SECTION 4—MATERIALS

4.1 General

4.1.1 Miscellaneous information is contained in 4.1.1.1 through 4.1.1.4.

4.1.1.1 See the Data Sheet for material specifications.

4.1.1.2 Rimmed or capped steels are not permitted.

4.1.1.3 Use of cast iron for any pressure part or any part attached to the tank by welding is prohibited.

- **4.1.1.4** Because of hydrogen embrittlement and toxicity concerns, cadmium-plated components shall not be used without the expressed consent of the Purchaser.

- **4.1.2** Materials used in the construction of tanks shall conform to the specifications listed in this section, subject to the modifications and limitations indicated in this standard. Material produced to specifications other than those listed in this section may be employed, provided that the material is certified to meet all of the requirements of an applicable material specification listed in this standard and the material's use is approved by the Purchaser. The Manufacturer's proposal shall identify the material specifications to be used. When this standard does not address material requirements for miscellaneous items and appurtenances, the Purchaser and/or the Manufacturer shall supply additional material requirements using a supplement to the Data Sheet.

- **4.1.3** When any new or unused plate and pipe material cannot be completely identified by records that are satisfactory to the Purchaser as material conforming to a specification listed in this standard, the material or product may be used in the construction of tanks covered by this standard only if the material passes the tests prescribed in Annex N.

4.1.4 Where materials of construction are used that are certified to two or more material specifications, the material specification chosen for the design calculations shall also be used consistently in the application of all other provisions of this standard. The Purchaser shall be notified of this choice and receive confirmation that the material fully complies with the chosen material specification in all respects.

4.1.5 When a tank is designed to the requirements of this standard using plate material from Group-I through Group-IIIA steels, the tank Manufacturer responsible for any proposed material substitution to use Group-IV through Group-VI steels must do the following.

a) Maintain all of the original design criteria for the lower stress Group-I through Group IIIA steels.

- b) Obtain the prior written approval of the Purchaser.

c) Ensure that all of the design, fabrication, erection, and inspection requirements for the material being substituted will meet the lower stress Group I through Group IIIA specifications for items including but not limited to:

1) material properties and production process methods;

2) allowable stress levels;

3) notch toughness;

4) welding procedures and consumables;

5) thermal stress relief;

6) temporary and permanent attachment details and procedures;

7) nondestructive examinations.

d) Include the pertinent information in the documents provided to the Purchaser, including a certification statement that the substituted material fully complies with 4.1.5 in all respects, and provide all other records covered by the work processes applied to the material such as impact testing, weld procedures, nondestructive examinations, and heat treatments.

4.2 Plates

4.2.1 General

4.2.1.1 Except as otherwise provided for in 4.1, plates shall conform to one of the specifications listed in 4.2.2 through 4.2.6, subject to the modifications and limitations in this standard.

4.2.1.2 Plate for shells, roofs, and bottoms shall be ordered on an edge-thickness basis as specified in 4.2.1.2.1 and 4.2.1.2.2.

4.2.1.2.1 The edge thickness ordered shall not be less than the computed design thickness or the minimum permitted thickness.

4.2.1.2.2 An underrun not more than 0.3 mm (0.01 in.) from the computed design thickness or the minimum permitted thickness is acceptable.

• **4.2.1.3** All plates shall be manufactured by the open-hearth, electric-furnace, or basic oxygen process. Steels produced by the thermo-mechanical control process (TMCP) may be used, provided that the combination of chemical composition and integrated controls of the steel manufacturing is mutually acceptable to the Purchaser and the Manufacturer, and provided that the specified mechanical properties in the required plate thicknesses are achieved. Copper-bearing steel shall be used if specified by the Purchaser.

4.2.1.4 Shell plates are limited to a maximum thickness of 45 mm (1.75 in.) unless a lesser thickness is stated in this standard or in the plate specification. Plates used as thickened inserts or flanges may be thicker than 45 mm (1.75 in.). Plates, as designated in 4.2.10.1 and thicker than 40 mm (1.5 in.), shall be normalized or quench tempered, killed, made to fine-grain practice, and impact tested.

4.2.1.5 Plate components not listed in 4.2.10.1 (i.e. nonpressure boundary compression components) shall be limited to the maximum thickness as designated by ASTM, CSA, ISO, EN, or other recognized national standard.

4.2.2 ASTM Specifications

Plates that conform to the following ASTM specifications are acceptable as long as the plates are within the stated limitations.

a) ASTM A36M/A36 for plates to a maximum thickness of 40 mm (1.5 in.). None of the specifications for the appurtenant materials listed in Table 1 of ASTM A36M/A36 are considered acceptable for tanks constructed under this standard unless it is expressly stated in this standard that the specifications are acceptable.

b) ASTM A131M/A131, Grade A, for plates to a maximum thickness of 13 mm (0.5 in.); Grade B for plates to a maximum thickness of 25 mm (1 in.); and Grade EH36 for plates to a maximum thickness of 45 mm (1.75 in.) [thickened insert plates and flanges to a maximum thickness of 50 mm (2 in.)].

c) ASTM A283M/A283, Grade C, for plates to a maximum thickness of 25 mm (1 in.).

d) ASTM A285M/A285, Grade C, for plates to a maximum thickness of 25 mm (1 in.).

e) ASTM A516M Grades 380, 415, 450, 485/A516, Grades 55, 60, 65, and 70, for plates to a maximum thickness of 40 mm (1.5 in.) [thickened insert plates and flanges to a maximum thickness of 100 mm (4 in.)].

f) ASTM A537M/A537, Class 1 and Class 2, for plates to a maximum thickness of 45 mm (1.75 in.) [thickened insert plates to a maximum thickness of 100 mm (4 in.)].

g) ASTM A573M Grades 400, 450, 485/A573, Grades 58, 65, and 70, for plates to a maximum thickness of 40 mm (1.5 in.).

h) ASTM A633M/A633, Grades C and D, for plates to a maximum thickness of 45 mm (1.75 in.) [thickened insert plates to a maximum thickness of 100 mm (4.0 in.)].

i) ASTM A662M/A662, Grades B and C, for plates to a maximum thickness of 40 mm (1.5 in.).

j) ASTM A737M/A737, Grade B, for plates to a maximum thickness of 40 mm (1.5 in.).

k) ASTM A841M/A841 Grade A, Class 1 and Grade B, Class 2 for plates to a maximum thickness of 40 mm (1.5 in.) [thickened insert plates to a maximum thickness of 65 mm (2.5 in.)].

4.2.3 CSA Specification

CSA Specification G40.21, Grades 260W/(38W), 300W/(44W), and 350W/(50W) are acceptable for plates within the limitations stated below. If impact tests are required, WT Grades are required.

a) Grades 260W/(38W) and 300W(44W) are acceptable for plate to a maximum thickness of 25 mm (1 in.) if semi-killed and to a maximum thickness of 40 mm (1.5 in.) if fully killed and made to fine-grain practice.

b) Grade 350W(50W) is acceptable for plate to a maximum thickness of 45 mm (1.75 in.) [thickened insert plates to a maximum thickness of 100 mm (4 in.)] if fully killed and made to fine-grain practice.

c) All CSA specification plates shall be ordered with the tensile strength limited to no greater than 140 MPa (20 ksi) above the minimum specification.

