."	**

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(Negative)					
John Lieb Tank Industry Consultants, Inc. (Negative)	X.4.5.4	Technical	Pickling product and method should both be appropriate.	Add "and method" at end of sentence.	Changed
John Lieb Tank Industry Consultants, Inc. (Negative)	X.4.8	Editorial		Correct spelling from "imbedded" to "embedded".	Changed
John Lieb Tank Industry Consultants, Inc. (Negative)	X.4.10.1	Technical	"Dwell time" should be clarified to refer to the penetrant dwell time.	Add "penetrant" between "The" and "dwell time...".	** Changed
John Lieb Tank Industry Consultants, Inc. (Negative)	X.4.11.2	Technical	Is the 1st sentence a realistic requirement? Is the purchaser going to know what filler metal chemistry to specify? Why is this wording different than that of Appendix S?	Change wording to be consistent with Appendix S, i.e., "Filler metal chemeistry shall match the type of base metals joined."	No change. A variety of filler metals – overalloyed, austenitic and nickel based, are used for Duplex – the purchaser should have or acquire the knowledge via appropriate sources.
John Lieb Tank Industry Consultants, Inc. (Negative)	Table X-1	Technical	Why are the rows and columns of this table reversed from those of Table S-1? It seems inconsistent and unnecessary.	Maintain a consistent Table layout with Table S-1.	This arrangement is more user friendly – especially where alloy/products forms are unavailable and substitutes may be required. **
John Lieb Tank Industry	Tables X-2 thru X-5a	Technical	Tables need to be metricated.	Show SI units first, followed by US Customary units in parentheses	Changed

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Consultants, Inc. (Negative)				parentheses.	
John Lieb Tank Industry Consultants, Inc. (Negative)	X.3.1	Editorial		In 2nd sentence, change "agreed to" to "approved".	**
John Lieb Tank Industry Consultants, Inc. (Negative)	X.3.2	Editorial		Add comma to 23200 to read 23,200.	Changed
John Lieb Tank Industry Consultants, Inc. (Negative)	X.3.3.2	Editorial		Change "agreed to" to "approved".	**
John Lieb Tank Industry Consultants, Inc. (Negative)	X.3.3.3.2	Technical	Why is this statement included? If it is to remain, it conflicts with Table X-4, as this table references radiography per A.5.3. This is the primary reason for my negative ballot. Metrication of the Tables in Appendix X is a secondary reason.	Delete X.3.3.3.2 unless there is a technical reason for keeping it.	Added 4.14.1.1 to cover this.
John Lieb Tank Industry Consultants, Inc. (Negative)	Table X-4	Technical	The reference to A.5.3 conflicts with X.3.3.3.2. i.e., if Appendix A is not applicable, then it should not be referenced in Table X-4.	See comment on X.3.3.3.2.	Removed reference from Table 4 (new table 3)
Randy Kissell TGB Partnership (Affirmative)	X..1.2	Technical		"minimum design temperature" should be "design metal temperature" to be consistent with 650-471 previously passed for publication.	**

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Randy Kissell TGB Partnership (Affirmative)	X.1.3	Technical	Delete this section as it provides no requirements and doesn't say anything the standard doesn't already say.		**
Randy Kissell TGB Partnership (Affirmative)	X.1.4	Technical	Change for grammatical correction as shown below.	The minimum thicknesses in this appendix do not contain any allowance for corrosion.	Corrected
Randy Kissell TGB Partnership (Affirmative)	X.2.2	Editorial	Delete "will" as shown below for clarity.	Precautions to protect the surface of the material depend on the surface finish supplied and may vary among manufacturers.	**
Randy Kissell TGB Partnership (Affirmative)	X.2.3.2	Technical	Change to "design metal temperature" to be consistent with 650-471 and metricate 3/8".	X.2.3.2 Charpy Impact testing per ASME UHA-51 is required at the design metal temperature to determine suitability for applications between -29C and -40C (-20F and -40F) and at all temperatures for any thickness greater than 10 mm [3/8”]. ASTM A 923 Practice B tests may be used for design metal temperatures to -40ºC (-40ºF) and any thickness when the lateral expansion is measured and reported.	** Metrification change corrected
Randy Kissell TGB Partnership (Affirmative)	X.3.7	Technical	Change "design temperature" to "maximum design temperature" to be consistent with 650-471.		**
Randy Kissell TGB Partnership (Affirmative)	X.4.4.1	Editorial	Delete the comma.		Corrected

