Agenda Item: 620-2069

Title: API 620 Low Temperature Low Stress Materials in Section 4, Annex Q and R

Date: May 16, 2024

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Purpose: To provide clarity and appropriate guidance on using low temperature low stress adjustment to impact values.

Source: Email from Eric Gnade, CB&I (shared at Fall 2023 RTTG meeting and follow up by email on Dec. 4, 2023)

Revision: A

Impact: Appropriate selection of materials for secondary purge containers, bolting, etc.

Rationale: The current wording in API 620 Annex Q and R do not clearly address all the tank components (beyond shell plates) allowing the use of low stress/low temperature provisions on warm vapor containers and purge gas containers. The low stress/low temperature provisions should be reviewed for applicability to other tank components on warm vapor containers or purge gas containers including casting, forging, pipe, flange, and bolting materials.

The plate portion was already clearly addressed in the current API 620 Section 4.2.2. Components for Forgings, Pipe, and Flange materials can be individually evaluated for lower DMT values per BPVC VIII-2 Part 3 in similar method as the plate materials.

For castings specifically, there is no need to provide any specific guidance on using the BPVC VIII-2 Part 3 as there is only “ASTM A27” as an approved material in API 620.

For bolting materials (which includes both bolts and nuts), there is a specific section in BPVC VIII-2 Part 3, Section 3.11.6 that lists the allowable temperatures for some bolt and nut materials. However, there are no direct rules or guidance for applying a stress ratio, thickness ratio, or pressure ratio to reduce the allowable DMT per BPVC VIII-2. The acceptable materials for bolts are nuts are listed in BPVC VIII-2 Table 3-A.1.

ASTM A320 does specifically address the allowable low temperature for which nut materials can be used without impact testing. Below is a snippet from ASTM A320 for some materials good to -325 deg F and -425 deg F.

6.2 *Impact Properties:*

6.2.1 *Requirements:*

6.2.1.1 Impact tests are required for the grades shown in Table 3. Class 1, 1A, and 2 austenitic steels for temperatures above –325 °F [–200 °C]; Class 1 and 1A austenitic Grades B8, B8A, B8P, B8PA, B8C, B8CA, B8LN, and B8LNA above –425 °F [–255 °C]; and ferritic or austenitic bolting ½ in. [12.5 mm] and smaller, are exempt from impact testing, unless Supplementary Requirement S1 is specified in the purchase order (see 1.4). All other material furnished under this specification shall be tested. Material of Grades L7, L7A, L7B, L7C, L7M, L43, L70, L71, L72, and L73 shall show a minimum impact energy absorption of 20 ft · lbf [27 J] and of Grade L1 a minimum impact energy absorption of 40 ft · lbf [54 J] at the specified test temperature.

Figure 1-ASTM A320 Section 6.2.1.1

10. Nuts and Washers

10.1 Bolts, studs, and stud bolts of Grades L7, L7A, L7B, L7C, L43, L1, L70, L71, L72, and L73 shall be equipped with ferritic alloy nuts conforming to Grade 7 of Specification A194/A194M or conforming to Grade L43 or Grade L73. Nuts manufactured of Grade L43 and Grade L73, in addition to the requirements stated for those grades, shall be subject to the proof-load requirements for Grade 7 nuts. Nuts manufactured of Grade L43 and Grade L73 shall be marked respectively with those grade symbols. Grade 7M nuts at a hardness not exceeding 235 HBW (or equivalent) shall be used with Grade L7M bolts, studs, and stud bolts. All nut materials, including those which may be supplied under Specification A194/A194M, shall be subject to the impact requirements of this specification in the following manner: impact tests shall be made on test specimens taken from the nuts or nut blanks or the bar from the heat of steel used for manufacturing the nuts, and heat treated with the nut blanks.

10.2 Bolts, studs, and stud bolts of Grades B8, B8C, B8T, B8P, B8F, B8M, B8LN, and B8MLN shall be equipped with austenitic alloy nuts conforming to Grades 8, 8C, 8T, 8F, 8M, 8LN, and 8MLN for Specification A194/A194M. Impact tests are not required for Grades 8F, 8M, 8T, and 8MLN for temperatures above –325 °F [–200 °C] and for Grades 8, 8P, 8C, and 8LN above –425 °F [–255 °C].

Figure 2-ASTM A320 Section 10.1 and 10.2

This agenda item provides clarity on including the use of the low stress/low temperature provisions for those additional components for warm vapor containers or purge gas containers.

Additionally, the options of material guidance for purge gas containers are expanded to match that of the warm product vapor containers for allowing the “atmospheric temperature materials” per Table R-3. There is no difference between these two types of containers when it comes to the temperature and toughness requirements of a purge gas or warm vapors as Table R-3 covers the temperature ranges for both purge gases and warm vapors (along with the expectation that these outer tank materials and components are not expected to function after exposure to product temperatures).

Proposal:

Agenda Item: 620-2069 – Attachment A (Section 4)

4.1 General

4.2 Plates

4.2.1 General

4.2.1.1 All plates that are subject to pressure-imposed membrane stress or are otherwise important to the structural integrity of a tank, including bottom plates welded to the cylindrical sidewall of flat-bottom tanks, shall conform to specifications selected to provide a high order of resistance to brittle fracture at the lowest temperature to which the metal in the walls of the tank is expected to fall on the coldest days of record for the locality where the tank is to be installed.

21 **4.2.1.2** The plates used for the tank shall conform to one or more of the specifications listed in Table 4-1 as being acceptable for use at the design metal temperature (refer to 4.2.5 for impact testing requirements).

4.2.1.3 Unless exempted per ~~4.2.2~~ 4.7.1, notch toughness of specially designed plate flanges and cover plates shall be evaluated using governing thickness in Table 4-1. (See 4.3.6.3 for definition of governing thickness.)

21 ~~**4.2.2 Low-stress/Low-temperature Design Provisions**~~

MOVED TO NEW SECTION 4.7

~~Either of the following a) or b) may be used:~~

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

~~1) Consideration of the design metal temperature is not required in selecting material from Table 4-1 for tank components that are not in contact with the liquid or vapor being stored and are not designed to contain the contents of an inner tank (see Q.2.4 and R.2.3).~~

~~2) The design metal temperature may be increased by 30 °F in selecting material from Table 4-1 for tank components conforming to any of the following:~~

14 ~~i) components exposed to the vapor from the liquid or vapor being stored and are not designed to contain the contents of the inner tank;~~

14 ~~ii) components located within, but not welded directly to, a primary liquid container, a secondary liquid container, or a warm product vapor container (see R.2.4).~~

~~3) Excluding bottom plates welded to the cylindrical sidewall of flat-bottom tanks, the plates of a non-refrigerated flat-bottom tank, counterbalanced in accordance with 5.11.2, may be constructed of any material selected from Table 4-1.~~

21 ~~b) Except for lap-welded bottoms, lap-welded suspended decks, lap-welded roofs, and lap-welded liner plates for concrete walls, the provisions of ASME *Boiler and Pressure Vessel Code* (*BPVC*) Section VIII Division 2 issue~~

21 ~~year 2017 (hereinafter referred to as *BPVC* VIII-2-2017) Sections 3.11.2.1 (general); 3.11.2.3 (Exemption From Impact Testing based on the MDMT, Thickness, and Material Specification); 3.11.2.5 (Exemption From Impact Testing Based on Design Stress Values); 3.11.2.6 (Adjusting the MDMT for Impact Tested Materials); 3.11.2.9 (PWHT); and 3.11.2.10 (weld procedure impact testing) together with any referenced paragraphs or sections may be used for material design of components, including but not limited to the allowable stresses, material specifications, locations requiring postweld heat treat, impact test temperatures, impact test exemption temperatures, and impact energy value requirements, with the following clarifications:~~

~~1) NDE methods and acceptance criteria may follow Section 7 of this standard.~~

~~2) The use of *BVPC* VIII-2-2017 may be by individual components, but for connected components which are materially different, such as annular plate attached to first shell ring, the most stringent criteria of the connected components apply to both parts.~~

~~3) Allowable stresses from API 620 still applies to component design, even when using *BPVC* VIII-2-2017. When determining stress ratios for the purpose of entering a table or figure in *BPVC* VIII-2-2017, ASME allowable stresses per ASME *BPVC*.II.D.C-2017 for Class 1 Vessels (no fatigue analysis) are applicable.~~

4.23 Plate Specifications

4.23.1 General

The specifications listed in 4.2.3.2, 4.2.3.3, and 4.2.3.4 are approved for plates, subject to the modifications and limitations of this paragraph, 4.2.4, and Table 4-1.