4.2.4 ISO Specifications

Plate furnished to ISO 630 in Grades S275 and S355 is acceptable within the following limitations:

a) Grade S275 in Qualities C and D for plate to a maximum thickness of 40 mm (1.5 in.);

b) Grade S355 in Qualities C and D for plate to a maximum thickness of 45 mm (1.75 in.) [thickened insert plates to a maximum thickness of 50 mm (2 in.)].

4.2.5 EN Specifications

Plate furnished to EN 10025 in Grades S275 and S355 is acceptable within the following limitations:

a) Grade S275 in Qualities J0 and J2 for plate to a maximum thickness of 40 mm (1.5 in.);

b) Grade S355 in Qualities J0, J2 and K2 for plate to a maximum thickness of 45 mm (1.75 in.) [thickened insert plates to a maximum thickness of 50 mm (2 in.)].

4.2.6 National Standards

Plates produced and tested in accordance with the requirements of a recognized national standard and within the mechanical and chemical limitations of one of the grades listed in Table 4.2 are acceptable when approved by the Purchaser. The requirements of this group do not apply to the ASTM, CSA, ISO, and EN specifications listed in 4.2.2, 4.2.3, 4.2.4, and 4.2.5. For the purposes of this standard, a *national standard* is a standard that has been sanctioned by the government of the country from which the standard originates.

4.2.7 General Requirements for Delivery

4.2.7.1 The material furnished shall conform to the applicable requirements of the listed specifications but is not restricted with respect to the location of the place of manufacture.

4.2.7.2 This material is intended to be suitable for fusion welding. Welding technique is of fundamental importance, and welding procedures must provide welds whose strength and toughness are consistent with the plate material being joined. All welding performed to repair surface defects shall be done with low-hydrogen welding electrodes compatible in chemistry, strength, and quality with the plate material.

4.2.7.3 When specified by the plate purchaser, the steel shall be fully killed. When specified by the plate purchaser, fully killed steel shall be made to fine-grain practice.

4.2.7.4 For plate that is to be made to specifications that limit the maximum manganese content to less than 1.60 %, the limit of the manganese content may be increased to 1.60 % (heat) at the option of the plate producer to maintain the required strength level, provided that the maximum carbon content is reduced to 0.20 % (heat) and the weldability of the plate is given consideration. The material shall be marked “Mod” following the specification listing. The material shall conform to the product analysis tolerances of Table B in ASTM A6M/A6.

4.2.7.5 The use or presence of columbium, vanadium, nitrogen, copper, nickel, chromium, or molybdenum shall not exceed the limitations of Table 4.1 for all Group VI materials (see Table 4.4a and Table 4.4b) and CSA G40.21 Grades 350W/(50W) and 350WT/(50WT); ISO 630 Grade S355; and EN 10025 Grade S355.

4.2.8 Heat Treatment of Plates

4.2.8.1 When specified by the plate purchaser, fully killed plates shall be heat treated to produce grain refinement by either normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in conjunction with hot forming, the temperature to which the plates are heated for hot forming shall be equivalent to and shall not significantly exceed the normalizing temperature. If the treatment of the plates is not specified to be done at the plate producer’s plant, testing shall be carried out in accordance with 4.2.8.2.

4.2.8.2 When a plate purchaser elects to perform the required normalizing or fabricates by hot forming (see 4.2.8.1), the plates shall be accepted on the basis of mill tests made on full-thickness specimens heat treated in accordance with the plate purchaser’s order. If the heat-treatment temperatures are not indicated on the contract, the specimens shall be heat treated under conditions considered appropriate for grain refinement and for meeting the test requirements. The plate producer shall inform the plate purchaser of the procedure followed in treating the specimens at the steel mill.

4.2.8.3 On the purchase order, the plate purchaser shall indicate to the plate producer whether the producer shall perform the heat treatment of the plates.

4.2.8.4 The tensile tests shall be performed on each plate as heat treated.

Table 4.1—Maximum Permissible Alloy Content

Alloy	Heat Analysis (%)	Notes
Columbium	0.05	1, 2, 3
Vanadium	0.10	1, 2, 4
Columbium (≤ 0.05 %) plus Vanadium	0.10	1, 2, 3
Nitrogen	0.015	1, 2, 4
Copper	0.35	1, 2
Nickel	0.50	1, 2
Chromium	0.25	1, 2
Molybdenum	0.08	1, 2

NOTE 1 When the use of these alloys or combinations of them is not included in the material specification, their use 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. When more restrictive limitations are included in the material specification, those shall govern.

NOTE 2 On product analysis, the material shall conform to these requirements, subject to the product analysis tolerances of the specification.

NOTE 3 When columbium is added either singly or in combination with vanadium, it shall be restricted to plates of 13 mm (0.50 in.) maximum thickness unless combined with 0.15 % minimum silicon.

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

Table 4.2—Acceptable Grades of Plate Material Produced to National Standards (See 4.2.6)

	Mechanical Properties								Chemical Composition			
	Tensile Strength[a]				Minimum Yield Strength[c]		Maximum Thickness		Maximum Percent Carbon		Maximum Percent Phosphorus and Sulfur	
	Minimum[c]		Maximum									
Grade[b]	MPa	ksi	MPa	ksi	MPa	ksi	mm	in.	Heat	Product	Heat	Product
235[d]	360	52	510	74	235	34	20	0.75	0.20	0.24	0.04	0.05
250	400	58	530	77	250	36	40	1.5	0.23	0.27	0.04	0.05
275	430	62	560	81	275	40	40	1.5	0.25	0.29	0.04	0.05

[a] The location and number of test specimens, elongation and bend tests, and acceptance criteria are to be in accordance with the appropriate national standard, ISO standard, or ASTM specification.

[b] Semi-killed or fully killed quality; as rolled or TMCP (20 mm [0.75 in.] maximum when TMCP is used in place of normalized steel), or normalized.

[c] Yield strength ÷ tensile strength ≤ 0.75, based on the minimum specified yield and tensile strength unless actual test values are required by the Purchaser.

[d] Nonrimming only.

4.2.9 Impact Testing of Plates

• **4.2.9.1** When required by the Purchaser or by 4.2.10, a set of Charpy V-notch impact specimens shall be taken from plates after heat treatment (if the plates have been heat treated), and the specimens shall fulfill the stated energy requirements. Test coupons shall be obtained adjacent to a tension-test coupon. Each full-size impact specimen shall have its central axis as close to the plane of one-quarter plate thickness as the plate thickness will permit.

4.2.9.2 When it is necessary to prepare test specimens from separate coupons or when plates are furnished by the plate producer in a hot-rolled condition with subsequent heat treatment by the fabricator, the procedure shall conform to ASTM A20.

4.2.9.3 An impact test shall be performed on three specimens taken from a single test coupon or test location. The average value of the specimens (with no more than one specimen value being less than the specified minimum value) shall comply with the specified minimum value. If more than one value is less than the specified minimum value, or if one value is less than two-thirds the specified minimum value, three additional specimens shall be tested, and each of these must have a value greater than or equal to the specified minimum value.

