Annex A
(normative)

Optional Design Basis for Small Tanks

This annex provides a number of design options requiring decisions by the Purchaser; standard requirements; recommendations; and information that supplements the basic standard. This annex becomes a requirement only when the Purchaser specifies an option covered by this annex or specifies the entire annex.

A.1 Scope

- **A.1.1** This Annex provides requirements for field-erected tanks of relatively small capacity in which the stressed components have a nominal thickness of no more than 13 mm ($^1/_2$ in.). The stressed components include the shell and reinforcing plates, shell reinforcing plates for flush-type cleanout fittings and flush-type shell connections, and bottom plates that are welded to the shell. The nominal thickness limit of 13 mm ($^1/_2$ in.) does not apply to:

    1) bottom plates not welded to the shell;

    2) the bottom reinforcing plate of flush-type cleanouts and flush-type shell connections;

    3) flanges and cover plates of flush-type cleanouts;

    4) flush-type shell connection necks attached to shell and flanges and cover plates of flush-type shell connections;

    5) nozzle and manhole necks, their flanges and cover plates;

    6) anchor bolt chair components and shell compression ring.

- **A.1.2** This Annex is applicable only when specified by the Purchaser and is limited to design metal temperatures above –30 °C (–20 °F) [above –40 °C (–40 °F) when killed, fine-grain material is used].

A.1.3 This Annex is applicable to any of the Section 4 materials, although the single allowable stress does not provide any advantage to higher strength steels.

A.1.4 This Annex states only the requirements that differ from the basic rules in this standard. When differing requirements are not stated, the basic rules must be followed; however, the overturning effect of a wind load should be considered.

A.1.5 Typical sizes and capacities are listed in Tables A.1a through A.2b.

A.2 Materials

A.2.1 Shell-plate materials shall not be more than 13 mm ($^1/_2$ in.) thick, as stated in A.1.1.

A.2.2 For stressed components, the Group-I and Group-II materials listed in Table 4.3a and Table 4.3b may be used at a design metal temperature of –30 °C (–20 °F) or warmer but need not conform to the toughness requirements of 4.2.9, Figure 4.1, and 9.2.2. Group-III and Group-IIIA materials may be used at a design metal temperature of –40 °C (–40 °F) or warmer and shall conform to impact requirements of 9.2.2.

A.2.3 Material used for shell nozzle and manhole necks and flanges shall conform to 4.5, 4.6, and Table 4.3a and Table 4.3b but need not conform to the toughness requirements of 4.2.9, 4.5.5, and Figure 4.1.

Table A.1a—Typical Sizes and Corresponding Nominal Capacities (m^3) for Tanks with 1800-mm Courses (SI)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11
Tank Diameter m	Capacity per m of Height m^3	Tank Height (m) / Number of Courses in Completed Tank								
		3.6 / 2	5.4 / 3	7.2 / 4	9 / 5	10.8 / 6	12.6 / 7	14.4 / 8	16.2 / 9	18 / 10
3	7.07	25	38	51	64	76	—	—	—	—
4.5	15.9	57	86	115	143	172	—	—	—	—
6	28.3	102	153	204	254	305	356	407	—	—
7.5	44.2	159	239	318	398	477	557	636	716	795
9	63.6	229	344	458	573	687	802	916	1,031	1,145
10.5	86.6	312	468	623	779	935	1,091	1,247	1,403	1,559
12	113	407	611	814	1,018	1,221	1,425	1,629	1,832	2,036
13.5	143	515	773	1,031	1,288	1,546	1,804	2,061	2,319	2,576
15	177	636	954	1,272	1,590	1,909	2,227	2,545	2,863	3,181
18	254	916	1,374	1,832	2,290	2,748	3,206	3,664	4,122	4,580
										D = 18
21	346	1,247	1,870	2,494	3,117	3,741	4,364	4,988	5,089	—
24	452	1,629	2,443	3,257	4,072	4,886	5,700	5,474	*D* = 20	—
27	573	2,061	3,092	4,122	5,153	6,184	6,690	*D* = 22	—	—
30	707	2,545	3,817	5,089	6,362	7,634	*D* = 26	—	—	—
36	1,018	3,664	5,497	7,329	9,161	*D* = 30	—	—	—	—
					D = 36					
42	1,385	4,988	7,481	9,975	—	—	—	—	—	—
48	1,810	6,514	9,772	11,966	—	—	—	—	—	—
54	2,290	8,245	12,367	*D* = 46	—	—	—	—	—	—
60	2,827	10,179	15,268	—	—	—	—	—	—	—
66	3,421	12,316	16,303	—	—	—	—	—	—	—
			D = 62							

NOTE The nominal capacities given in this table were calculated using the following formula:

In SI units:

$$C = 0.785D^2H$$

where

C is the capacity of tank, in m^3;

D is the diameter of tank, in m (see A.4.1);

H is the height of tank, in m (see A.4.1).