4.23.2 ASTM Specifications

The following ASTM specifications are approved for plates.

1) A20.

2) A36.

18 3) A131 (structural quality only).

4) A283 (Grades C and D only, with a maximum nominal thickness of $^{3}/_{4}$ in.).

5) A285 (Grade C only, with a maximum nominal thickness of $^{3}/_{4}$ in.).

14 6) A516.

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

8) A573.

9) A633 (Grades C and D only).

18 10) A662 (Grades B and C only).

11) A737 (Grade B only).

18 12) A841 Classes 1, 2 (Grades A and B only) with the following modification: carbon equivalency (CE) shall be per supplementary requirement S77.

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

Design Metal Temperature (See 4.2.1)	Plate Thickness Including Corrosion Allowance (in.)	Permissible Specifications			
		Specification	Grade/Class	Special Requirements (in Addition to 4.2.3)	
65 °F and warmer	≤ 3/4	Any listed in 4.2.3	—	None	18
	≤ 1	ASTM A36	—	None	14
	> 1	G40.21	38W, 44W, 50W	Note 1	
25 °F and warmer	≤ 1/2	Any listed in 4.2.3	—	None	18
	≤ 1	ASTM A36	—	Note 5	
		ASTM A131	B	None	
		CSA G40.21	38W, 44W, 50W	None	
–5 °F and warmer	≤ 1/2	ASTM A131	B	None	18
		CSA G40.21	38W, 44W, 50W	None	
	> 1/2	ASTM A516	55, 60, 65, 70	Note 1	
		ASTM A537	Class 1	None	18
		ASTM A537	Class 2	Note 6	18
		ASTM A573	58, 65, 70	Note 1	
		ASTM A662	B and C	Note 1	
		CSA G40.21	38W, 44W, 50W	Note 2	18
		ISO 630	S275, S355 Quality D	Notes 1 and 2	18
		EN 10025	S275, S355 Quality J2	Notes 1 and 2	
–35 °F and warmer	≤ 1/2	ASTM A516	55, 60, 65, 70	None	18
		ASTM A573	58, 65, 70	None	18
		ASTM A662	B and C	None	
		CSA G40.21	38W, 44W, 50W	Note 2	
		ISO 630	S275, S355 Quality D	Note 2	18
		EN 10025	S275, S355 Quality J2, K2	Note 2	
	≤ 1	ASTM A516	55, 60, 65, 70	Note 3	
		ASTM A537	Class 1	None	18
		ASTM A537	Class 2	Note 6	18
		ASTM A573	58	Note 3	
		ASTM A633	C and D	None	
		ASTM A662	B and C	Note 3	18
		ASTM A737	B	None	
		ASTM A841	Classes 1, 2 (Grades A and B)	Notes 4 and 6	18
		CSA G40.21	38W, 44W, 50W	Notes 2 and 3	
		ISO 630	S275, S355 Quality D	Notes 2 and 3	18
		EN 10025	S275, S355 Quality J2, K2	Notes 2 and 3	

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

Design Metal Temperature (See 4.2.1)	Plate Thickness Including Corrosion Allowance (in.)	Permissible Specifications		
		Specification	Grade/Class	Special Requirements (in Addition to 4.2.3)
	> 1	ASTM A516	55, 60, 65, 70	Notes 3 and 4
		ASTM A537	Class 1	Note 4
		ASTM A537	Class 2	Notes 4 and 6
		ASTM A573	58	Notes 3 and 4
		ASTM A633	C and D	Note 4
		ASTM A662	B and C	Notes 3 and 4
		ASTM A737	B	Note 4
		ASTM A841	Classes 1, 2 (Grades A and B)	Notes 4 and 6
		CSA G40.21	38W, 44W, 50W	Notes 2, 3, and 4
		ISO 630	S275, S355 Quality D	Notes 2, 3, and 4
		EN 10025	S275, S355 Quality J2, K2	Notes 2, 3, and 4
Colder than –35 °F but warmer than or equal to –55 °F	Thicknesses as designated/allowed above, or as allowed by the references in 4.2.2.	At the DMT, any material specification and grade listed above when both of the following are satisfied: a) the impact requirements in 4.2.5 and Table 4-3 with 5 ft-lbs added to the minimums are satisfied, and b) the weld procedure requirements in 6.7 are satisfied.		Alternatively, the low-stress/low-temperature allowances per 4.2.2 may be used.

NOTE 1 All plates over $1\frac{1}{2}$ in. thick shall be normalized.

NOTE 2 The steel shall be killed and made with fine-grain practice.

NOTE 3 The plates shall be normalized or quench tempered (see 4.2.4.2).

NOTE 4 Each plate shall be impact tested in accordance with 4.2.5.

NOTE 5 The manganese content shall be within the range of 0.80 % to 1.20 %.

NOTE 6 See Section 4.2.6.

4.2.3.3 CSA Specification

The following CSA specification is approved for plates: G40.21 (Grades 38W, 44W, and 50W only; if impact tests are required, these grades are designated 38WT, 44WT, and 50WT). All CSA specification plates shall be ordered with the tensile strength limited to no greater than 140 MPa (20 ksi) above the minimum specified tensile strength.

4.2.3.4 ISO Specification

The following ISO specification is approved for plates: 630 (Grades S275 and S355 in Qualities C and D only). Elements added for grain refining or strengthening shall be restricted in accordance with Table 4-2.

4.2.3.5 EN Specification

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

Table 4-2—Maximum Permissible Alloy Content

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

NOTE 1 When not included in the material specification, the use of these alloys, or combinations thereof, shall be at the option of the plate producer, subject to the approval of the purchaser. These elements shall be reported when requested by the purchaser.

NOTE 2 The material shall conform to these requirements on product analysis subject to the product analyses tolerances of the specification.

NOTE 3 Columbium, when added either singly or in combination with vanadium, shall be restricted to plates of 0.50-in. maximum thickness unless it is combined with a minimum of 0.15 % silicon.

NOTE 4 When added as a supplement to vanadium, nitrogen (a maximum of 0.015 %) shall be reported and the minimum ratio of vanadium to nitrogen shall be 4:1.

4.2.4 Plate Manufacture

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

4.2.4.2 Subject to the purchaser's approval, thermo-mechanical-control-process (TMCP) plates (plates produced by a mechanical-thermal rolling process designed to enhance notch toughness) may alternatively be used where heat treated plates are normally required by Table 4-1 (note 1) because of thickness over 1½ in. In this case, each TMCP plate-as-rolled shall receive Charpy V-notch impact energy testing in accordance with 4.2.5.

