

Specification for Fiberglass Reinforced Plastic Tanks

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Specification for Fiberglass Reinforced Plastic Tanks

1 Scope

1.1 General

This specification covers material, design, fabrication, and testing requirements for fiberglass-reinforced plastic (FRP) tanks. Only shop-fabricated, vertical, cylindrical tanks are covered. Tanks covered by this specification are intended for aboveground and atmospheric pressure service. Unsupported cone bottom tanks are outside the scope of this specification.

This specification is designed to provide the petroleum industry with various standard sizes of FRP tanks. Because of the versatility of FRP tanks, the user shall be responsible for determining the suitability of FRP tanks for the intended service.

NOTE The consequences of exposing FRP tanks to high temperatures created by exposure fires should be considered. This material loses strength as the temperature increases. FRP tanks should be suitably protected against fire exposure or so located that any spills resulting from the failure of these materials could not unduly expose persons, buildings, structures, or other equipment to the possible fire incident.

1.2 Compliance

1.2.1 The manufacturer is responsible for complying with all of the provisions of this specification. The purchaser is responsible defining their specific requirements in the data sheet (see Figure D.1; hereafter referred to as “the data sheet”). The purchaser may make any investigation necessary to be satisfied with compliance by the manufacturer and may reject any material that does not comply with this specification.

NOTE The purchaser is encouraged to arrange for inspection independent of the inspection furnished by the manufacturer, and the purchaser’s inspector should follow closely all the details of shop fabrication and testing herein specified that affect the integrity and safety of the completed structure.

1.2.2 If specified by the purchaser on the data sheet, the tank shall be constructed in accordance with API Q1 and the API Monogram Program (see Annex A).

1.2.3 This specification applies to new tanks. The requirements may be applied to existing tanks at the discretion of the owner/operator.

1.2.4 This specification has requirements given in two alternate systems of units. The manufacturer shall comply with the U.S. customary (USC) units. The SI unit equivalent is provided for convenience.

NOTE Per API document style, SI unit values appear first, followed by their USC equivalents in parentheses

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Standard 650, *Welded Tanks for Oil Storage*

API Standard 2000, *Venting Atmospheric and Low-pressure Storage Tanks*

API Recommended Practice 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*

AISC.,¹ *Steel Construction Manual*

ASCE 7,² *Minimum Design Loads for Buildings and Other Structures*

ASME B16.5, *Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard*

ASTM A153, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

ASTM A193/A193M, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A307, *Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60000 PSI Tensile Strength*

ASTM A325, *Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength*

ASTM A325M, *Standard Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength (Metric)*

ASTM C581, *Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service*

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

ASTM D790, *Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*

ASTM D2583, *Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor*

ASTM D2584, *Standard Test Method for Ignition Loss of Cured Reinforced Resins*

ASTM D2990, *Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics*

ASTM D3299, *Standard Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks*

ASTM D4097, *Standard Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks*

IBC., *International Building Code*³

SPI E-1067.,⁴ *Recommended Practice for Acoustic Emission Examination of Fiberglass Tanks/Vessels*

SSPC-SP1,⁵ *Solvent Cleaning*

U.S. Government, 29 CFR Section 1910, General Industry Regulations, OSHA⁶

¹ American Institute of Steel Construction, One East Wacker Drive Suite 700, Chicago, IL 60601-1802, www.aisc.org.

² American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191, www.asce.org.

³ International Building Code, 500 New Jersey Avenue, NW, 6th Floor, Washington, DC 20001, www.iccsafe.org.

⁴ Society of the Plastics Industry, 1425 K Street NW., Suite 500, Washington, DC 20005, <http://www.plasticsindustry.org>.

⁵ The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, PA 15222, www.sspc.org.

⁶ U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov.

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1

chop-hoop

A unique blend of chop-spray and filament winding. The FRP composite is constructed using the chop-spray and the filament winding processes simultaneously. This process gives the strength from the directional glass from the filament winding process plus the higher resin content from the chop-spray process, which provides improved corrosion protection to the reinforcement.

3.2

chop-spray

Continuous strand glass roving, and catalyzed resin are fed through a chopper gun, which cuts the fiberglass into specific lengths that can be adjusted on site. The chopper gun deposits the resin-saturated "chop" on the mold. The laminate is then rolled to thoroughly saturate the glass strands and compact the chop. Additional layers of chop laminate are added as required for thickness.

3.3

design thickness

The thickness necessary to satisfy tension and compression strength requirements by this Specification or, in the absence of such expressions, by good and acceptable engineering practice for specified design conditions, without regard to construction limitations or corrosion allowances.

3.4

fiberglass-reinforced plastic (FRP)

A fiber-reinforced plastic composite which is a combination of a polymer matrix resin, referred to as plastic, (thermoset resin such as polyester, isopolyester, vinyl ester, epoxy, phenolic) and fiber reinforcement such as glass, carbon, aramid, or other reinforcing material.