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Randy Kissell TGB Partnership (Affirmative)	X.4.4.2	Technical		X.4.4.2 The maximum strain produced by cold forming shall not exceed 10% and spring-back shall be controlled during forming.	**
Randy Kissell TGB Partnership (Affirmative)	X.4.10.1	Technical	Delete the " at the beginning		**
Bhana Mistry TIW Steel Platework (Affirmative)		Technical	Allowable Stress Tables and Yield Strenth Table should be provided in SI as well as Imperial units as has been done for Appendix-S	Add SI tables for Allowable Stress and Yield Strenth. Values of Modulus of Elasticity should also be provided in dual units.	Corrected
Larry Hiner CBI (NonVoter)		Technical	No Comments		OK
Bruce Roberts (YetToVote)		Technical	See separate sheet for my comments.		**See attached**
Douglas Miller Chicago Bridge & Iron Company(CB&I) (Affirmative)	Table X-3	Technical	Why are the Table X-3 allowable stresses for flange design higher than the basic tank allowables? That is not the case for carbon steel in API 620 5.20.2. Since the YS/UTS ratio of duplex stainless steel is similar to that of carbon steel, the allowable stress basis should is the same as for CS including for flange design.	Delete Table X-3 and change X.3.4.4 to refer to Table X-2 rather than Table X-3.	All changes made.
Robert Hendrix Eastman Chemical Co (Affirmative)	X.4.12	Technical	For alloys such as 2101 that have no P-number, is it clear from Section 7 that WPS and PQR must be for that unique alloy such as required by Code Case 2418?		Add 4.12.2 For materials, which have not been assigned a P-number the WP/WQ must be developed for that specific material.

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Voter Name (Vote)	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Type of Comment**	**Comment (justification for change) by the Voting Member**	**Proposed change by the Voting Member**	**Comment Resolution**

**** Present wording duplicates that in appendix S. Many of these comments were considered suitable editorial changes – but for both documents.**

In order to have consistent wording in both documents these changes are being held until appendix X is approved and then a task group will propose the changes for both appendix S and X on a simultaneously or single ballot.

B.E. Roberts Comments:

1. Delete X.1.3. PVT does not reveal our "intentions" in the standards. ******

   Simply state the rules, but not the reason why, or the intent, etc.

2. The subject and verb in X.1.4 are not in agreement. Change thickness to thicknesses? Corrected

3. Delete X.1.5. This rule is stated elsewhere in the document. There is no need to duplicate it in this appendix. ******

4. The wording proposed for X.2.1.3 would allow any material to be used for attachments. ******
   Suggest revising to read: "External structural attachments may only be materials listed in this appendix or carbon steels meeting the requirements of Section 2 of this standard, providing any carbon steel 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.

~~5.~~ In X.2.2, delete the non-specific tutorial wording: "~~Packaging duplex stainless steel for shipment is important to its corrosion resistance. Precautions to protect the surface of the material will 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, the purchaser ~~should~~ shall specify special instructions." Also, add a bullet to this paragraph. ******

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6. In X.2.3.1, revise to read: "Tests for detecting the detrimental intermetallic phase per ASTM A923 are required from one plate per heat treat lot as follows …." As written, it isn't clear what the tests are, unless the reader knows what A923 covers. Changed

7. X.2.3.2 needs some clarifications. "Charpy Impact testing per ASME UHA-51 at minimum Designtemperatureisrequiredfor: Changed
a. all thicknesses of shell, annular plate, and ????? materials ~~to determine suitability for applications,~~ if the minimum design temperature is between -29°C and-40°C(-20°Fand-40°F),and
b. all thicknesses of shell, annular plate and ??? greater than 3/8", regardlessoftheminimumdesigntemperature.

ASTM A 923 Practice B tests may be used for design temperatures to down to ~~-~~40ºC (-40ºF) ~~and~~ or for any thickness when the lateral expansion is measured and reported. [Is this the intended requirement?]

8. In X.3.1 and similarly in X.3 3.2 and X.3.5, suggest a subtle rewording to avoid someone misreading the requirement: ** " ……Unless otherwise agreed to by the purchaser, the minimum nominal width of all rectangular and sketch plates (bottom plates on which the shell rests that have one end rectangular) is 1200 mm (48 in.)."