The capacities and diameters in italics (Columns 4 through 11) are the maximums for the tank heights given in the column heads, based on a maximum permissible shell-plate thickness of 13 mm, a maximum allowable design stress of 145 MPa, a joint efficiency of 0.85, and no corrosion allowance (see A.4.1).

Table A.1b—Typical Sizes and Corresponding Nominal Capacities (Barrels) for Tanks with 72-in. Courses (USC)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11
Tank Diameter ft	Capacity per ft of Height barrels	Tank Height (ft) / Number of Courses in Completed Tank								
		12 / 2	18 / 3	24 / 4	30 / 5	36 / 6	42 / 7	48 / 8	54 / 9	60 / 10
10	14.0	170	250	335	420	505	—	—	—	—
15	31.5	380	565	755	945	1,130	—	—	—	—
20	56.0	670	1,010	1,340	1,680	2,010	2,350	2,690	—	—
25	87.4	1,050	1,570	2,100	2,620	3,150	3,670	4,200	4,720	5,250
30	126	1,510	2,270	3,020	3,780	4,530	5,290	6,040	6,800	7,550
35	171	2,060	3,080	4,110	5,140	6,170	7,200	8,230	9,250	10,280
40	224	2,690	4,030	5,370	6,710	8,060	9,400	10,740	12,100	13,430
45	283	3,400	5,100	6,800	8,500	10,200	11,900	13,600	15,300	17,000
50	350	4,200	6,300	8,400	10,500	12,600	14,700	16,800	18,900	21,000
60	504	6,040	9,060	12,100	15,110	18,130	21,150	24,190	37,220	28,260
										D = 58
70	685	8,230	12,340	16,450	20,580	24,700	28,800	32,930	30,970	—
80	895	10,740	16,120	21,500	26,880	32,260	37,600	35,810	*D* = 64	—
90	1,133	13,600	20,400	27,220	34,030	40,820	40,510	*D* = 73	—	—
100	1,399	16,800	25,200	33,600	42,000	48,400	*D* = 83	—	—	—
120	2,014	24,190	36,290	48,380	58,480	*D* = 98	—	—	—	—
					D = 118					
140	2,742	32,930	49,350	65,860	—	—	—	—	—	—
160	3,581	43,000	64,510	74,600	—	—	—	—	—	—
180	4,532	54,430	81,650	*D* = 149	—	—	—	—	—	—
200	5,595	67,200	100,800	—	—	—	—	—	—	—
220	6,770	81,310	102,830	—	—	—	—	—	—	—
			D = 202							

NOTE The nominal capacities given in this table were calculated using the following formula:

In USC units:

$$C = 0.14D^2H$$

where

C is the capacity of tank, 42-gal barrels;

D is the diameter of tank, in ft (see A.4.1);

H is the height of tank, in ft (see A.4.1).

The capacities and diameters in italics (Columns 4 through 11) are the maximums for the tank heights given in the column heads, based on a maximum permissible shell-plate thickness of $^1/_2$ in., a maximum allowable design stress of 21,000 lbf/in.^{2}, a joint efficiency of 0.85, and no corrosion allowance (see A.4.1).