3.5

filament wound

Filament winding is an automated open molding process that uses a rotating mandrel as the mold. The male mold configuration produces a finished inner surface and a laminate surface on the outside diameter of the product. Filament winding results in a high degree of fiber loading, which provides high tensile strengths in the manufacture of hollow, generally cylindrical products such as chemical and fuel storage tanks, pipes, stacks, and pressure vessels.

3.6

inspector

The person(s) designated by the purchaser or manufacturer to perform inspections.

3.7

mandatory

Required sections of the specification become mandatory if the specification has been adopted by a legal jurisdiction or if the purchaser and the manufacturer choose to make reference to this specification on the nameplate of in the manufacturer's certification.

3.8

manufacturer

The party having the primary responsibility to construct the tank.

3.9

purchaser

The owner, owner's engineer, or operator who specifies the tank data sheet for the purchase.

3.10

purchaser's option

A choice to be selected by the purchaser and indicated on the data sheet. When the purchaser specifies an option covered by an annex; it then becomes a requirement.

3.11

recommendation

Criteria that provides a good/acceptable design and may be used at the option of the purchaser and the manufacturer.

4 Material

4.1 General

The materials used in the manufacture of tanks furnished to this specification are composite materials consisting of a thermosetting polymer reinforced with glass fibers. Permitted polymer resins are polyester resins, epoxy resins, or vinyl ester resins. The purchaser shall define the specific material on the data sheet if there is any specific condition, such as extreme temperature, in the service that could affect the material selection.

4.2 Resin

4.2.1 The resin used shall be commercial grade thermosetting polymer and shall not contain fillers and pigments, except if specified by the purchaser on the data sheet.

Any thixotropic agent used for viscosity control shall not interfere with visual inspection. The thixotropic agent shall not exceed 5 % by weight. Resin paste/putty used to fill crevices before overlay shall not be subject to these limitations.

4.2.2 The effects of long exposure to ultraviolet radiation, such as surface chalking and discoloration, shall be mitigated by incorporating one or more of the following:

- a) UV absorber into the resin—these are incorporated in the external coat at a level of 0.1 to 0.3 weight percent,
- b) pigment outer resin layers/pigment to opacity,
- c) external surface paint as specified in the data sheet (see Annex D for additional coating requirements),
- d) UV-inhibited gelcoat compatible with underlying resin.

NOTE Additions of any of the above may interfere with visual inspection of laminate quality.

4.2.3 If specified on the data sheet, antimony compounds or other fire retardant agents shall be added to the laminate to provide improved fire resistance. The resulting laminate must meet the physical properties of this specification.

NOTE Metal powder, carbon, or other types of conductive compounds provide improved conductivity. Additions of such compounds interfere with visual inspection of laminate quality and physical properties of the laminate.

4.2.4 Resistance to attack by hydrocarbons shall be verified by testing in accordance with ASTM C581. Tensile and flexural strength shall be determined at the rated temperature by testing in accordance with ASTM D2990 or combination of D638 and D790. This testing shall be conducted by the manufacturer or his agent, the records kept on file, and submitted to the purchaser upon request.

4.3 Reinforcing Material

Reinforcing materials shall be a commercial grade of E- or E-CR-type glass fiber having a coupling agent chemically compatible with the resin used. The reinforcing material used to fabricate the tank shall be that used to generate the corrosion resistance and physical property design data required by Section 4.

4.4 Surfacing Material

Reinforcing used on the inner surface shall comply with ASTM D3299.

4.5 Appurtenances

Woven roving used for reinforcement of knuckles, manways, and other appurtenances shall be tested in compliance with, and meet the requirements of, the most suitable industry standard.

4.6 Bolting

- a) Unless specified otherwise by the purchaser, all carbon steel bolts for flange bolting shall conform to ASTM A193M/A193. Nuts shall comply with ASTM A194M/A194. See Figure D.1 for any additional requirements.
- b) Bolt hole dimension and bolting installation tension requirements shall follow the AISC *Steel Construction Manual*.
- c) An anchor bolt system, if required, shall be designed according to the *International Building Code*.

5 Design

5.1 General

5.1.1 The purchaser shall determine and specify the design and operating pressures on the data sheet. The standard design is limited to:

- working pressure of 150 mm (6 in.) water column with the static head of the stored fluid for the operating pressure, and
- vacuum condition of 50 mm (2 in.) water column.

5.1.2 Design requirements pertaining to filament winding, chop-spray, and combinations of these methods (commonly referred to as chop-hoop) are covered in this section. Tanks constructed using hand lay-up (contact molding) shall be designed to the same standard as chop-spray construction. Dimensions shall conform to Figure 3 and Table 1b.