9. Modify **X.3.3.3.2: "** Appendix A (see 3.6.2.3) is not applicable." Adding the reference clarifies the requirement. ** Note: I also suggest that you take out another agenda item to modify Appendix A to indicate that it is permitted only for carbon steel materials, if that is true. I assume that Appendix S and Appendix A cannot be combined either. Expanding this idea, the agenda item should take at look at all appendices in 650 and determine which combinations are not acceptable.

10. In X.3.3.3.3, change "alternately" to "alternatively". Also, shouldn't the purchaser be involved in the decision to use a joint efficiency in the design of the tank? Changed

11. In X.3.4.5, revise to read: "The definition of S_d in 3.7.2.7 shall be as follows: ** Sd = the maximum allowable design stress (the lesser value of the base materials joined) permitted by Table X-2."

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12. X.3.6 is not clear enough for all readers. Suggest restating the equations in full here, rather than as proposed in words. **

13. Revise X.3.7.1 to read: "If the design temperature is over 40°C (100°F), the requirements is Appendix M apply, as modified by X.3.7.2 through X.3.7.7." **

14. In X.4.1, revise the 3rd sentence in the first paragraph to read: " The temperature of the material during fabrication must also be controlled." defined as "thermal history"

15. In X.4.2, revise to remove the word "should". This is a "weasel word" that PVT has tried to keep out of 650. Suggest the following: "If possible, 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 be allowed to contact duplex stainless steel." Keep as recommendation

16. In X.4.4.2 there is no indication of how to calculate the % strain. Suggest adding the equation here, or referring the reader to the appropriate paragraph in ASME Section VIII, which I believe gives the equation. **

17. In X.4.8, suggest revising to read: "When the purchaser specifies passivation or surface iron removal, this surface cleaning shall be achieved by treatment with nitric or citric acid. Nitric hydrofluoric acid shall be used to remove imbedded iron." Also add a bullet to this paragraph. OK

18. Add a bullet to X.4.9.2 and X.6. OK

19. In X.4.10.2, revise the 2nd sentence to read: "If specified by the purchaser, the quality of test water shall meet the following:". You should also review the new rules in 5.3.5 that will be published in the 11th Edition. See the API website for a copy. **

20. Add a bullet to X.4.11.2. and X.4.12.1. OK

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21. In X.5, suggest changing the title to "Nameplates", and rewording to read: Nameplates shall not be attached by brazing. See 8.1.2. **

22. In X.6, suggest rewording as follows: **

a. Appendix C is may be used for duplex stainless steel tanks; however, the purchaser shall identify all materials
b. of construction. The minimum deck thickness using duplex stainless steel is 2.5mm (0.094 in.).
b. Appendix F may be used with the restrictions in X.3.5 of this appendix.
c. Appendix H may be used. However the purchaser shall identify all materials of construction. The minimum deck
d. thickness using duplex stainless steel is 2.5mm (0.094 in.)."
d. Appendix J may be used, except the minimum shell thickness for all tank diameters is 5 mm (3/16 in.).
e. Appendix K is not applicable to tanks built to this appendix.
f. Appendix M may be used with the restrictions in X.3.6 of this appendix.
g. Appendix N is not applicable.
h. Appendix O may be used; however, the structural members of Table O-1 shall be of an acceptable grade of material.
i. All other appendices may be used without modifications.

Also, X.3.3.3.2 prohibits use of Appendix A. Add here as well?

Table X-1 ASTM Materials for Duplex Stainless Steel Components

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

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.

Table X-2 Allowable Stresses for Tank Shells

Alloy	Min Yld Mpa(PSI)	Min Ten Mpa(PSI)	Allowable Stress Mpa (PSI) for Design Temp Not Exceeding (Sd) 40C(100F)	90C(200F)	150C(300F)	200C(400F)	260C(500F)	St ambient
S31803	450(65,000)	620(90,000)	248(36,000)	248(36,000)	239(34,700)	230(33,400)	225(32,600)	266(38,600)
S32003	450(65,000)	655(95,000)	262(38,000)	231(33,600)	218(3,600)	215(31,200)	212(30,700)	281(40,800)
S32101	450(65,000)	650(94,000)	260(37,600)	234(34,000)	223(32,400)	215(31,200)	212(30,700)	278(40,300)
S32205	450(65,000)	655(95,000)	262(38,000)	234(34,000)	225(32,700)	208(30,000)	198(28,700)	281(40,800)
S32304	400(58,000)	600(87,000)	240(34,800)	229(33,200)	213(30,900)	205(29,700)	200(29,000)	257(37,300)
S32550	550(80,000)	760(110,000)	303(44,000)	302(43,800)	285(41,400)	279(40,400)	272(39,400)	325(47,200)
S32520	550(80,000)	770(112,000)	308(44,800)	270(39,200)	265(38,400)	256(37,200)	251(36,400)	331(48,000)
S32750	550(80,000)	795(116,000)	318(46,400)	319(46,200)	298(43,200)	279(40,500)	268(38,900)	343(49,800)
S32760	550(80,000)	750(108,000)	298(43,200)	314(39,200)	259(37,600)	256(37,200)	256(37,200)	319(46,300)