4.2.9.4 The test specimens shall be Charpy V-notch Type A specimens (see ASTM A370), with the notch perpendicular to the surface of the plate being tested.

4.2.9.5 For a plate whose thickness is insufficient to permit preparation of full-size specimens [10 mm × 10 mm (0.394 in. × 0.394 in.], tests shall be made on the largest subsize specimens that can be prepared from the plate. Subsize specimens shall have a width along the notch of at least 80 % of the material thickness.

4.2.9.6 The impact energy values obtained from subsize specimens shall not be less than values that are proportional to the energy values required for full-size specimens of the same material.

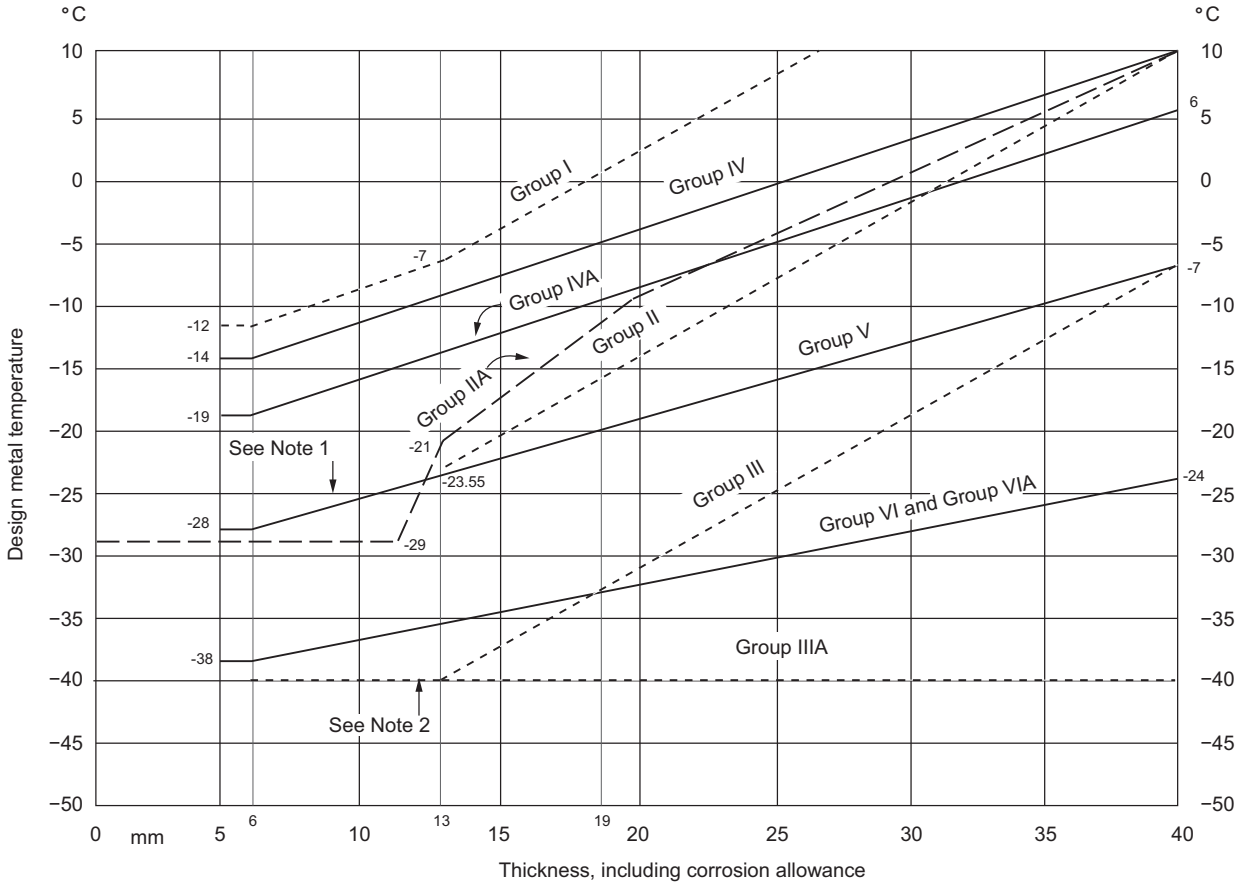
4.2.9.7 The testing apparatus, including the calibration of impact machines and the permissible variations in the temperature of specimens, shall conform to ASTM A370 or an equivalent testing apparatus conforming to national standards or ISO standards.

4.2.10 Toughness Requirements

4.2.10.1 The thickness and design metal temperature of all shell plates, shell reinforcing plates, shell insert plates and thickened insert plates, bottom plates welded to the shell, plates used for manhole and nozzle necks, plate-ring shell-nozzle flanges, blind flanges, and manhole cover plates shall be in accordance with Figure 4.1a and Figure 4.1b. Notch toughness evaluation of plate-ring flanges, blind flanges, and manhole cover plates shall be based on "governing thickness" as defined in 4.5.4.3. In addition, plates more than 40 mm (1.5 in.) thick shall be of killed steel made to fine-grain practice and heat treated by normalizing, normalizing and tempering, or quenching and tempering, and each plate as heat treated shall be impact tested according to 4.2.11.2. Each TMCP A841 plate-as-rolled shall be impact tested. Impact test temperature and required energy shall be in accordance with 4.2.11.2 in lieu of the default temperature and energy given in A841.

4.2.10.2 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 4.2.10.1 because of thickness over 40 mm (1.5 in.). In this case, each TMCP plate-as-rolled shall receive Charpy V-notch impact energy testing in accordance with 4.2.9, 4.2.10, and 4.2.11. When TMCP steels are used, consideration should be given to the service conditions outlined in 5.3.3.

• **4.2.10.3** Plates less than or equal to 40 mm (1.5 in.) thick may be used at or above the design metal temperatures indicated in Figure 4.1a and Figure 4.1b without being impact tested. To be used at design metal temperatures lower than the temperatures indicated in Figure 4.1a and Figure 4.1b, plates shall demonstrate adequate notch toughness in accordance with 4.2.11.3 unless 4.2.11.2 or 4.2.11.4 has been specified by the Purchaser. For heat-treated material



NOTE 1 The Group II and Group V lines coincide at thicknesses less than 13 mm.

NOTE 2 The Group III and Group IIIA lines coincide at thicknesses less than 13 mm.

NOTE 3 The materials in each group are listed in Table 4.4a and Table 4.4b.

NOTE 4 Deleted.

NOTE 5 Use the Group IIA and Group VIA curves for pipe and flanges (see 4.5.4.2 and 4.5.4.3).