5.2 Shell Design—Chop-spray

5.2.1 The allowable shell design tensile stress (S_a) shall be 10 % of the ultimate stress (S_u). Ultimate stress shall be determined by tests in accordance with ASTM D638 for each composite combination used by the manufacturer. This test shall be conducted for all standard composite combinations offered by the manufacturer. Shell thickness for testing is defined as the structural layer plus the exterior layer. Test specimens shall be constructed with resins containing all additives used in the finished product. These tests may be conducted on a one-time basis and kept the results on file if there have been no revisions to ASTM D638.

5.2.2 The minimum shell thickness shall be in accordance with the following design equation, but not less than 4.8 mm (0.1875 in.):

$$t = PD/2S_a \quad (1)$$

where

- t is the minimum allowable shell thickness at the point where P is determined, in mm (inches);
- P is the pressure exerted by a combination of fluid head and gas blanket, in MPa (lbf/in.²);
- D is the inside diameter of the tank, in mm (inches);
- is the allowable shell design tensile stress, in MPa (lbf/in.²).

Table 1a—Tank Dimensions (SI) (See Figure 2)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Nom. Capacity	Inside Diameter ±13 mm	Shell Height ±13 mm	Height of Overflow Line Connection ±3 mm	Height of Walkway Lugs ±3 mm	Size of Connections	Size of Connections
—	A	B	C	D	C-1, C-4	C-2, C-3, C-5, C-6
M ³	mm	mm	mm	mm	mm	mm
15	2400	3000	2850	2275	75	75
20	2400	3750	3600	3025	75	75
25	2400	4950	4800	4225	75	75
25	3000	3150	3000	2425	75	75
30	3600	3000	2950	2275	75	100
35	3000	4500	4325	3775	75	100
35	3600	3150	3000	2425	75	100
40	3600	3750	3600	3025	100	100
50	3600	4500	4350	3775	100	100
65	3600	6000	5850	5275	200	100
80	4200	5550	5400	4825	100	100
80	4650	4800	4650	4075	100	100
80	3600	7500	7450	6775	100	100
125	4650	7200	7050	6475	100	100
160	4650	9000	8850	8275	100	100
160	6450	4800	4650	4075	100	100
240	6450	7200	7050	6475	100	100

NOTE The approximate working capacities shown in column 2 apply to flat-bottom tanks.

Table 1b—Tank Dimensions (U.S. Customary) (See Figure 2)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Nominal Capacity bbl	Inside Diameter ft, in. ± ½ in.	Shell Height ft, in. ± ½ in.	Height of Overflow Line Connection ft, in. ± ½ in.	Height of Walkways Lugs ft, in. ± ⅛ in.	Size of Connections in.	Size of Connections in.
—	A	B	C	D	C-1, C-4	C-3, C-2, C-5, C-6
90	8, 0	10, 0	9, 6	7, 7	3	3
110	8, 0	12, 6	12, 0	10, 1	3	3
150	8, 0	16, 6	16, 0	14, 1	3	3

Table 1b—Tank Dimensions (U.S. Customary) (See Figure 2) (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Nominal Capacity bbl	Inside Diameter ft, in. ± ½ in.	Shell Height ft, in. ± ½ in.	Height of Overflow Line Connection ft, in. ± ½ in.	Height of Walkways Lugs ft, in. ± ⅛ in.	Size of Connections in.	Size of Connections in.
—	A	B	C	D	C-1, C-4	C-3, C-2, C-5, C-6
150	10, 0	10, 6	10, 0	8, 1	3	3
200	12, 0	10, 0	9, 6	7, 7	3	4
210	10, 0	15, 0	14, 6	12, 7	3	4
210	12, 0	10, 6	10, 0	8, 1	3	4
250	12, 0	12, 6	12, 0	10, 1	4	4
300	12, 0	15, 0	14, 6	12, 7	4	4
400	12, 0	20, 0	19, 6	17, 7	4	4
500	14, 0	18, 6	18, 0	16, 1	4	4
500	15, 6	16, 0	15, 6	13, 7	4	4
500	12, 0	25, 0	24, 6	22, 7	4	4
750	15, 6	24, 0	23, 6	21, 7	4	4
1000	15, 6	30, 0	29, 6	27, 7	4	4
1000	21, 6	16, 0	15, 6	13, 7	4	4
1500	21, 6	24, 0	23, 6	21, 7	4	4

NOTE The approximate working capacities shown in column 2 apply to flat-bottom tanks.

5.3 Shell Design—Filament Wound and Chop-hoop

Allowable design tensile stress (S_a) is that stress which produces 0.001 mm/mm (in./in.) tensile strain according to the formula:

$$S_a = 0.001E \quad (2)$$

where

E is the tensile modulus of elasticity for the particular filament wound laminate in the direction of loading. Modulus of elasticity and ultimate stress shall be determined in accordance with ASTM D638.