Notes

1. Sd may be interpolated between temperatures.
2. The design stress shall be the lesser of 2/5 of the minimum tensile strength or 2/3 of the minimum yield strength.
3. The hydrotest stress shall be the lesser of 3/7 of the minimum tensile strength or 3/4 of the minimum yield strength.
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	Radiograph Requirements
1	Radiograph per 6.1.2
0.85	Radiograph per X.4.14.1.1
0.7	No radiography required

Table X-4 Yield Strength Values in MPa (PSI)

Alloy	Yield Strength MPa (PSI) for Design Temp Not Exceeding				
	40C(100F)	90C(200F)	150C(300F)	200C(400F)	260C(500F)
S31803	450(65,000)	396(57,500)	370(53,700)	353(51,200)	342(49,600)
S32003	450(65,000)	386(56,000)	352(51,000)	331(48,000)	317(46,000)
S32101	450(65,000)	379(55,000)	351(51,000)	324(47,000)	317(46,000)
S32205	450(65,000)	358(52,000)	338(49,000)	319(45,000)	296(43,000)
S32304	400(58,000)	343(49,800)	319(46,300)	307(44,500)	299(43,400)
S32550	550(80,000)	484(70,200)	443(64,300)	421(61,000)	407(59,000)
S32520	550(80,000)	448(65,000)	421(61,000)	400(58,000)	379(55,000)
S32750	550(80,000)	486(70,500)	446(64,700)	418(60,700)	402(58,300)
S32760	550(80,000)	455(66,000)	428(62,000)	414(60,000)	400(58,000)

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

Table X-5 Modulus of Elasticity at the Maximum Operating Temperature

Alloy	Modulus of Elasticity in MPa (PSI) for Design Temperatures Not exceeding 40C(100F)	90C(200F)	150C(300F)	200C(400F)	260C(500F)
S31803	198,000,000(28,700)	190,000(27,600)	185,000(26,800)	180,000(26,100)	174,000(25,300)
S32003	203,000(30,300)	205,000(29,800)	201,000(29,200)	197,000(28,600)	192,000(27,900)
S32101	198 ,000(28,700)	194,000(28,100)	190,000(27,500)	185,000(26,900)	182,000(26,400)
S32205	198 ,000(28,700)	190,000(27,600)	185,000(26,800)	180,000(26,100)	174,000(25,300)
S32304	198 ,000(28,700)	190,000(27,600)	185,000(26,800)	180,000(26,100)	174,000(25,300)
S32550	203,000(30,300)	206,000(29,900)	202,000(29,300)	198,000(28,700)	194,000(28,100)
S32520	203,000(30,300)	206,000(29,900)	202,000(29,300)	198,000(28,700)	180,000(26,100)
S32750	202,000(29,300)	194,000(28,100)	188,000(27,200)	180,000(26,200)	175,000(25,400)
S32760	198,000(28,800)	193,000(28,000)	190,000(27,600)	185,000(26,900)	182,000(26,400)

Notes 1. Interpolate between temperatures.

Table X-6 Hot Forming Temperatures

Alloy	C (F) Max	C (F) Min	C (F) Min Soaking Temp
S31803	1230(2250)	950(1740)	1040(1900)
S32003	1100(2010)	950(1740)	1010(1850)
S32101	1100(2010)	900(1650)	980(1800)
S32205	1230(22500	950(1740)	1040(1900)
S32304	1100(2010)	950(1740)	980(1800)
S32550	1230(22500	1000(1830)	1080(1975)
S32520	1230(22500	1000(1830)	1080(1975)
S32750	1230(22500	1025(1875)	1050(1920)
S32760	1230(22500	1000(1830)	1100(2010)