4.2.5 Impact Test Requirements for Plates

4.2.5.1 Table 4-1 provides exemption and impact testing requirements of plates for various grades for given thickness range and design metal temperature. Any material listed in Table 4-1 may be used for any thickness and temperature provided the material meets impact test requirements as specified in 4.2.5 and Table 4-3 and welding procedure requirements specified in 6.7. When the plate is not exempted from impact testing per Table 4-1 or ~~4.2.2~~ 4.7.1, each plate shall be impact tested; plate refers to the unit plate rolled from a slab or directly from an ingot. The ASTM A370, Type A, Charpy V-notch test shall be used. The long dimension of the specimen shall be parallel to the direction of the expected maximum stress. When the coincident stresses are approximately equal, the specimens shall be taken transverse to the final direction of the plate rolling. The minimum energy absorption values of Table 4-3 shall be satisfied.

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

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

[a] The stated values apply to full-sized specimens. For sub-size specimen acceptance criteria, see ASTM A20. An impact test temperature lower than the design metal temperature may be used by the manufacturer, but the impact value at the test temperature must comply with Table 4-3. When plate is selected, consideration must be given to the possible degradation of the impact properties of the plate in the weld heat-affected zone.

[b] The steel shall be made with fine-grain practice, without normalizing, for thicknesses of 3/16 in. to 1 1/2 in.

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

[d] The manganese content shall be in the range of 0.80 % to 1.20 %.

[e] See Section 4.2.6

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

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

4.2.6 Simulated Test Coupons

When used in stress-relieved assemblies, the material of quenched and tempered steels A537, Cl 2, and TMCP steel A841 shall be represented by test specimens that have been subjected to the same heat treatment as that used for the stress relieved assembly. 18

4.3 Pipe, Flanges, Forging, and Castings

4.3.1 General

All pipe, flanges, forgings, and castings used in the parts of the tanks that are subject to internal pressure shall conform to applicable requirements of 4.3.2 to 4.3.6 inclusive.

4.3.2 Pipe 18

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

a) ASTM A53;

b) ASTM A106;

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

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

e) ASTM A333;

f) ASTM A524;

g) ASTM A671 (Grades CA, CC, and CD); 18

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

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

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

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

c) Impact tests for qualifying the welding procedure for the pipe longitudinal welds shall be performed in accordance with 6.7.1. 18

4.3.2.3 For design metal temperatures below –20 °F, the materials shall conform to Tables R-1 and/or R-3, or 4.7.1. 18

4.3.3 Built-up Fittings

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

4.3.4 Flanges

4.3.4.1 Hub, slip-on welding neck and long welding neck flanges shall conform to the material requirements of ASME B16.5 for forges carbon steel flanges. Plate material used for nozzle flanges shall have physical properties better than or equal to those required by ASME B16.5. Plate flange material shall conform to 4.2.1.3 and 4.2.3.

4.3.4.2 For nominal pipe sizes greater than 24 in., flanges that conform to ASME B16.47, Series B, may be used, subject to the purchaser's approval. Particular attention should be given to ensuring that mating flanges of appurtenances are compatible.

4.3.5 Castings and Forgings

Large castings and forgings not covered in 4.1.3 shall be of welding grade if welding is to be done on them. If castings or forging materials have design metal temperatures below –20 °F, the materials shall conform to Tables R-1 and/or R-3. They shall conform to one of the following ASTM specifications: 18

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

b) A105,

c) A181,

d) A350.

4.3.6 Toughness Requirements of Pipe, Flanges, and Forgings

Except as covered in 4.3.2.2 and 4.3.5, the toughness requirements of pipe, flanges, and forgings shall be established as described in 4.3.6.1 through 4.3.6.4 or in 4.7.1.

4.3.6.1 No impact testing is required for ASME B16.5 ferritic steel flanges used at minimum design metal temperature, no colder than –20 °F. Piping materials made according to ASTM A333 and ASTM A350 may be used at a minimum design metal temperatures, no lower than the impact test temperature required by the ASTM specification for the applicable material grade, unless additional impact tests (see 4.3.6.4) are conducted.

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

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

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

4.3.6.3 The materials in the groups listed in 4.3.6.2 may be used at nominal thicknesses, including corrosion allowance, at minimum design metal temperatures no lower than those shown in Figure 4-2 without impact testing (see 4.3.6.4). The governing thickness (see Figure 4-3) to be used in Figure 4-2 shall be as follows.

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

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

c) For nonwelded parts (such as bolted flanges), it is $^1/_4$ of flat cover nominal thickness.

4.3.6.4 When impact tests are required by 4.3.6.2 or 4.3.6.3, they shall be performed in accordance with the requirements, including minimum energy requirements of ASTM A333, Grade 1 for pipe, or ASTM A350 Grade LF1,