The specified test shall be conducted for each standard composite combination used by the manufacturer. Test specimens shall be constructed with resins containing all additives used in the finished product. If S_a calculated by Equation (2) is greater than 0.10 of the ultimate tensile stress, then S_a becomes $S_a = 0.10 \times S_u$. Minimum shell thickness shall be determined using Equation (1), but not less than 5 mm (0.1875 in.).

5.4 Shell Design—Laminate Construction

5.4.1 General

The laminate comprising the structural components (bottom, cylindrical shell, and roof) shall consist of an inner surface, interior layer, structured layer, and an exterior layer.

5.4.2 Inner Surface

The inner surface shall be between 0.25 mm to 0.50 mm (0.01 in. to 0.02 in.) of reinforced resin-rich material, reinforced with a chemical-resistant glass fiber surface veil or with an organic fiber surface veil, as specified in the data sheet. The manufacturer shall provide documentation that the material used for the inner surface layer is suitable for the fluid specified in the data sheet. This resin-rich surface shall contain less than 20 % by weight of reinforcing material.

5.4.3 Interior Layer

To eliminate weeping, the inner surface exposed to the corrosive environment shall be applied over an interior layer composed of resin, reinforced only with non-continuous glass-fiber strands applied in a minimum of two piles of chopped-strand mat equivalent to a total of 0.9 kg/m² (3 oz/ft²). As an alternative, a minimum of two passes of chopped roving with a minimum length of 13 mm (0.5 in.) to a maximum length of 50 mm (2 in.) shall be applied uniformly to an equivalent weight of 0.9 kg/m² (3 oz/ft²). Each ply of mat or pass of chopped roving shall be rolled prior to the application of additional reinforcement. The combined thickness of the inner surface and interior layer shall not be less than 2.0 mm (0.08 in.). To prevent weeping, glass content of the inner surface and the interior layer combined shall be 27 ±5 % by weight when tested in accordance with ASTM D2584.

5.4.4 Structural Layer (Chop-hoop, Filament Wound)

Subsequent reinforcement shall be continuous strand roving. The thickness of the structural layer shall be sufficient to provide minimum strength requirements at various tank heights, as specified in 5.3. If additional reinforcement is required, woven fabric, unidirectional fabric, chopped-strand mat, or chopped strands interspersed in the winding may be used to provide additional strength. Glass content of this structural layer shall range from 45 % to 55 % for chop-hoop wound laminates and from 50 % to 80 % for filament wound laminates when tested in accordance with ASTM D2584.

5.4.5 Structural Layer (Chop-spray)

As an alternative to 5.4.4, subsequent reinforcement shall consist of 0.5 kg/m² (1.5 oz/ft²) chopped strand mat or an equivalent weight of chopped roving and an additional number of alternating piles of 0.8 kg/m² (2.7 oz/ft²) woven roving and 0.5 kg/m² (1.5 oz/ft²) chopped-strand mat, or equivalent chopped roving, as required to achieve the thickness calculated per 4.2. Each successive ply or pass of reinforcement shall be rolled prior to the application of additional reinforcement. Glass content of this structural layer shall be a minimum of 35 % when tested in accordance with ASTM D2584. Alternating layers of directional reinforcement shall be lapped a minimum of 40 mm (1.5 in.) with laps staggered at least 60 mm (2.25 in.) from one layer to the next.

5.4.6 Exterior Layer

Tank shell, bottom, and roof shall have an exterior layer consisting of chopped strand, chopped-strand mat, or surfacing mat. No glass fibers shall be exposed. Resin used in the exterior layer shall be resistant to ultraviolet degradation. Ultraviolet resistance shall be accomplished as specified by 4.2.2.

5.5 Bottom Knuckle Radius Design

The bottom knuckle shall be reinforced with an overlay of glass fiber and resin extending from the flat bottom tangent line upward a minimum of 300 mm (12 in.), with an additional 100 mm (4 in.) of thickness transition. Reinforcement of the knuckle radius shall taper so that it is tangent with the flat bottom and shall not extend beyond the tangent line onto the tank bottom. The reinforced perimeter shall not prevent the bottom from uniformly contacting a flat support surface when liquid covers the bottom inside of the tank. The minimum thickness of this radius section shall be equal to the combined thicknesses of the bottom shell wall and the bottom. The minimum acceptable knuckle radius shall be 2 in. (50 mm), as shown in Figure 1.