Table A.2a—Typical Sizes and Corresponding Nominal Capacities (m^3) for Tanks with 2400-mm Courses (SI)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
Tank Diameter m	Capacity per m of Height m^3	Tank Height (m) / Number of Courses in Completed Tank						
		4.8 / 2	7.2 / 3	9.6 / 4	12 / 5	14.4 / 6	16.8 / 7	19.2 / 8
3	7.07	34	51	68	—	—	—	—
4.5	15.9	76	115	153	191	—	—	—
6	28.3	136	204	272	339	407	—	—
7.5	44.2	212	318	424	530	636	742	848
9	63.6	305	458	610	763	916	1,069	1,221
10.5	86.6	416	623	831	1,039	1,247	1,455	1,663
12	113	543	814	1085	1,357	1,629	1,900	2,171
13.5	143	687	1,031	1373	1,718	2,061	2,405	2,748
15	177	848	1,272	1696	2,121	2,545	2,969	3,393
18	254	1,221	1,832	2442	3,054	3,664	4,275	4,358
								D = 17
21	346	1,663	2,494	3323	4,156	4,988	4,763	—
24	452	2,171	3,257	4341	5,429	5,474	*D* = 19	—
27	573	2,748	4,122	5494	6,871	*D* = 22	—	—
30	707	3,393	5,089	6782	*D* = 27	—	—	—
36	1,018	4,886	7,329	8712	—	—	—	—
				D = 34				
42	1,385	6,650	9,975	—	—	—	—	—
48	1,810	8,686	11,966	—	—	—	—	—
54	2,290	10,993	*D* = 46	—	—	—	—	—
60	2,827	13,572	—	—	—	—	—	—
66	3,421	16,422	—	—	—	—	—	—

NOTE The nominal capacities given in this table were calculated using the following formula:

In SI units:

$$C = 0.785D^2H$$

where

C is the capacity of tank, in m^3;

D is the diameter of tank, in m (see A.4.1);

H is the height of tank, in m (see A.4.1).

The capacities and diameters in italics (Columns 4 through 9) are the maximums for the tank heights given in the column heads, based on a maximum permissible shell-plate thickness of 13 mm, a maximum allowable design stress of 145 MPa, a joint efficiency of 0.85, and no corrosion allowance (see A.4.1).

Table A.2b—Typical Sizes and Corresponding Nominal Capacities (Barrels) for Tanks with 96-in. Courses (USC)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
Tank Diameter ft	Capacity per ft of Height barrels	Tank Height (ft) / Number of Courses in Completed Tank						
		16 / 2	24 / 3	32 / 4	40 / 5	48 / 6	56 / 7	64 / 8
10	14.0	225	335	450	—	—	—	—
15	31.5	505	755	1,010	1,260	—	—	—
20	56.0	900	1,340	1,790	2,240	2,690	—	—
25	87.4	1,400	2,100	2,800	3,500	4,200	4,900	5,600
30	126	2,020	3,020	4,030	5,040	6,040	7,050	8,060
35	171	2,740	4,110	5,480	6,850	8,230	9,600	10,980
40	224	3,580	5,370	7,160	8,950	10,740	12,540	14,340
45	283	4,530	6,800	9,060	11,340	13,600	15,880	18,140
50	350	5,600	8,400	11,200	14,000	16,800	19,600	22,400
60	504	8,060	12,100	16,130	20,160	24,190	28,220	26,130
								D = 54
70	685	10,960	16,450	21,950	27,440	32,930	30,140	—
80	895	14,320	21,500	28,670	35,840	35,810	*D* = 62	—
90	1,133	18,130	27,220	36,290	45,360	*D* = 73	—	—
100	1,399	22,380	33,600	44,800	*D* = 88	—	—	—
120	2,014	32,250	48,380	54,200	—	—	—	—
				D = 110				
140	2,742	43,900	65,860	—	—	—	—	—
160	3,581	57,340	74,600	—	—	—	—	—
180	4,532	72,570	*D* = 149	—	—	—	—	—
200	5,595	89,600	—	—	—	—	—	—
220	6,770	108,410	—	—	—	—	—	—

NOTE The nominal capacities given in this table were calculated using the following formula:

In USC units:

$C = 0.14D^2H$

where

C is the capacity of tank, 42-gal barrels;

D is the diameter of tank, in ft (see A.4.1);

H is the height of tank, in ft (see A.4.1).

The capacities and diameters in italics (Columns 4 through 9) are the maximums for the tank heights given in the column heads, based on a maximum permissible shell-plate thickness of 1/2 in., a maximum allowable design stress of 21,000 lbf/in.^{2}, a joint efficiency of 0.85, and no corrosion allowance (see A.4.1).

A.2.4 Bottom reinforcing plates in flush-type cleanouts and flush-type shell connections, and flush-type fitting necks attached to shell shall conform to toughness requirements of 4.2.9 and Figure 4.1 at design metal temperature.

A.3 Design

A.3.1 The maximum tensile stress before the joint efficiency factor is applied shall be 145 MPa (21,000 lbf/in.^{2}).

A.3.2 Stresses shall be computed on the assumption that the tank is filled with water (specific gravity = 1.0) or with the liquid to be stored if it is heavier than water.