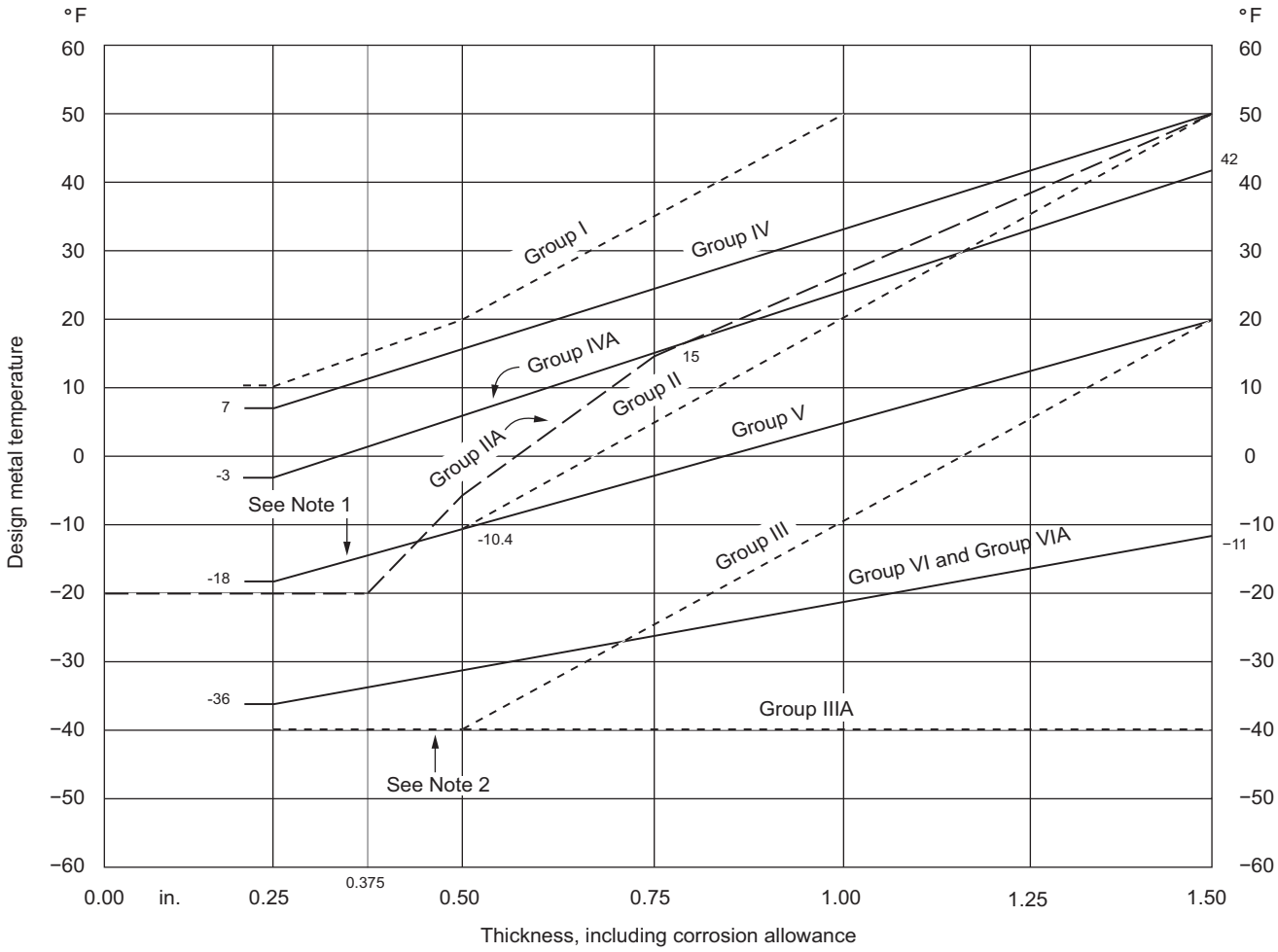
NOTE 6 Linear equations provided in Table 4.3a can be used to calculate Design Metal Temperature (DMT) for each API material group and the thickness range.

Figure 4.1a—Minimum Permissible Design Metal Temperature for Materials Used in Tank Shells without Impact Testing (SI)

(normalized, normalized and tempered, or quenched and tempered), notch toughness shall be demonstrated on each plate as heat treated when 4.2.11.2 requirements are specified. Isothermal lines of lowest one-day mean temperature are shown in Figure 4.2.

4.2.10.4 Plate used to reinforce shell openings and insert plates or thickened insert plates shall be of the same material as the shell plate to which they are attached or shall be of any appropriate material listed in Table 4.4a, Table 4.4b, Figure 4.1a, and Figure 4.1b. Except for nozzle and manway necks, the material shall be of equal or greater yield and tensile strength and shall be compatible with the adjacent shell material (see 4.2.10.1 and 5.7.2.3, Item d).

4.2.10.5 The requirements in 4.2.10.4 apply only to shell nozzles and manholes. Materials for roof nozzles and manholes do not require special toughness.



NOTE 1 The Group II and Group V lines coincide at thicknesses less than 1/2 in.

NOTE 2 The Group III and Group IIIA lines coincide at thicknesses less than 1/2 in.

NOTE 3 The materials in each group are listed in Table 4.4a and Table 4.4b.

NOTE 4 Deleted.

NOTE 5 Use the Group IIA and Group VIA curves for pipe and flanges (see 4.5.4.2 and 4.5.4.3).

NOTE6 Linear equations provided in Table 4.3b can be used to calculate Design Metal Temperature (DMT) for each API material group and the thickness range.

Figure 4.1b—Minimum Permissible Design Metal Temperature for Materials Used in Tank Shells without Impact Testing (USC)

4.2.11 Toughness Procedure

4.2.11.1 When a material's toughness must be determined, it shall be done by one of the procedures described in 4.2.11.2, 4.2.11.3, and 4.2.11.4, as specified in 4.2.10.

Table 4.3a—Linear Equations for 4.1a (SI)

API Group #	Thickness Range	Equation
I	$6 \le X < 13$	$Y = 0.714X - 16.286$
I	$13 \le X \le 25$	$Y = 1.417X - 25.417$
II	$6 \le X < 13$	$Y = 0.634X - 31.81$
II	$13 \le X \le 40$	$Y = 1.243X - 39.72$
IIA	$10 \le X < 13$	$Y = 2.667X - 55.667$
IIA	$13 \le X \le 19$	$Y = 2X - 47$
IIA	$19 \le X \le 40$	$Y = 0.905X - 26.19$
III	$6 \le X \le 13$	$Y = -40$
III	$13 \le X \le 40$	$Y = 1.222X - 55.89$
IIIA	$6 \le X \le 40$	$Y = -40$
IV	$6 \le X \le 40$	$Y = 0.7059X - 18.235$
IVA	$6 \le X \le 40$	$Y = 0.7353X - 23.412$
V	$6 \le X \le 40$	$Y = 0.6176X - 31.71$
VI, VIA	$6 \le X \le 40$	$Y = 0.4112X - 40.471$

Y = Design Metal Temperature (°C)

X = Thickness including corrosion (mm)

Table 4.3b—Linear Equations for 4.1b (USC)

API Group #	Thickness Range	Equation
I	$0.25 \le X < 0.5$	$Y = 40X$
I	$0.5 \le X \le 1.0$	$Y = 60X - 10$
II	$0.25 \le X < 0.5$	$Y = 30.4X - 25.6$
II	$0.5 \le X \le 1.5$	$Y = 60.4X - 40.6$
IIA	$0.375 \le X < 0.5$	$Y = 120X - 65$
IIA	$0.5 \le X \le 0.75$	$Y = 80X - 45$
IIA	$0.75 \le X \le 1.5$	$Y = 46.667X - 20$
III	$0.25 \le X \le 0.5$	$Y = -40$
III	$0.5 \le X \le 1.5$	$Y = 60X - 70$
IIIA	$0.25 \le X \le 1.5$	$Y = -40$
IV	$0.25 \le X \le 1.5$	$Y = 34.4X - 1.6$
IVA	$0.25 \le X \le 1.5$	$Y = 36X - 12$
V	$0.25 \le X \le 1.5$	$Y = 30.4X - 25.6$
VI, VIA	$0.25 \le X \le 1.5$	$Y = 20X - 41$

Y = Design Metal Temperature (°F)

X = Thickness including corrosion (in.)