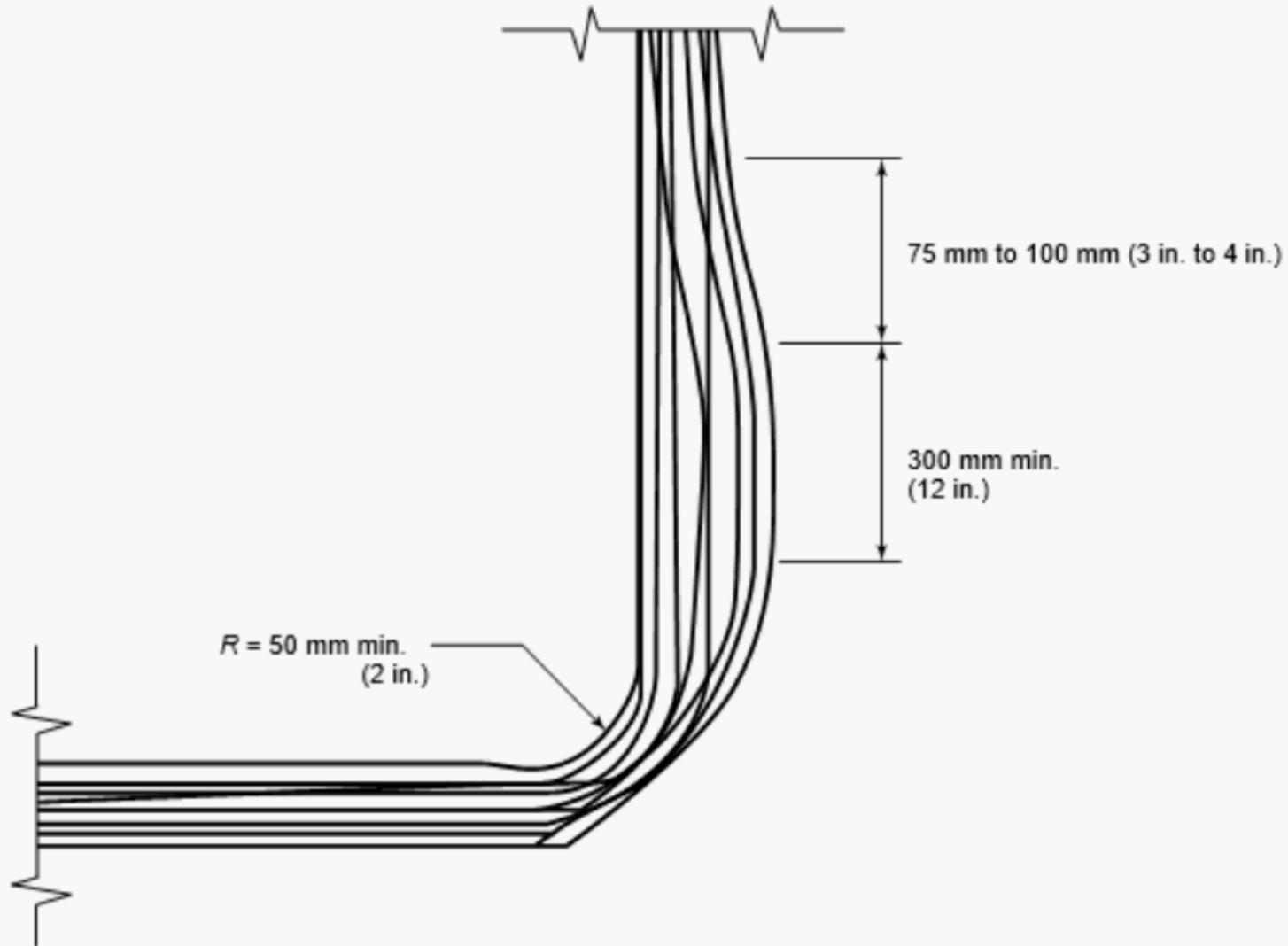


Figure 1—Bottom Knuckle of Flat-bottom Tank

5.6 Bottom-to-Shell Joint (Chop-spray) Design

If tank bottoms and shells are fabricated separately and joined by use of a laminate bond, the joint shall be of alternating layers of mat (or chopped strand) and 0.8 kg/m^2 (24 oz/yd^2) woven roving. The minimum thickness of this overlay shall be equal to the thickness of the tank shell at the joint. The reinforcement shall meet the requirements specified in Section 6.5 of ASTM D4097. The interior layer of the joint shall be reinforced with at least two layers of 0.5 kg/m^2 (1.5 oz/ft^2) material. The minimum width of this seal joint is 150 mm (6 in.). The inner surface of the joint shall be sealed according to 5.4.

5.7 Bottom Strength

Minimum acceptable bottom thickness shall be 6.35 mm (0.25 in.) for fully supported flat or cone bottoms for tanks 3.7 m (12 ft) in diameter, or less. For tanks greater than 3.7 m (12 ft) in diameter, the minimum acceptable bottom thickness shall be 10 mm (0.375 in.). Bottom laminate construction shall conform to 5.4, 5.4.2, 5.4.3, and 5.4.5.