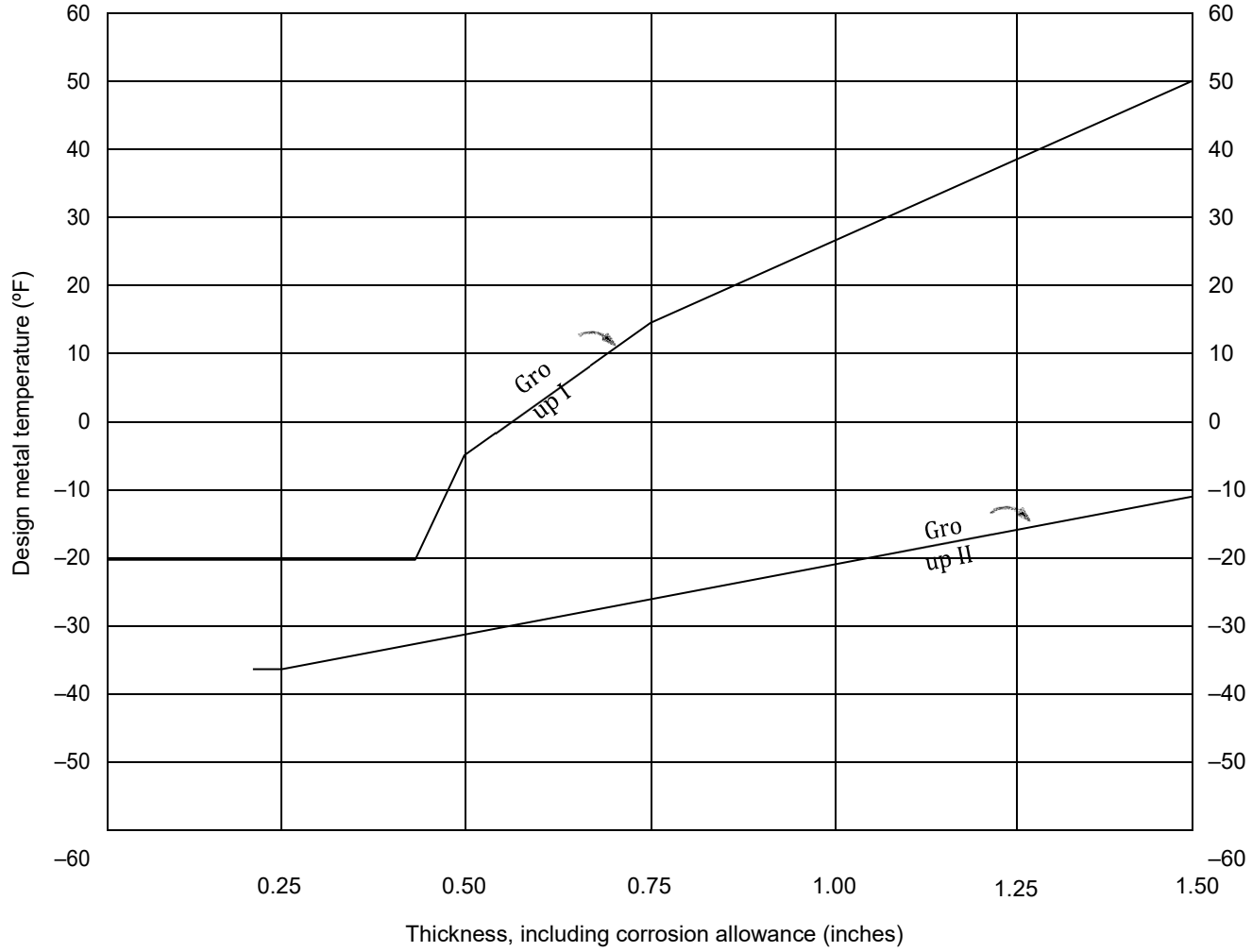


Figure 4-2—Minimum Permissible Design Metal Temperature for Pipe, Flanges, and Forgings without Impact Testing

for forgings at a test temperature no higher than the minimum design metal temperature. Except for the plate specified in 4.2.3, the material specified in 4.3 shall have a minimum Charpy V-notch impact strength of 13 ft-lb (full size specimen) at a temperature no higher than the minimum design metal temperature.

4.4 Bolting Material

4.4.1 Carbon steel bolts and nuts may be used if they conform to the following, or to better[15], specifications: 18

a) ASTM A193,

b) ASTM A307,

c) ASTM A320,

d) ASTM A194,

e) ASTM A563.

4.4.2 For design metal temperatures below –20 °F, bolting materials shall conform to Tables R-1 and/or R-3, or 4.7.2. 18

[15] If higher-strength grades of bolts are used, higher bolt stress values are not recommended with full-faced gaskets.

4.5 Structural Shapes

18 All structural shapes that are subject to pressure-imposed loads or are otherwise important to the structural integrity of a tank shall be made only by the open-hearth, electric-furnace, or basic-oxygen process. If structural shapes have design metal temperatures below –20 °F, the materials shall conform to Tables R-1 and/or R-3, or 4.7.1. Structural shapes shall conform to one of the following specifications:

a) ASTM A36;

b) ASTM A131;

c) ASTM A633 (Grade A only);

d) ASTM A992;

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

18 f) ISO 630, Grade S275, Qualities B, C, and D;

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

4.6 Anchor Bolting Material

4.6.1 Unless otherwise specified by the purchaser, anchor bolts shall be one of the following:

a) round bar to ASTM A36, threaded and galvanized;

18 b) bolts to ASTM F1554, Grade 36 or 55, galvanized;

c) round bar to ASTM A479-TP304 stainless steel, annealed;

d) bolts to ASTM A193-B8-CLASS 1;

e) bolts to ASTM F468, Alloy 6061-T6.

4.6.2 Anchor bolts with minimum specified yield strength greater than 55 ksi are prohibited.

18 **4.6.3** Nuts for carbon steel anchors shall be galvanized heavy hex. Welding is not permitted on anchors that are galvanized. Nuts for stainless steel anchors shall be Type 316 stainless steel heavy hex.

4.6.4 Aluminum anchorage option is provided for certain tanks designed to the provisions of Annex Q.

4.7 Low Stress/Low Temperature Design Provisions

4.7.1 The following apply to materials in 4.2, 4.3, and 4.5.

Either of the following a) or b) may be used:

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

1) Consideration of the design metal temperature is not required in selecting material from Table 4-1 for tank components that are not in contact with the liquid or vapor being stored and are not designed to contain the contents of an inner tank (see Q.2.4 and R.2.3).

2) The design metal temperature may be increased by 30 °F in selecting material from Table 4-1 for tank components conforming to any of the following:

i) components exposed to the vapor from the liquid or vapor being stored and are not designed to contain the contents of the inner tank;

ii) components located within, but not welded directly to, a primary liquid container, a secondary liquid container, or a warm product vapor container (see R.2.4).

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

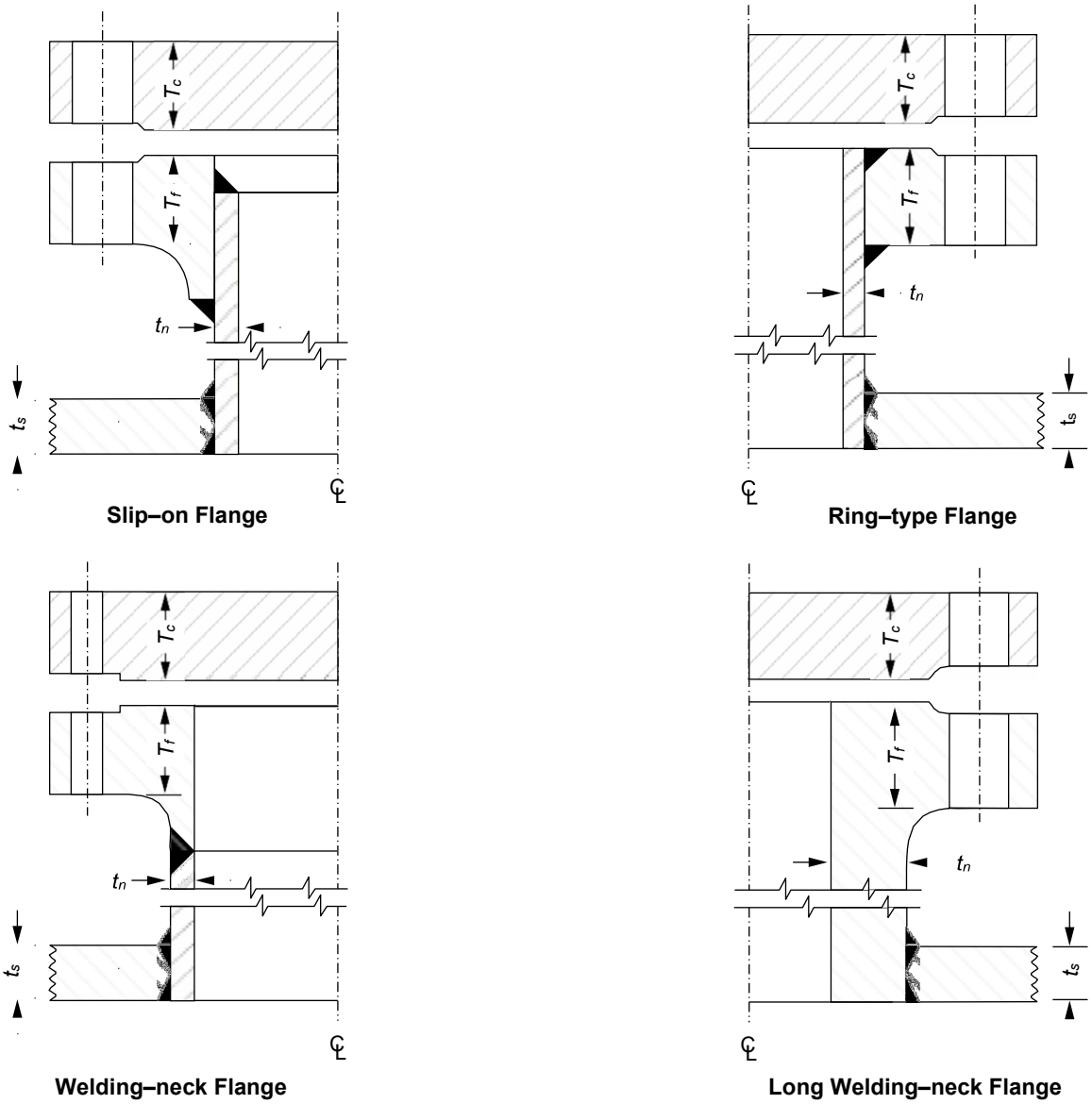
b) Except for lap-welded bottoms, lap-welded suspended decks, lap-welded roofs, and lap-welded liner plates for concrete walls, the provisions of ASME *Boiler and Pressure Vessel Code* (*BPVC*) Section VIII Division 2 issue year 2017 (hereinafter referred to as *BPVC* VIII-2-2017) Sections 3.11.2.1 (general); 3.11.2.3 (Exemption From Impact Testing based on the MDMT, Thickness, and Material Specification); 3.11.2.5 (Exemption From Impact Testing Based on Design Stress Values); 3.11.2.6 (Adjusting the MDMT for Impact Tested Materials); 3.11.2.9 (PWHT); and 3.11.2.10 (weld procedure impact testing) together with any referenced paragraphs or sections may be used for material design of components, including but not limited to the allowable stresses, material specifications, locations requiring postweld heat treat, impact test temperatures, impact test exemption temperatures, and impact energy value requirements, with the following clarifications:

1) NDE methods and acceptance criteria may follow Section 7 of this standard.

2) The use of *BVPC* VIII-2-2017 may be by individual components, but for connected components which are materially different, such as annular plate attached to first shell ring, the most stringent criteria of the connected components apply to both parts.

3) Allowable stresses from API 620 still applies to component design, even when using *BPVC* VIII-2-2017. When determining stress ratios for the purpose of entering a table or figure in *BPVC* VIII-2-2017, ASME allowable stresses per ASME *BPVC*.II.D.C-2017 for Class 1 Vessels (no fatigue analysis) are applicable.

4.7.2 For bolting materials listed in 4.4 bolting materials (bolts and nuts) the provisions of *BPVC* VIII-2-2017 Sections 3.11.6 (bolting materials) with any referenced paragraphs or sections may be used for material design of bolts and nuts, including but not limited to the allowable stresses, material specifications, impact test temperatures, impact test exemption temperatures, and impact energy value requirements.



NOTE 1 Shell reinforcing plate is not included inthe illustration above.

NOTE 2 t_s = shell thickness; t_n = nozzle neck thickness; T_f = flange thickness; T_c = bolted cover thickness.

NOTE 3 The governing thickness for each component shall be as follows:

Components	Governing Thickness (whichever is less)
Nozzle neck	t_n or t_s
Slip-on flange	t_n or T_f
Ring-type flange	t_n or T_f
Welding-neck flange	t_n or T_f
Long welding-neck flange	t_n or t_s
Bolted cover	$^1/_4\ T_c$

Figure 4-3—Governing Thickness for Impact Test Determination of Pipe, Flanges, and Forgings

Agenda Item: 620-2069 – Attachment B (Annex Q Modifications)

Q.1 Scope

Q.2 Materials

Q.2.1 General

Q.2.2 Product Temperature Materials

18

Q.2.3 Impact Test Requirements for Product Temperature Materials

Q.2.3.1 9 %, 7 %, or 5 % nickel steel shall be impact tested in accordance with Q.2.3.2 through Q.2.3.4. Impact testing is not required for austenitic stainless steel, nickel alloy, and aluminum materials. Welds in high-alloy (austenitic) stainless steel shall be impact tested if required by Q.4.4. 18

Q.2.3.2 Impact testing of plates, including structural members made of plate, shall comply with the following.

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

b) For ASTM A353, A553, A841, and A844 steels, Charpy V-notch specimens shall be cooled to a temperature of –320 °F. 18

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

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

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

e) Each test shall consist of three specimens, and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. (15 mils) as required by ASTM A353, A553, A645, A 841, and A844. 18

f) Retests shall be in accordance with ASTM A370. 18

Q.2.3.3 Impact testing of structural members shall comply with the following:

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

b) Charpy V-notch specimens shall be cooled to a temperature of –320 °F (see Q.2.3.2, Items b and c) for A353, A553, A645, Grade A or B, A841 Grade G, and A844 steels for impact testing.

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

d) Each test shall consist of three specimens, and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. (15 mils).

e) Retests shall be in accordance with ASTM A370.

Q.2.3.4 Impact testing of forgings, piping, and tubing shall comply with the following:

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

b) Charpy V-notch specimens shall be cooled to a temperature of –320 °F (see Q.2.3.2, Items b and c) for A522, A333 (Grade 8), and A334 (Grade 8) steels for impact testing.

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

d) Each test shall consist of three specimens, and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. (15 ml) as required by ASTM A522, A333 (Grade 8), and A334 (Grade 8).

e) Retests shall be in accordance with ASTM A522, A333 (Grade 8), and A334 (Grade 8).

Table Q.1—ASTM Standards for Product Temperature Materials

Plates, Structural Members, and Bars	Piping, Pipe Fittings, and Tubing	Forgings	Bolting	
A353	A333, Grade 8 (note 2)	A522		18
A553, Type 1	A334, Grade 8 (note 2)			18
A553, Type III	B444 (UNS-N06625), Gr. 1			18
A844	B444 (UNS-N06625), Gr. 2			
A841, Gr G, Cl 9 (note 7)	B619 (UNS-N10276) (notes 3 & 6)			
A645, Grade A	B622 (UNS-N10276)			
A645, Grade B				18
A240, Type 304	A213, Grade TP 304	A182, Grade F304	A320, Grades B8, B8C, B8M, and B8T	
A240, Type 304L	A213, Grade TP 304L	A182, Grade F304L	A193-B8, Class 1	14
A276, Type 304, Condition A (note 1)	A312, Grade TP 304 (note 3)	A182, Grade F316	A193-B8M, Class 1	
A276, Type 304L, Condition A (note 1)	A312, Grade TP 304L (note 3)	A182, Grade F316L		18
A479, Type 304, Condition A (note 1)	A403, Grade WP304		A276, Type 304, Condition A (note 8)	
A479, Type 304L, Condition A (note 1)	A403, Grade WP304L			18
A240, Type 316	A213, Grade TP316		A276, Type 304L, Condition A (note 8)	
A240, Type 316L	A213, Grade TP316L			18
A276, Type 316, Condition A (note 1)	A312, Grade TP316 (note 3)		A479, Type 304, Condition A (note 8)	
A276, Type 316L, Condition A (note 1)	A312, Grade TP316L (note 3)			18
A479, Type 316, Condition A (note 1)	A403, Grade WP316		A479, Type 304L, Condition A (note 8)	
A479, Type 316L, Condition A (note 1)	A403, Grade WP316L			18
A240, Type 201LN (UNS-S20153)	A358, Grade 304, Class 1 (note 4)		A276, Type 316, Condition A (note 8)	
	A358, Grade 304L, Class 1 (note 4)			18
	A358, Grade 316, Class 1 (note 4)		A276, Type 316L, Condition A (note 8)	
	A358, Grade 316L, Class 1 (note 4)			18
			A479, Type 316, Condition A (note 8)	
				18
			A479, Type 316L, Condition A (note 8)	
				18
			A194, Grades 8, 8C, 8M, and 8T	
B209, Alloy 3003-0 (note 5)	B210, Alloy 3003-0	B247, Alloy 3003-H112	F468, Alloy 6061-T6	
B209, Alloy 5052-0 (note 5)	B210, Alloy 3003-H113		F467, Alloy 6061-T6	
B209, Alloy 5083-0 (note 5)	B210, Alloy 5052-0	B247, Alloy 5083-H112		
B209, Alloy 5086-0 (note 5)	B210, Alloy 5086-0	B247, Alloy 6061-T6		
B209, Alloy 5154-0 (note 5)	B210, Alloy 5154-0			
B209, Alloy 5456-0 (note 5)	B241, Alloy 5052-0			
B221, Alloy 6061-T4 and T6	B241, Alloy 5083-0			
B308, Alloy 6061-T6	B241, Alloy 5086-0			
	B241, Alloy 5454-0			