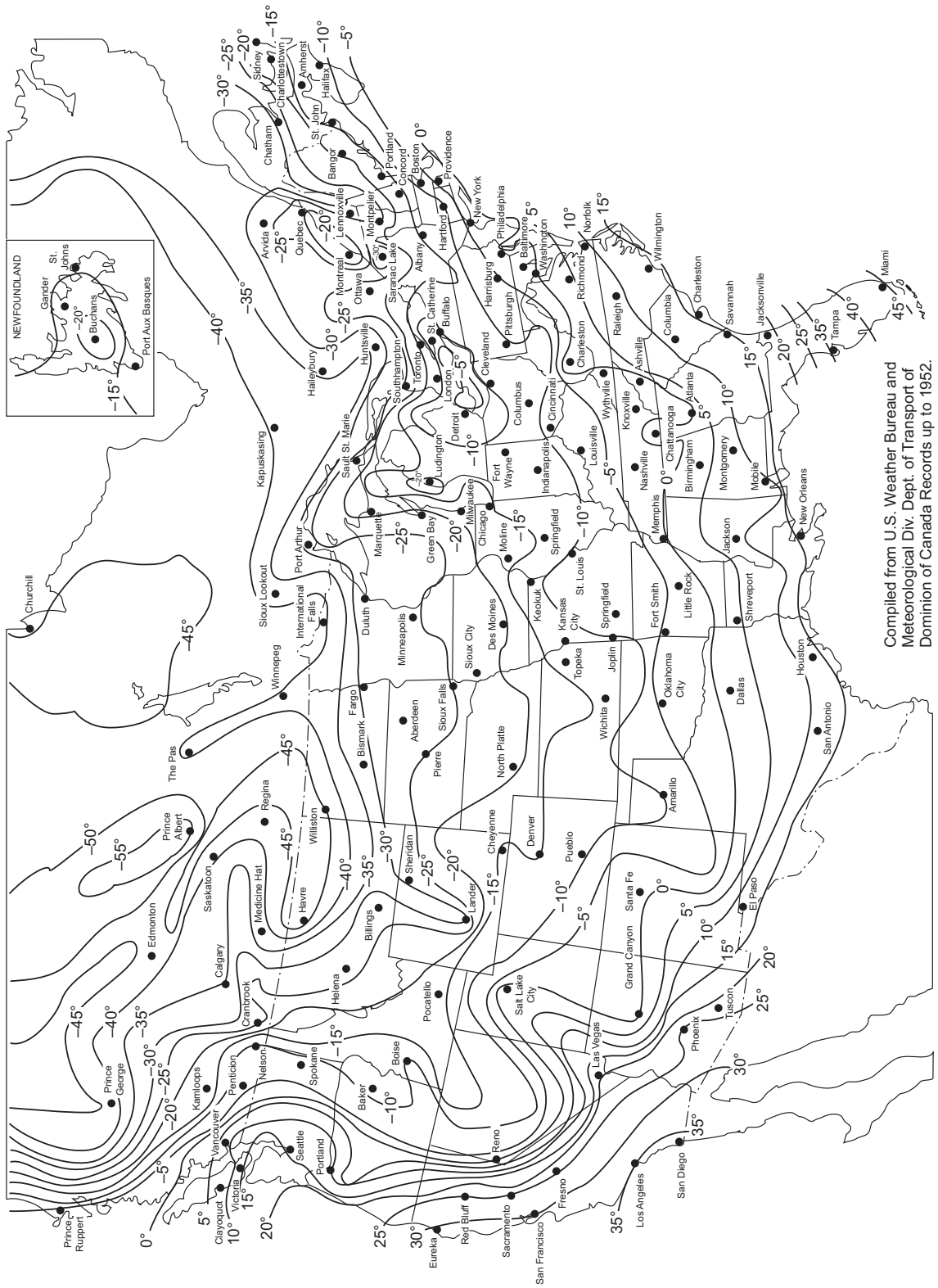
4.2.11.2 Each plate as rolled or heat treated shall be impact tested in accordance with 4.2.9 at or below the design metal temperature to show Charpy V-notch longitudinal (or transverse) values that fulfill the minimum requirements of Table 4.5a and Table 4.5b (see 4.2.9 for the minimum values for one specimen and for subsize specimens). As used here, the term plate as rolled refers to the unit plate rolled from a slab or directly from an ingot in its relation to the location and number of specimens, not to the condition of the plate.

4.2.11.3 For plate in the as-rolled condition, the thickest plate from each heat shall be impact tested. For TMCP material, each plate-as-rolled shall be impact tested. Impact testing shall be in accordance with 4.2.9 and shall fulfill the impact requirements of 4.2.11.2 at the design metal temperature.

- **4.2.11.4** The Manufacturer shall submit to the Purchaser test data for plates of the material demonstrating that based on past production from the same mill, the material has provided the required toughness at the design metal temperature.

4.3 Sheets

Sheets for fixed and floating roofs shall conform to ASTM A1011M, Grade 33. They shall be made by the open-hearth or basic oxygen process. Copper-bearing steel shall be used if specified by the Purchaser. Sheets shall be ordered on a thickness basis. An underrun not more than 0.3 mm (0.01 in.) from the computed design thickness or the minimum permitted thickness is acceptable.



NOTE °C = (°F – 32)/1.8

Figure 4.2—Isothermal Lines of Lowest One-Day Mean Temperatures (°F)

Table 4.4a—Material Groups (SI)

(See Figure 4.1a and Note 1 below.)

Group I As Rolled, Semi-Killed		Group II As Rolled, Killed or Semi-Killed		Group III As Rolled, Killed Fine-Grain Practice		Group IIIA Normalized, Killed Fine-Grain Practice	
Material	**Notes**	**Material**	**Notes**	**Material**	**Notes**	**Material**	**Notes**
A283M C		A131M B	6	A573M-400		A573M-400	9
A285M C	2	A36M	5	A516M-380		A516M-380	9
A131M A		G40.21-260W		A516M-415		A516M-415	9
A36M	3	Grade 250	7	G40.21-260W	8	G40.21-260W	8, 9
Grade 235	3			Grade 250	8	Grade 250	8, 9
Grade 250	5						