5.8 Roof

5.8.1 The roof configuration shall be:

- ellipsoidal dome, or
- flanged or dished dome, or
- conical roof with 1:12 pitch or steeper.

5.8.2 Regardless of shape, the roof shall be able to support a concentrated 1.1 kN (250 lbf) load on any single 100 mm × 100 mm (4 in. × 4 in.) area without damage, with a maximum deflection of $\frac{1}{2}$ % of the inside tank diameter. The use of stiffener ribs or sandwich construction stiffening systems is acceptable.

5.9 Roof Laminate Construction

5.9.1 Roof laminate construction shall conform to Sections 5.4, 5.4.2, 5.4.3, and 5.4.5. The minimum roof thickness shall be 5 mm (0.1875 in.).

5.9.2 If the tank has a gas blanket installed, the purchaser shall consider the option of laminating the interior of the top roof seam (see Figure D.1).

5.10 Cleanout

Cleanout or manway flange cover dimensions and bolting shall conform to the dimensions shown in Table 2 or ASTM D3299, Table 5. Cleanout flanged nozzle construction shall conform to ASTM D3299, Table 4. The bottom of the cleanout shall not extend lower than 300 mm (12 in.) from the bottom of the tank. The requirements in Annex C apply to cleanout and manway bolting.

5.11 Nozzles

Unless specified otherwise by the purchaser, the tank shall be furnished with the nozzles shown in Figure 2. The size and location of the nozzles shall conform to Table 1b and Figure 2.

NOTE The configuration covered above is the default or standard design.

Table 2—Dimension of Manways

Size ^a		Diameter of Flange and Cover		Thickness of Flange and Cover		Diameter of Bolt Circle		No. of Bolts	Bolt Hole Diameter	
mm	(in.)	±2.5 mm	(in. ± $\frac{3}{32}$)	±0.8 mm	(in. ± $\frac{1}{32}$)	±2.5 mm	(in. ± $\frac{3}{32}$)		±0.8 mm	(in. ± $\frac{1}{32}$)
Side-shell Manway—Up to 15 psig (104 kPa) Hydrostatic Head										
450	(18)	635	(25)	25	(1)	578	(22 $\frac{3}{4}$)	16	19	($\frac{3}{4}$)
500	(20)	699	(27 $\frac{1}{2}$)	25	(1)	635	(25)	20	22	($\frac{7}{16}$)
560	(22)	762	(30)	25	(1)	686	(27)	20	25	(1)
635	(24)	813	(32)	38	(1 $\frac{1}{2}$)	749	(29 $\frac{1}{2}$)	20	25	(1)
450	(18)	635	(25)	10	($\frac{3}{8}$)	578	(22 $\frac{3}{4}$)	16	13	($\frac{1}{2}$)
500	(20)	699	(27 $\frac{1}{2}$)	10	($\frac{3}{8}$)	635	(25)	20	13	($\frac{1}{2}$)
560	(22)	762	(30)	10	($\frac{3}{8}$)	686	(27)	20	13	($\frac{1}{2}$)
635	(24)	813	(32)	10	($\frac{3}{8}$)	749	(29 $\frac{1}{2}$)	20	13	($\frac{1}{2}$)

^a Bolt size = bolt hole diameter minus 3 mm ($\frac{1}{8}$ in.).

The purchaser may modify the orientation, size, and quantity of nozzles. The nameplate marking shall denote the nozzle configuration. See Section 8.

Nozzles shall be female NPT. However, the purchaser may specify on the data sheet other types of nozzles such as flanged, grooved, or male NPT. Fittings C-1 and C-4 shall be of a full coupling design to allow for internal connection (drain and inlet downcomer). All nozzles shall be of the glassed-in type.