Table Q.1—ASTM Standards for Product Temperature Materials (Continued)

Plates, Structural Members, and Bars	Piping, Pipe Fittings, and Tubing	Forgings	Bolting
NOTE 1 Cold finishing after annealing is not permitted on material used for parts with loading transverse to the rolling direction.			
NOTE 2 Seamless piping and tubing only.			
NOTE 3 Purchased welded pipe shall be welded without the addition of filler metal using a process permitted by the named ASTM specification and shall be tested hydrostatically or by eddy current to ASTM requirements.			
NOTE 4 Impact test of welds shall be made for the welding procedure when required by Q.4.4.			
NOTE 5 ASTM B221 structural sections are also permitted.			
NOTE 6 Pipe conforming to ASTM B619 and note 3 of this table may be used in diameters exceeding the 8-in. limit stated in B619 when approved by purchaser. Further, for this pipe over 8-in. diameter, the addition of filler metal is permitted.			
NOTE 7 ASTM A841, Grade G, Class 9, is permitted only with supplementary requirement S64.			
NOTE 8 Cold finishing after annealing is not permitted on material used for parts with loading in shear.			

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

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

[a] When the alternate flaw acceptance criteria of Table U-2 are applied, the higher impact values of Table U-3 are required for plates.

[b] Average of three specimens.

[c] Only one specimen of a set.

Q.2.4 Atmospheric Temperature Materials

Q.2.4.1 The following are considered warm product vapor container components:

a) roofs over suspended decks;

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

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

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

Q.2.4.2 Material for warm product vapor containers shall conform to one of the following.

a) Table 4-1 and 4.3 to 4.6 for design metal temperatures down to –35 °F ~~(lowest one-day mean ambient temperature of –35 °F)~~ without impact tests unless they are required by Table 4-1 or by the purchaser.

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

c) Q.2.2 without impact tests unless they are specified by the purchaser.

d) Selection per the low-stress/low-temperature provisions of ~~4.2.2~~ 4.7.1. 21

Q.2.4.3 The following are considered purge gas container components:

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

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

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

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

e) roofs in membrane containment systems (both Type M-1 and M-CC) that are lined with insulation and a metallic membrane. 21

Q.2.4.4 Material for purge gas containers shall conform to one of the ~~approved materials listed in Table 4-1.~~ following:

a) A Table 4-1 and 4.3 to 4.6 for design metal temperatures down to –35 °F impact tests unless they are required by Table 4-1 or by the purchaser.

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

c) Consideration of the design metal temperature is not required if the actual stress does not exceed one-half the allowable tensile design stress for the material.

Q.2.4.5 Material for the membrane tank outer container of a membrane containment tank system Type M-1 shall conform to one of the approved materials listed in Table 4-1. 21

Q.2.5 Structural Shapes

Structural shapes of 9 %, 7 %, and 5 % nickel steel may be furnished to the chemical and physical requirements of ASTM A353, A553, A645, A841, or A844. Physical tests shall be in accordance with the requirements of ASTM A6. 18

Q.2.6 Piping, Tubing, and Forgings

Q.2.6.1 In addition to the specific requirements of this annex, all piping within the limitations of Q.1.2 shall fulfill the minimum material requirements of ASME B31.3.

Q.2.6.2 Except as allowed by Q.2.6.3 and Q.2.6.4, piping, tubing, and forgings used for openings within a distance of $2 \times \sqrt{d \times t_n}$ from the tank wall shall be compatible in welding, strength, and thermal expansion coefficient with the tank wall material (d and t_n are defined in Figure 5-7).

Q.2.6.3 Nickel alloy material B444 (UNS-N06625), B622 and B619 (UNS-N10276) in Table Q-1 may be used for piping and tubing as a substitute for A333, Grade 8 or A334, Grade 8 for openings through 9 % Ni (A353, A553, A844), 7 % Ni (A841 and A553), and 5 % Ni (A645) storage tanks, providing these materials meet the applicable 18

requirements in this annex and are not used for reinforcement.

Q.2.6.4 300 series stainless steel materials in Table Q-1 may be used for piping and tubing for openings through 201LN storage tanks, providing these materials meet the applicable requirements in this annex and are not used for reinforcement. 14

Q.2.7 Internal Components

Materials for components located within, but not welded directly to the primary liquid container, the secondary liquid container, the warm product vapor container, the purge gas container, the membrane, or the membrane tank outer container shall conform to one of the following, as determined by design metal temperature: 21

a) the requirements of Q.2.2;

b) Table Q-1 without impacts, unless specified by the purchaser; 14

c) Table R-3 for design metal temperatures down to –60 °F without impacts, unless they are required by Table R-4 or by the purchaser.

Agenda Item: 620-2069 – Attachment C (Annex R Modifications)

R.1 Scope

R.1.1 General

This annex together with the basic sections of API 620 provides requirements for the materials, design, and fabrication of the metallic portions of a refrigerated tank system. The requirements for a basic API 620 tank apply to primary and secondary liquid containers, metallic membrane tank outer containers, refrigerated temperature roofs, warm product vapor containers, purge gas containers, and their appurtenances except where they are superseded by any requirements of this annex. The complete tank system, of which the metallic components are a part, shall be in accordance with API 625. 21

R.1.2 Piping Limitations

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

R.1.3 Pressure Range

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

R.1.4 Temperature

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

R.1.5 Definitions

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

— refrigerated tank system;

— single containment tank system;

— double containment tank system;

— full containment tank system;

— membrane containment tank system: 21

  — membrane containment tank system Type M-1;

  — membrane containment tank system Type M-CC;

— primary liquid container;

— secondary liquid container;

— warm product vapor container;

— purge gas container;

— membrane tank outer container; 21

— refrigerated temperature roof;

— design pressure;

— annular space;

— suspended deck;

— design metal temperature.

R.2 Materials

R.2.1 General

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

R.2.2 Product Temperature Materials

R.2.2.1 General

R.2.2.1.1 Materials for the following metallic components (including their penetrations, piping, anchors, stiffeners, and attachments) shall be selected from Table R-1 and shall be impact tested in accordance with R.2.2.2 through R.2.2.5 (see Note following list).

a) Primary liquid containers;

b) Secondary liquid containers;

c) Membrane tank outer container Type M-CC;

d) Refrigerated temperature roofs (see R.2.2.1.3 for low stress exception):

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

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

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

g) Metallic suspended decks for insulation (see R.2.2.1.4 for exceptions);

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

NOTE Specified toughness levels together with workmanship, tolerance, and NDE requirements specified in this standard provide for prevention of crack initiation under the design conditions and specified upset conditions named herein and in API 625. These minimum requirements may not provide for arrest of a running crack should one initiate from conditions outside the named conditions or from container materials and/or construction not compliant with this standard. A project-specific fracture mechanics analysis could be considered if the purchaser specifies crack arrest performance.