A.3.3 The tension in each ring shall be computed 300 mm (12 in.) above the centerline of the lower horizontal joint of the course in question. When these stresses are computed, the tank diameter shall be taken as the nominal diameter of the bottom course.

• **A.3.4** The joint efficiency factor shall be 0.85 with the spot radiography required by A.5.3. By agreement between the Purchaser and the Manufacturer, the spot radiography may be omitted, and a joint efficiency factor of 0.70 shall be used.

A.4 Thickness of Shell Plates

A.4.1 The nominal thicknesses of shell plates shall not be less than that computed from the stress on the vertical joints, using the following formula:

In SI units:

$$t = \frac{4.9D(H-0.3)G}{(E)(145)} + CA$$

where

t is the nominal thickness, in mm (see 5.6.1.1);

D is the nominal diameter of the tank, in m (see 5.6.1.1, Note 1);

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

• G is the design specific gravity of the liquid to be stored, as specified by the Purchaser. The design specific gravity shall not be less than 1.0;

E is the joint efficiency, which is either 0.85 or 0.70 (see A.3.4);

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

In USC units:

$$t = \frac{2.6D(H-1)G}{(E)(21{,}000)} + CA$$

where

t is the nominal thickness, in inches (see 5.6.1.1);

D is the nominal diameter of the tank, in ft (see 5.6.1.1, Note 1);

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

- G is the design specific gravity of the liquid to be stored, as specified by the Purchaser. The design specific gravity shall not be less than 1.0;

E is the joint efficiency, which is either 0.85 or 0.70 (see A.3.4);

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

A.4.2 The nominal thickness of shell plates (including shell extensions for floating roofs) shall not be less than that listed in 5.6.1.1. The nominal thickness of shell plates refers to the tank shell as constructed. The nominal thicknesses given in 5.6.1.1 are based on erection requirements.

A.5 Tank Joints

A.5.1 Vertical and horizontal joints in the shell, bottom joints, shell-to-bottom joints, wind-girder joints, and roof and top-angle joints shall conform to 5.1.5.

A.5.2 The requirements of 5.7.3 for the spacing of welds do not apply except for the requirement that the spacing between the toes of welds around a connection shall not be less than $2^1/_2$ times the shell thickness at the connection (i.e. dimension A, B, C, or E in Figure 5.6 shall not be less than $2^1/_2$ times the shell thickness).

A.5.3 When radiographic examination is required (joint efficiency = 0.85), the spot radiographs of vertical joints shall conform to 8.1.2.2, Item a only, excluding the 10 mm ($^3/_8$ in.) shell-thickness limitation in Item a and excluding the additional random spot radiograph required by Item a. The spot radiographs of horizontal joints shall conform to 8.1.2.3.

A.6 Intermediate Wind Girders

Calculations for and installation of intermediate wind girders are not required unless specified by the Purchaser.

A.7 Shell Manholes and Nozzles

A.7.1 Except for other designs and shapes permitted by 5.7.1.2, shell manholes shall conform to 5.7.5, Figure 5.7a, Figure 5.7b, and Tables 5.3a through 5.5b.

A.7.2 Shell nozzles and flanges shall conform to 5.7.6; Figure 5.7b, Figure 5.8, and Figure 5.10; and Tables 5.6a through 5.8b. For regular type reinforced nozzles, minimum elevation dimension H_N shown in column 8 of Table 5.6 may be reduced when specified by the Purchaser provided the minimum weld spacing of A.5.2 is maintained.

A.7.3 The radiographic requirements of 5.7.3.4 do not apply.

A.8 Flush-Type Cleanout Fittings

A.8.1 The details and dimensions of flush-type cleanout fittings shall conform to 5.7.7, Figure 5.12 and Figure 5.13, and Tables 5.9a through 5.11b.

- **A.8.2** The provisions for stress relief specified in 5.7.4 and 5.7.7.3 are not required unless they are specified by the Purchaser or unless any plate in the unit has a thickness greater than 16 mm ($^5/_8$ in.).

A.9 Flush-Type Shell Connections

A.9.1 The details and dimensions of flush-type shell connections shall conform to 5.7.8, Figure 5.14, and Table 5.12a and Table 5.12b.

- **A.9.2** The provisions for stress relief specified in 5.7.4 and 5.7.8.3 are not required unless they are specified by the Purchaser or unless any plate in the assembly has a thickness greater than 16 mm ($^5/_8$ in.).