5.12 Cutout Reinforcements

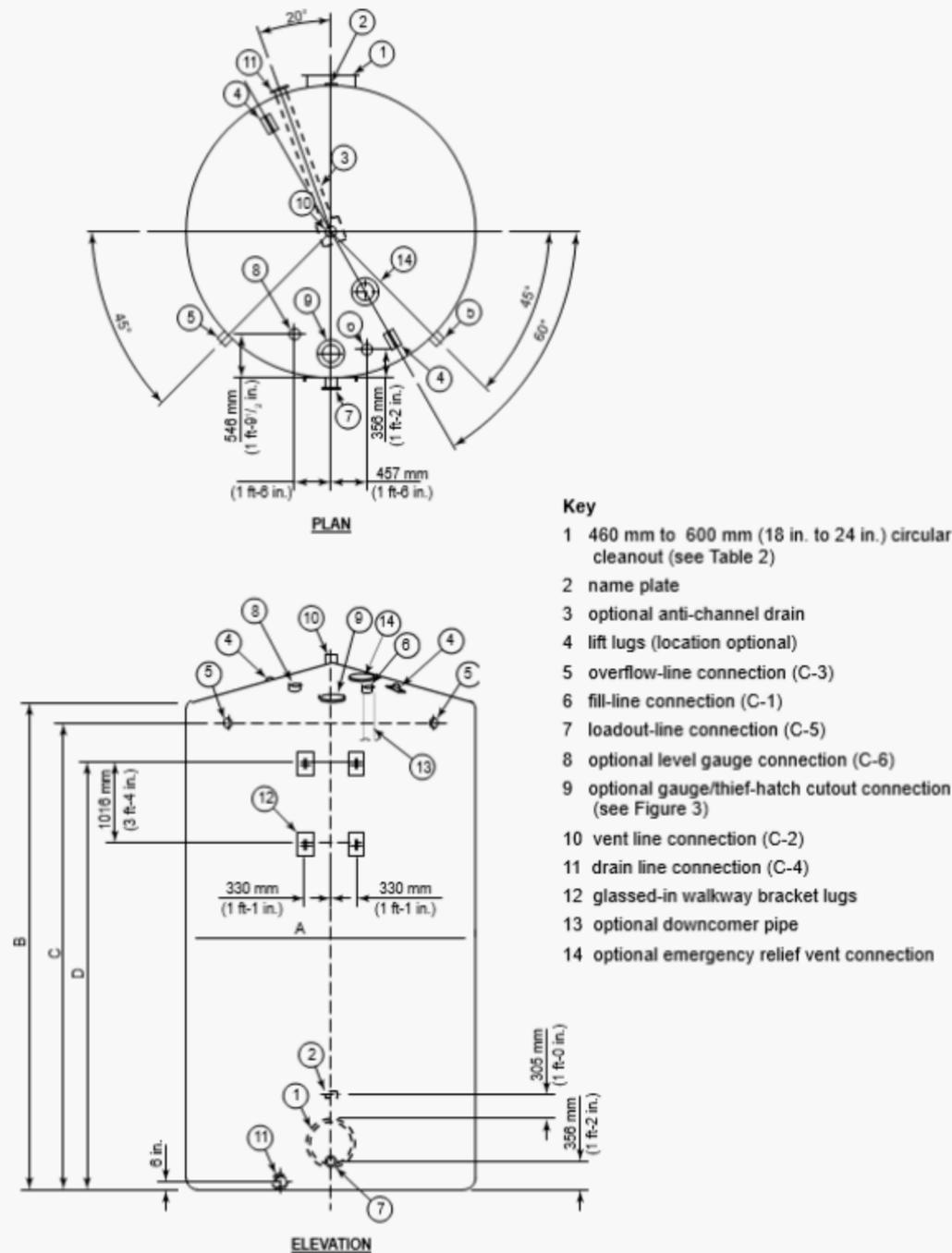
Cutouts for nozzles and cleanouts that will bear hydrostatic pressure shall be reinforced on a circular area concentric with the cutout. The thickness of the reinforcement (T_r) in mm (in.) shall be determined as follows:

$$T_r = PDK/2S_a \tag{3}$$

where

- K is 1.0 for nozzles DN 150 (NPS 6) and larger or $d/(d_r - d)$ for nozzles smaller than DN 150 (NPS 6);
- d is the nozzle outside diameter; mm (inches);
- d_r is the reinforcement diameter, mm (inches) = $2 \times d$ for nozzles DN 150 (NPS 6) or larger or $d + 6$ for nozzles smaller than DN 150; (NPS 6);
- P is the hydrostatic pressure at the point of nozzle installation; in MPa (lbf/in.²);
- D is the inside diameter of the tank; in mm (inches);
- S_a is the allowable tensile stress (see 5.2.1). in MPa (lbf/in.²).

For $T_r < 3$ mm ($1/8$ in.), no additional reinforcement shall be required other than the overlay for glassed-in nozzles.



NOTE See Table 1 for connection sizes.

Figure 2—Closed Top FRP Tank Dimensions (See Table 1b)

5.13 Appurtenances

5.13.1 Nozzles, cleanouts, and other appurtenances shall be installed in accordance with 5.10 to 5.12. Installation laminates shall meet minimum standards shown in Figure 5 and Figure 6 of ASTM D3299.

5.13.2 FRP flanged nozzle construction and design shall conform to ASTM D3299, Table 4. Flange drilling and bolting shall conform to ASME B16.5 for class 150 flat faced flanges.

5.13.3 All fittings below the liquid level shall be reinforced internally with at least two layers of 0.5 kg/m² (1.5 oz/ft²) mat. The inner surface shall be sealed according to 5.4.3.

5.13.4 For bolting requirements applicable to all appurtenances, see Annex C.

5.14 Walkway, Ladder, Lifting, Hold-down, and Tie-down Lugs

5.14.1 The manufacturer shall demonstrate by physical testing on a prototype that all lifting lugs, as a set, are capable of withstanding two times the empty weight of the tank. Lugs shall not be installed by the use of fasteners that penetrate the shell. Walkway and ladder loads are specified in Annex C.