Group IV As Rolled, Killed Fine-Grain Practice		Group IVA As Rolled, Killed Fine-Grain Practice		Group V Normalized, Killed Fine-Grain Practice		Group VI Normalized or Quenched and Tempered, Killed Fine-Grain Practice Reduced Carbon	
Material	**Notes**	**Material**	**Notes**	**Material**	**Notes**	**Material**	**Notes**
A573M-450		A662M C		A573M-485	9	A131M EH 36	
A573M-485		A573M-485	10	A516M-450	9	A633M C	
A516M-450		G40.21-300W	8, 10	A516M-485	9	A633M D	
A516M-485		G40.21-350W	8, 10	G40.21-300W	8, 9	A537M Class 1	
A662M B		ISO S275 D	8	G40.21-350W	8, 9	A537M Class 2	12
G40.21-300W	8	ISO S355 D	8				
G40.21-350W	8	ENS275	8				
ISO S275 C	8	EN S355 (J2 or K2)	8			A737M B	
ISO S355 C	8					A841M, Grade A, Classes 1 and 2	11, 12, 13, 14
EN S275 J0	8					A841M, Grade B, Classes 1 and 2	11, 12, 13, 14
EN355 J0	8						
Grade 275	8						

NOTES

1. Most of the listed material specification numbers refer to ASTM specifications (including Grade or Class); there are, however, some exceptions: G40.21 (including Grade) is a CSA specification, and Grade 235, Grade 250, and Grade 275 are related to national standards (see 4.2.6).
2. Must be semi-killed or killed.
3. Thickness ≤ 20 mm.
4. Deleted.
5. Manganese content shall be 0.80 % to 1.2 % by heat analysis for thicknesses greater than 20 mm, except that for each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to the maximum of 1.35 %. Thicknesses ≤ 20 mm shall have a manganese content of 0.80 % to 1.2 % by heat analysis.
6. Thickness ≤ 25 mm.
7. Must be killed.
8. Must be killed and made to fine-grain practice.
9. Must be normalized.
10. Must have chemistry (heat) modified to a maximum carbon content of 0.20 % and a maximum manganese content of 1.60 % (see 4.2.7.4).
11. Produced by the thermo-mechanical control process (TMCP).
12. See 5.7.4.9 for tests on simulated test coupons for material used in stress-relieved assemblies.
13. See 4.2.10 for impact test requirements (each plate-as-rolled tested).
14. A841 Classes 1,2 (Grades A and B only) with the following modification: Carbon Equivalent (CE) shall be per Supplementary Requirement S77.

Table 4.4b—Material Groups (USC)

(See Figure 4.1b and Note 1 below.)

Group I As Rolled, Semi-killed		Group II As Rolled, Killed or Semi-killed		Group III As Rolled, Killed Fine-Grain Practice		Group IIIA Normalized, Killed Fine-Grain Practice	
Material	**Notes**	**Material**	**Notes**	**Material**	**Notes**	**Material**	**Notes**
A283 C		A131 B	6	A573-58		A573-58	9
A285 C	2	A36	5	A516-55		A516-55	9
A131 A		G40.21-38W		A516-60		A516-60	9
A36	3	Grade 250	7	G40.21-38W	8	G40.21-38W	8, 9
Grade 235	3			Grade 250	8	Grade 250	8, 9
Grade 250	5						

Group IV As Rolled, Killed Fine-Grain Practice		Group IVA As Rolled, Killed Fine-Grain Practice		Group V Normalized, Killed Fine-Grain Practice		Group VI Normalized or Quenched and Tempered, Killed Fine-Grain Practice Reduced Carbon	
Material	**Notes**	**Material**	**Notes**	**Material**	**Notes**	**Material**	**Notes**
A573-65		A662 C		A573-70	9	A131 EH 36	
A573-70		A573-70	10	A516-65	9	A633 C	
A516-65		G40.21-44W	8, 10	A516-70	9	A633 D	
A516-70		G40.21-50W	8, 10	G40.21-44W	8, 9	A537 Class 1	
A662 B		ISO S275 D	8	G40.21-50W	8, 9	A537 Class 2	12
G40.21-44W	8	ISO S355 D	8				
G40.21-50W	8	ENS275 J2	8				
ISO S275 C	8	EN S355 (J2 or K2)	8			A737 B	
ISO S355 C	8					A841M, Grade A, Classes 1 and 2	11, 12, 13, 14
EN S275 J0	8					A841M, Grade B, Classes 1 and 2	11, 12, 13, 14
EN355 J0	8						
Grade 275	8						

NOTES

1. Most of the listed material specification numbers refer to ASTM specifications (including Grade or Class); there are, however, some exceptions: G40.21 (including Grade) is a CSA specification, and Grade 235, Grade 250, and Grade 275 are related to national standards (see 4.2.6).
2. Must be semi-killed or killed.
3. Thickness $\leq$ 0.75 in.
4. Deleted.
5. Manganese content shall be 0.80% to 1.2 % by heat analysis for thicknesses greater than 0.75 in., except that for each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to the maximum of 1.35 %. Thicknesses $\leq$ 0.75 in. shall have a manganese content of 0.80 % to 1.2 % by heat analysis.
6. Thickness $\leq$ 1 in.
7. Must be killed.
8. Must be killed and made to fine-grain practice.
9. Must be normalized.
10. Must have chemistry (heat) modified to a maximum carbon content of 0.20% and a maximum manganese content of 1.60 % (see 4.2.7.4).
11. Produced by the thermo-mechanical control process (TMCP).
12. See 5.7.4.9 for tests on simulated test coupons for material used in stress-relieved assemblies.
13. See 4.2.10 for impact test requirements (each plate-as-rolled tested).
14. A841 Classes 1,2 (Grades A and B only) with the following modification: Carbon Equivalent (CE) shall be per Supplementary Requirement S77.

Table 4.5a—Minimum Impact Test Requirements for Plates (SI) (See Note)

Plate Material[a] and Thickness (t) in mm	Thickness	Average Impact Value of Three Specimens[b]	
		Longitudinal	Transverse
	mm	J	J
Groups I, II, III, and IIIA $t \leq$ maximum thicknesses in 4.2.2 through 4.2.5		20	18
Groups IV, IVA, V, and VI (except quenched and tempered and TMCP)	$t \leq 40$	41	27
	$t = 45$	48	34
	$t = 50$	54	41
	$t = 100$	68	54
Group VI (quenched and tempered and TMCP)	$t \leq 40$	48	34
	$t = 45$	54	41
	$t = 50$	61	48
	$t = 100$	68	54

[a] See Table 4.4a.

[b] Interpolation is permitted when determining minimum average impact value for plate thickness between the named thicknesses.

NOTE For plate ring flanges, the minimum impact test requirements for all thicknesses shall be those for $t \leq 40$ mm.

Table 4.5b—Minimum Impact Test Requirements for Plates (USC) (See Note)

Plate Material[a] and Thickness (t) in Inches	Thickness	Average Impact Value of Three Specimens[b]	
		Longitudinal	Transverse
	in.	ft-lbf	ft-lbf
Groups I, II, III, and IIIA $t \leq$ maximum thicknesses in 4.2.2 through 4.2.5		15	13
Groups IV, IVA, V, and VI (except quenched and tempered and TMCP)	$t \leq 1.5$	30	20
	$t = 1.75$	35	25
	$t = 2$	40	30
	$t = 4$	50	40
Group VI (quenched and tempered and TMCP)	$t \leq 1.5$	35	25
	$t = 1.75$	40	30
	$t = 2$	45	35
	$t = 4$	50	40

[a] See Table 4.4b.

[b] Interpolation is permitted when determining minimum average impact value for plate thickness between the named thicknesses.