R.2.2.1.2 Materials for liner plates, if required for liquid containment, in concrete primary or secondary liquid containers, loaded in compression under all design conditions shall be selected from materials explicitly listed in Table 4-1 excluding materials rated for design metal temperature 65 °F and over.

R.2.2.1.3 Material for refrigerated temperature roofs where combined membrane and primary bending tensile stress does not exceed 6000 lb/in.^{2}, may also satisfy the criteria of R.2.3.2 a, b, or c in lieu of the requirements of R.2.2.

R.2.2.1.4 Materials for metallic suspended decks supporting insulation where combined membrane and primary bending tensile stress does not exceed 6000 lb/in.^{2} require no impact testing and any metallic material is permitted. Alternately, the material may be selected from Table Q-1 without regard to stress level. Material to be welded shall be of weldable quality.

R222 Impact Test Requirements for Plates

R2221 Impact testing of plates, including structural members made of plate, shall comply with Table R-2. | 21

R2222 Impact test specimens shall be taken transverse to the direction of final plate rolling.

Table R-1—Standards for Product Temperature Materials (see Note 2) | 14

Component	Materials	Notes	
Plate	Materials listed in Table R-2	1	21
Pipe	ASTM A333 (seamless only)	3	18
	ASTM A671 Class 22 in Grades CC60, CC65, CC70, CD70, and CD80, with Supplementary Requirement S2	3 and 9	
Pipe fittings	ASTM A420	3	14
Structural members	Plate or pipe as listed above	4	
	Structural shapes	5	
	ASTM A36	6	
	ASTM A992		
	ASTM A131 Grades D and E		
	ASTM A633 Grade A		
	CSA G40.21 Grades 38WT, 44WT, and 50WT		18
	ISO 630 S275 and S355 in Quality D	7, 8	
	EN 10025-2 S275 in Quality J2	7, 8	
	EN 10025-2 S355 in Quality J2 and K2	7, 8	
Forgings	ASTM A350	3	14
~~Bolts~~ Bolting	ASTM A320 Grade L7	3	
	ASTM~~A~~ 193 Class 1: Grades B8 and B8M		18
	ASTM~~A~~ 193 Class 2: Grades B8 and B8M		
	ASTM~~A~~ 276 Type 304, 304L, 316, and 316L (Condition A, B, or S)		
	ASTM~~A~~ 479 Type 304, 304L, 316, and 316L (Condition A, S1, or S2)		
	ASTM A194, Grades B8, B8M		

NOTE 1 See R.2.2.4.

NOTE 2 Type 304, 304L, 316, or 316L stainless steel material, as permitted in Table Q-1 may be used at the maximum allowable stress values permitted by Table Q-3. Impact tests of this material are not required. Welding procedures shall be qualified in accordance with the more restrictive requirements of R.4.2 and Q.4.4 as applicable to the base materials and welding material. The limitations on cold finishing of ASTM A276 and A479 in Table Q-1 need not be applied. | 18

NOTE 3 See R.2.2.3.

NOTE 4 Plate or pipe materials to be made into a structural member shall conform to the impact testing requirements of R.2.2.5.

NOTE 5 Structural shapes shall be normalized, if necessary, to meet the required minimum Charpy V-notch impact values of R.2.2.5. | 18

NOTE 6 The steel shall be made with fine grain practice, and manganese content shall be in the range of 0.80 % to 1.20 % by ladle analysis.

R.2.2.3 The Charpy V-notch test shall be used, and the minimum impact value at the design metal temperature shall be as given in Table R-2. For subsize specimen acceptance criteria, see ASTM A20. An impact test temperature lower than the design metal temperature may be used by the manufacturer, but in such a case the impact values at the test temperature must comply with Table R-2.

R.2.2.4 All other impact requirements of ASTM A20, Supplementary Requirement S5, shall apply for all materials listed in Table R-2, including specifications that do not refer to ASTM A20.

R.2.2.5 When as-rolled plate material complies with impact test requirements as specified here, the material need not be normalized. If, as with ASTM A516, the specification prohibits impact test without normalizing, but otherwise permits as-rolled plates, the material may be ordered in accordance with the above provision and identified as "MOD" for this API modification.

R.2.2.2.6 The low-stress/low-temperature provisions of 4.2.2 b) may be used for determining the acceptability of conditions wherein a primary liquid container is not full, but temperature is lower than the materials' impact test temperature.

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

Specification Number	Grade/Class	Range in Thickness (in.)	Plate Impact Value[b] (ft–lb)		Weld Impact Value (ft-lb)	
			Average	Individual	Average	Individual
ASTM A516	55 and 60	3/16 to 2	25	20	20	15
ASTM A516	65 and 70	3/16 to 2	25	20	20	15.
ASTM A537	Class 1	3/16 to 2	25	20	20	15
ASTM A537[f]	Class 2	3/16 to 2	30	25	25	20
ASTM A662	B and C	3/16 to 2	25	20	20	15.
ASTM A737	B	3/16 to 2	25	20	20	15
ASTM A841[f]	Class 1 (Grades A and B)	3/16 to 2	25	20	20	15
ASTM A841[f]	Class 2 (Grades A and B)	3/16 to 2	30	25	25	20
ISO 630	S355 Quality D[c,d,e]	3/16 to 2	25	20	20	15
EN 10028	P275 Qualities NH, NL1, and NL2	3/16 to 2	25	20	20	15
EN 10028	P355 Qualities N, NH, NL1, and NL2	3/16 to 2	25	20	20	15
CSA G40.21	38WT[c,d,e]	3/16 to 2	25	20	20	15
CSA G40.21	44WT[c,d,e]	3/16 to 2	25	20	20	15
CSA G40.21	50wt[c,d,e]	3/16 to 2	25	20	20	15

[a] See R.2.2.2.

[b] For design metal temperatures of –40 °F and lower, the plate impact values shall be raised 5 ft-lb.

[c] The frequencies of testing for mechanical and chemical properties shall be at least equal to those of ASTM A20.

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

[e] The steel shall be fully killed and made with fine-grain practice.

[f] See Section 4.2.6.1

R.2.2.3 Impact Requirements for Pipe, Bolting, and Forgings

R.2.2.3.1 Pipe (including structural members made of pipe), bolting, and forgings shall be impact tested as defined below. Pipe, bolting, and forgings shall also be in accordance with ASTM specifications referred to in Table R-1, except as permitted in R.2.2.3.3.

R.2.2.3.2 Piping materials made according to the ASTM specifications referred to in Table R-1 shall not be used at design metal temperatures lower than the impact test temperature required by the ASTM specification for the applicable material grade except as permitted in R.2.2.3.3.

R.2.2.3.3 For design metal temperatures below the impact test temperatures required in Table R-1 specifications, and for seamless pipe, bolting, and forgings to other specifications listed in Table R-3, one of the following shall be satisfied.

a) The impact test temperature shall be at least 30 °F colder than the design metal temperature. 18

b) Materials impact tested at the design metal temperature or lower with Charpy impact test energy value of 25 ft-lb (average), 20 ft-lb (minimum) are acceptable for design metal temperatures above –40 °F. Materials with an energy value of 30 ft-lb (average), 25 ft-lb (minimum) are acceptable for design metal temperatures of –40 °F or lower.

Table R-3—Atmospheric Temperature Material Specifications

Material	Component Design Metal Temperature	
	–60 °F to below –20 °F	**–20 °F to 40 °F.** 18
Plate	Materials as listed in Table R-4	Materials as listed in Table R-4
Pipe	ASTM A106	As listed in 4.3
Piping fittings	ASTM A420	As listed in 4.3
Structural members	Plate or pipe as listed above ASTM A36 structural shapes (see Note 2) ASTM A131 Grade D and E CSA G40.21 Grades 38W, 44W, and 50W (see Note 1) 18 ISO 630 S275 and S355 in Quality D. 18 EN 10025-2 S275 in Quality J2 EN 10025-2 S355 in Quality J2 and K2	Plate or pipe as listed above Structural shapes as listed in 4.5 or as listed under the –60 °F to –20 °F temperature heading
Forgings	ASTM A105	As listed in 4.3
~~Bolts~~ Bolting	ASTM A193 Grade B7 ASTM A320 Grade L7 ASTM A194 Grade 7	As listed in 4.4

NOTE 1 The steel shall be fully killed and made to fine-grain practice.
NOTE 2 The steel shall be made with fine grain practice, and manganese content shall be in the range of 0.80 % to 1.20 % by ladle analysis.

R.2.2.4 Impact Requirements for Thermo-mechanical Control Process (TMCP) Plates

Subject to the approval of the purchaser, TMCP plates (material produced by a mechanical-thermal rolling process designed to enhance the notch toughness) may alternatively be used where heat-treated plates are normally

required. In this case, each TMCP plate-as-rolled shall receive Charpy V-notch impact energy testing in accordance with R.2.2.2.

R.2.2.5 Impact Requirements for Structural Shapes

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

R.2.3 Atmospheric Temperature Materials

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

a) roofs over suspended decks;

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

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

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

21

e) roofs in membrane containment tank systems (both Type M-1 and M-CC) that are lined with insulation and a membrane.

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

a) Table 4-1 and 4.3 to 4.6 for design metal temperatures down to –35 °F ~~(lowest 1-day mean ambient temperature of –35 °F)~~ without impact test unless they are required by Table 4-1 or by the purchaser.

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

21 c) Material may be selected and designed using the low-stress/low-temperature provisions of ~~4.2.2~~ 4.7.1.

R.2.3.3 The following are considered purge gas container components:

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

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

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

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

R.2.3.4 Material for purge gas containers shall conform to one of the ~~approved materials listed in Table 4-1.~~ following:

a) Table 4-1 and 4.3 to 4.6 for design metal temperatures down to –35 °F impact tests unless they are required by Table 4-1 or by the purchaser.

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

c) Consideration of the design metal temperature is not required if the actual stress does not exceed one-half the allowable tensile design stress for the material.

21 **R.2.3.5** Material for membrane tank outer container of membrane containment tank system Type M-1 shall conform to one of the approved materials listed in Table4-1.

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

Group	Specification Number	Grade/Class.	Minimum Design Metal Temperature, °F				
			Plate Thickness Including Corrosion Allowance, in.				18
			3/16 to 3/8	> 3/8 to 1/2	> 1/2 to 1	> 1 to 1 1/2	
I (semikilled)	A36[d]		–20	–10	+5	—	18
	A31	B	–20	–10	+5	—	18
	CSA G40.21	38W	0	+10	+25	—	
	ISO 630	S275 Quality C[b]	–20	–10	+5	+5	18
	EN 10025	S275 Quality J0[b]	–20	–10	+5	+5	18
II (fully killed)	A573	58[b]	–30	–20	–10	0	
	A516	55 and 60	–30	–20	–10	0	
	A516	55 and 60[c]	–40	–30	—	—	
	ISO 630	S275 Quality D	–30	–20	–10	0	21
	EN 10025	S275 Quality J2[b]	–30	–20	–10	0	18
	CSA G40.21	38W[b]	–40	–30	–15	0	
III (fully killed and high strength)	A573	65 and 70	–30	–20	–10	+5	18
	A516	65 and 70	–30	–20	–10	+5	18
	A516	65 and 70[a]	–40	–30	–15	0	18
	A537	Class 1 and 2	–60	–50	–35	–20	18
	A662	B and C	–40	–30	–15	0	18
	A633	C and D	–60	–50	–35	–20	18
	A737	B	–60	–50	–35	–20	18
	ISO 630	S355 Quality D	–30	–20	–10	+5	21
	EN 10025	S355 Quality J2 and K2[b]	–30	–20	–10	+5	18
	CSA G40.21	44W[b]	–40	–30	–15	0	
	CSA G40.21	50W[b]	–30	–10	+5	+20	

NOTE When normalized, materials in this table may be used at temperatures 20°F below those shown (except for A537 Classes 1 and 2, A633 Grades C and D, and A737 Grade B). If impact tests are required for the materials listed in this table, they shall be in accordance with Table R-5. 18

[a] The carbon content to be restricted to a maximum of 0.20 % by ladle analysis. 14

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

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

[d] The manganese content shall be within the range of 0.80 % to 1.20 %. 14

R.2.4 Internal Components

Materials for components located within, but not welded directly to the primary liquid container, the secondary liquid container, the warm product vapor container, the purge gas container, the membrane, or the membrane tank outer container shall conform to one of the following, as determined by design metal temperature. 21

a) The requirements of R.2.2. 14

b) Table R-3 for design metal temperatures down to -60 °F without impacts, unless they are required by Table R-4 or by the purchaser.

c) If the actual stress under design conditions does not exceed one-third of the allowable tensile stress, and if approved by the purchaser, the design metal temperature may be increased by 30 °F in selecting material from

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

Group	Specification Number	Grade/Class	Range in Thickness (in.)	Impact Value[a] (foot-lbs)	
				Average	Individual
I (semikilled)	A36[d]		3/16 to 1	13	9
	A131	B	3/16 to 1	13	9
	ISO 630	S275 Quality C	3/16 to 1 1/2	13	9
	EN 10025	S275 Quality J0	3/16 to 1 1/2	13	9
II (fully killed)	A573	58[b]	3/16 to 1 1/2	15	10
	A516	55 and 60	3/16 to 2	15	10
	A516	55 and 60[c]	3/16 to 1/2	15	10
	ISO 630	S275 Quality D	3/16 to 1 1/2	15	10
	EN 10025	S275 Quality J2	3/16 to 1 1/2	15	10
	CSA G40.21	38WT	3/16 to 2	15	10
III (fully killed and high strength)	A573	65 and 70	3/16 to 2	15	10
	A516	65 and 70	3/16 to 2	15	10
	A537	Class 1	3/16 to 2	15	10
	A537[e]	Class 2	3/16 to 2	20	15
	A633	C and D	3/16 to 2	15	10
	A662	B	3/16 to 2	15	10
	ISO 630	S355 Quality D	3/16 to 2	15	10
	EN 10025	S355 Quality J2 and K2	3/16 to 2	15	10
	CSA G40.21	44WT	3/16 to 2	15	10
	A841[e]	Class 1 (Grades A and B)	3/16 to 2	15	10
	A841[e]	Class 2 (Grades A and B)	3/16 to 2	20	15

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

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[b] The steel shall be made with fine-grain practice, without normalizing, for thicknesses of 3/16 in. to 1 1/2 in.

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

[d] The manganese content shall be within the range of 0.80 % to 1.20 %.

[e] See Section 4.2.6.1.

Table 4-1, Table R-3, or Table R-4. Calculation of stress shall include restraint stresses including those that are mechanically or thermally induced.