NOTE For plate ring flanges, the minimum impact test requirements for all thicknesses shall be those for $t \leq 1.5$ in.

4.4 Structural Shapes

4.4.1 Structural steel shall conform to one of the following specifications.

a) ASTM A36M/A36.

b) ASTM A131M/A131.

c) ASTM A992M/A992.

d) Structural Steels listed in AISC, *Manual of Steel Construction.*

e) CSA G40.21, Grades 260W(38W), 300W(44W), 350W(50W), 260WT(38WT), 300WT(44WT), and 350WT(50WT). Imperial unit equivalent grades of CSA Specification G40.21, shown in parenthesis, are also acceptable.

f) ISO 630, Grade E275, Qualities B, C, and D.

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

• h) Recognized national standards. Structural steel that is produced in accordance with a recognized national standard and that meets the requirements of Table 4.2 is acceptable when approved by the Purchaser.

• **4.4.2** All steel for structural shapes shall be made by the open-hearth, electric-furnace, or basic oxygen process. Copper-bearing steel is acceptable when approved by the Purchaser.

4.4.3 Not all of the structural steel shapes listed in AISC (4.4.1 [d]) and other national standards (4.4.1[h]) are well suited for welding. Material selection for structural shapes requiring welded connections shall include confirmation of the material's weldability from the structural shape Manufacturer, other reputable sources, or by weld testing. Structural steel shapes having poor weldability shall only be used for bolted connection designs.

4.4.4 Weldable-quality pipe that conforms to the physical properties specified in any of the standards listed in 4.5.1 may be used for structural purposes with the allowable stresses stated in 5.10.3.

4.5 Piping and Forgings

4.5.1 Unless otherwise specified in this standard, pipe and pipe couplings and forgings shall conform to the specifications listed in 4.5.1.1 and 4.5.1.2 or to national standards equivalent to the specifications listed.

4.5.1.1 The following specifications are acceptable for pipe and pipe couplings:

a) API Spec 5L, Grades A, B, and X42;

b) ASTM A53M/A53, Grades A and B;

c) ASTM A106 M/A106, Grades A and B;

d) ASTM A234M/A234, Grade WPB;

e) ASTM A333M/A333, Grades 1 and 6;

f) ASTM A334M/A334, Grades 1 and 6;

g) ASTM A420M/A420, Grade WPL6;

h) ASTM A524, Grades I and II;

i) ASTM A671 (see 4.5.3).

4.5.1.2 The following specifications are acceptable for forgings:

a) ASTM A105M/A105;

b) ASTM A181M/A181;

c) ASTM A350M/A350, Grades LF1 and LF2.

4.5.2 Unless ASTM A671 pipe is used (electric-fusion-welded pipe) (see 4.5.3), material for shell nozzles and shell manhole necks shall be seamless pipe, seamless forging, or plate material as specified in 4.2.10.1. When shell materials are Group IV, IVA, V, or VI, seamless pipe shall comply with ASTM A106, Grade B; ASTM A524; ASTM A333M/A333, Grade 6; or ASTM A334M/A334, Grade 6.

4.5.3 When ASTM A671 pipe is used for shell nozzles and shell manhole necks, it shall comply with the following.

a) Material selection shall be limited to Grades CA 55, CC 60, CC 65, CC 70, CD 70, CD 80, CE 55, and CE 60.

b) The pipe shall be pressure tested in accordance with 8.3 of ASTM A671.

c) The plate specification for the pipe shall satisfy the requirements of 4.2.7, 4.2.8, and 4.2.9 that are applicable to that plate specification.

d) Impact tests for qualifying the welding procedure for the pipe longitudinal welds shall be performed in accordance with 9.2.2.

4.5.4 Except as covered in 4.5.3, the toughness requirements of pipe and forgings to be used for shell nozzles and manholes shall be established as described in 4.5.4.1, 4.5.4.2, 4.5.4.3, and 4.5.4.4.

4.5.4.1 Piping materials made according to ASTM A333M/A333, A334M/A334, A350M/A350, and A420, Grade WPL6 may be used at a design metal temperature no lower than the impact test temperature required by the ASTM specification for the applicable material grade without additional impact tests (see 4.5.4.4).

4.5.4.2 Other pipe and forging materials shall be classified under the material groups shown in Figure 4.1a and Figure 4.1b as follows:

a) Group IIA—API Spec 5L, Grades A, B, and X42; ASTM A106M/A106, Grades A and B; ASTM A53M/A53, Grades A and B; ASTM A181M/A181; ASTM A105M/A105; and A234M/A234, Grade WPB;

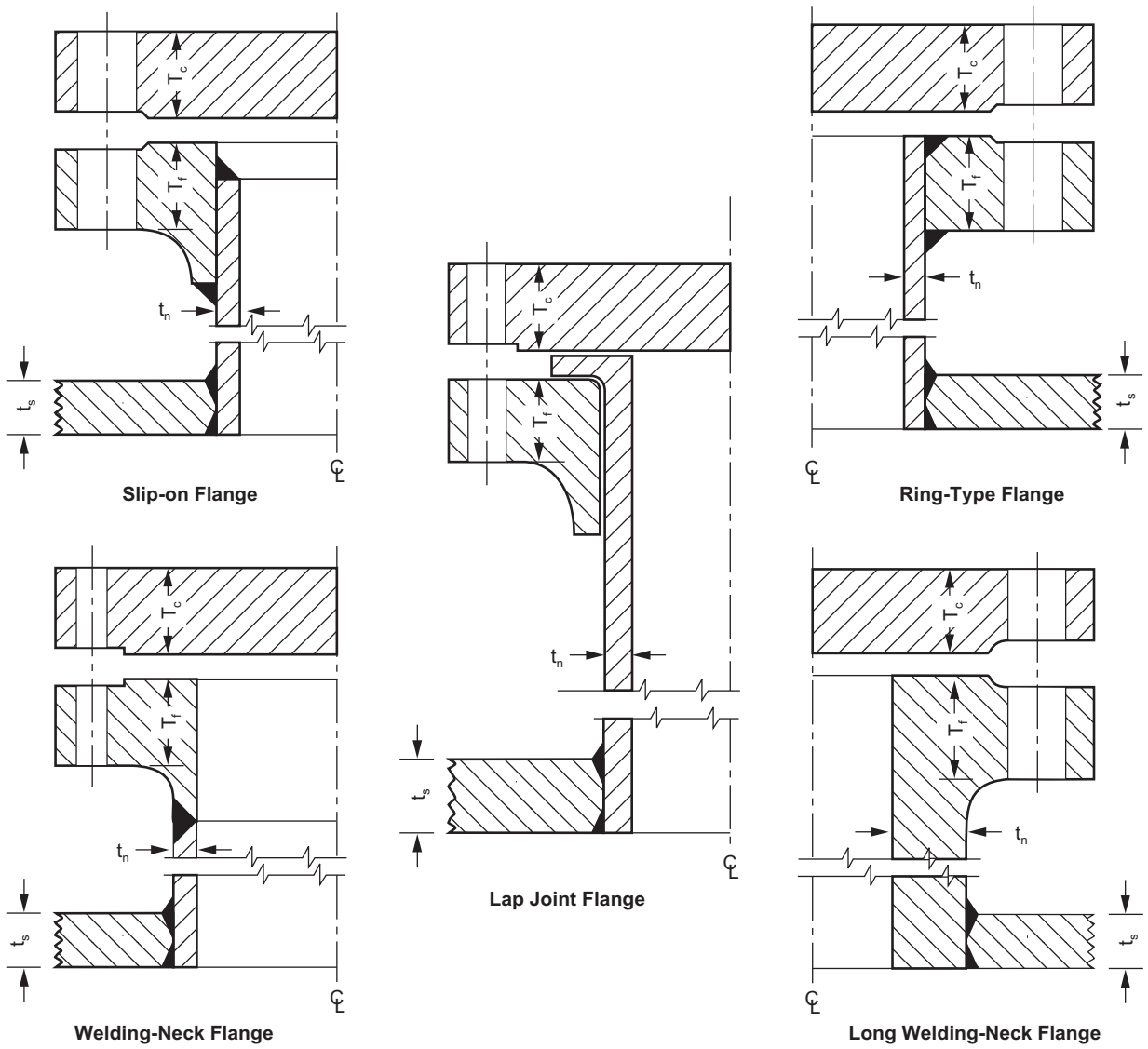
b) Group VIA—ASTM A524, Grades I and II.

4.5.4.3 The materials in the groups listed in 4.5.4.2 may be used at nominal thicknesses, including corrosion allowance, at a design metal temperature no lower than those shown in Figure 4.1a and Figure 4.1b without impact testing (see 4.5.4.4 and Figure 4.3). The governing thicknesses to be used in Figures 4.1a and Figure 4.1b shall be as follows:

a) for butt-welded joints, the nominal thickness of the thickest welded joint;

b) for corner or lap welds, the thinner of the two parts joined;

c) for nonwelded parts such as bolted blind flanges and manhole covers, $^1/_4$ of their nominal thickness.



NOTE 1 Shell reinforcing plate is not included in these illustrations.

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 (thinner of)
Nozzle neck at shell	t_n or t_s
Slip-on flange and nozzle neck	t_n or T_f
Ring-type flange and nozzle neck	t_n or T_f
Welding-neck flange and nozzle neck	t_n
Long welding-neck flange	t_n or t_s
Nonwelded bolted cover	$^1/_4$ T_c
Lap-type joint flange	t_n or T_f

Figure 4.3—Governing Thickness for Impact Test Determination of Shell Nozzle and Manhole Materials (see 4.5.4.3)

4.5.4.4 When impact tests are required by 4.5.4.1 or 4.5.4.3, they shall be performed in accordance with the requirements, including the minimum energy requirements, of ASTM A333M/A333, Grade 6, for pipe or ASTM A350M/A350, Grade LF1, for forgings at a test temperature no higher than the design metal temperature. Except for the plate specified in 4.2.9.2, the materials specified in 4.5.1 and 4.5.2 for shell nozzles, shell manhole necks, and all forgings used on shell openings shall have a minimum Charpy V-notch impact strength of 18 J (13 ft-lbf) (full-size specimen) at a temperature no higher than the design metal temperature.

4.6 Flanges

4.6.1 Flange Material

4.6.1.1 Forged slip on, ring-type, welding neck, long welding neck, and lap joint flanges shall conform to the material requirements of ASME B16.5.

4.6.1.2 Plate material used for nozzle flanges shall have physical properties better than or equal to those required by ASME B16.5. Plate material used for manhole flanges shall be per 4.2. Plate for shell nozzle and shell manhole flange material shall conform to 4.2.10.1 or 4.2.10.2.

- **4.6.2** Lap joint flanges shall not be used without the approval of the Purchaser.

- **4.6.3** For nominal pipe sizes greater than NPS 24, 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.

4.7 Bolting

- a) Unless otherwise specified on the Data Sheet, Table 2, flange bolting shall conform to ASTM A193 B7 and the dimensions specified in ASME B18.2.1. Nuts shall conform to ASTM A194 Grade 2H and the dimensions specified in ASME B18.2.2. Both shall be heavy hex pattern. All bolts and nuts shall be threaded in accordance with ASME B1.13M (SI), or with ASME B1.1(US) as follows:

  1) bolts up to and including 1 in. diameter: UNC Class 2A fit

  2) nuts for bolts up to and including 1 in. diameter: UNC Class 2B fit

  3) bolts 1.125 in. diameter and larger: 8N Class 2A fit

  4) nuts for bolts 1.125 in. diameter and larger: 8N Class 2B fit

- b) Unless otherwise specified on the Data Sheet, Table 2, anchors shall be one of the following:

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

  2) bolts to ASTM F1554, Grade 36 or 55, galvanized.

  Nuts for anchors shall be galvanized heavy hex. Welding is not permitted on anchors that are galvanized. Bolts with minimum specified yield strength greater than 55 ksi are prohibited.

- c) All other bolting shall conform to ASTM A307 or A193M/A193. A325M/A325 may be used for structural purposes only. The Purchaser should specify on the order what shape of bolt heads and nuts is desired and whether regular or heavy dimensions are desired.

4.8 Welding Electrodes

4.8.1 For the welding of materials with a minimum tensile strength less than 550 MPa (80 ksi), the manual arc-welding electrodes shall conform to the E60 and E70 classification series (suitable for the electric current characteristics, the position of welding, and other conditions of intended use) in AWS A5.1 and shall conform to 7.2.1.10 as applicable.

4.8.2 For the welding of materials with a minimum tensile strength of 550 MPa to 585 MPa (80 ksi to 85 ksi), the manual arc-welding electrodes shall conform to the E80XX-CX classification series in AWS A5.5.

4.9 Gaskets

4.9.1 General

- **4.9.1.1** Gasket materials shall be specified in Table 3 of the Data Sheet. Unless otherwise specified by the Purchaser, gasket materials shall not contain asbestos.

4.9.1.2 Sheet gaskets shall be continuous. Metal gaskets made continuous by welding are acceptable if the weld is ground flush and finished the same as the non-welded portion of the gasket. Rope or tape gaskets shall have overlapped ends.

4.9.1.3 Each gasket shall be made with an integral centering or positioning device.

- **4.9.1.4** No joint sealing compound, gasket adhesive, adhesive positioning tape, or lubricant shall be used on the sealing surfaces of gaskets, or flanges during joint make-up unless specifically allowed by the Purchaser. When these materials are approved by the Purchaser, consideration should be given to chemical compatibility with the gasket and flange materials.

- **4.9.1.5** Spare gaskets are not required unless specified in the Data Sheet, Line 23.

4.9.2 Service

- When service gaskets are designated to be furnished by the Manufacturer, the gaskets provided shall be as specified in the Data Sheet, Table 3.

4.9.3 Test

- **4.9.3.1** Test gaskets must have comparable dimensions and compressibility characteristics as service gaskets. Descriptions of gaskets for temporary use only as test gaskets shall be submitted for Purchaser's approval.

4.9.3.2 For joints that will not be disassembled after testing, the test gasket must be the specified service gasket.

4.9.3.3 Except for stainless steel bolting, flange bolts and nuts used for testing are acceptable for use in the completed tank.