5.14.2 If hold-downs (wind anchorage lugs) are specified by purchaser, the manufacturer shall use ASCE 7-16 or IBC to calculate wind loads. Hold-down lugs shall be placed on the tank, so they do not protrude below the bottom surface of the tank.

5.14.3 If a safety tie down is specified in the data sheet for field personnel working on the tank roof, a tie down anchor lug shall be provided at an appropriate roof location. The anchor lug shall be designed per 29 CFR 1910 or equivalent national regulation. A tank lifting lug may be used as the tie down anchor if it is designed accordingly.

5.15 Downcomer Pipe

A conductive downcomer pipe, with a spray deflector shall be installed if specified in the data sheet.

NOTE The downcomer pipe system is used to reduce the internal static build up caused by liquid splashing from the filling drop.

5.16 Gauge/Thief Hatches

Gauge or thief or hatch pressure and vacuum ratings shall be in accordance with the design conditions (see 5.1). Figure 3 provides suggested bolt patterns for two typical flanges used on gauge/thief hatch openings. A grounding lug shall be installed on the hatch for grounding purposes. The lug size shall accommodate the attachment of an AWG No. 4 wire. A striker plate consisting of a minimum of 5 mm × 450 mm × 450 mm (0.1875 in. × 16 in. × 16 in.) steel plate shall be laminated to the tank bottom directly below the gauge/thief hatch.

NOTE Manual gauging that includes opening the gauge or thief hatch has some inherent personal safety risk due to the personnel exposure to possible gases in the tank. The purchaser can mitigate this risk by providing a remote tank level gauging system using radar gauge, float valve, level transmitter, or other device.

5.17 Design Considerations for Potential Electrostatic Hazards

Electrostatic hazards which might arise when filling or emptying FRP tanks may be divided into two types:

- 1) those due to the accumulation of a charge on the outside of the tank,
- 2) those due to the build-up of an electric field inside the tank.

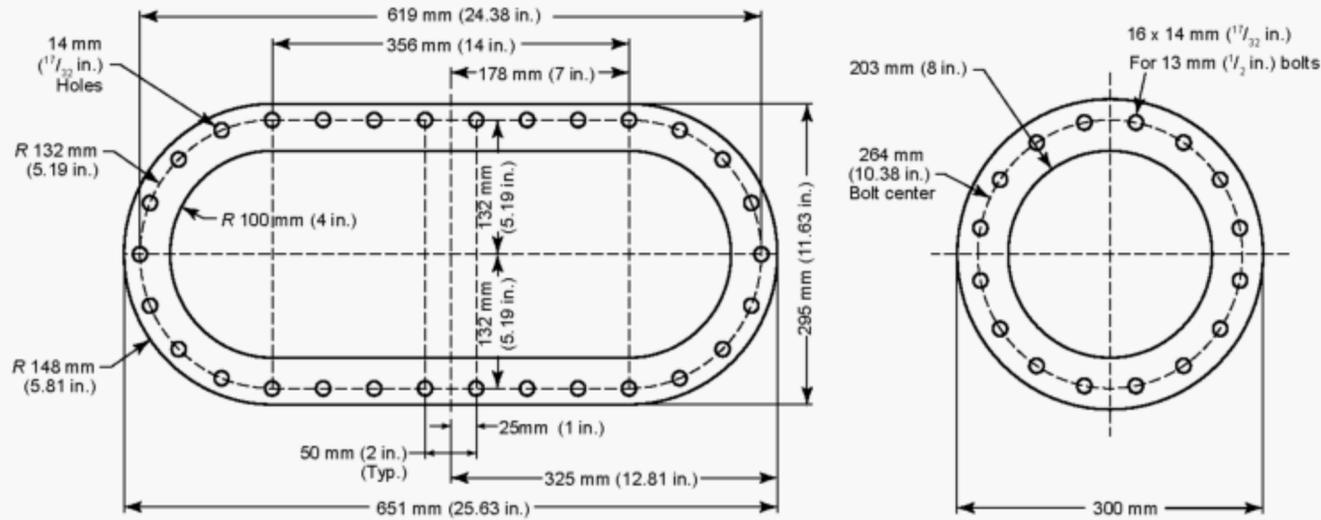


Figure 3—Typical Gauge/Thief Hatch Opening

Each tank metal appurtenance shall be equipped with a flexible bonding conductor. To minimize the risk of the first type of hazard, the gauge/thief hatch shall be connected to electrical ground. Any metallic walkway, stairway, or ladder attached to an FRP tank shall be connected to electrical ground.

To minimize the risk of the second type of hazard, several different options shall be considered by the purchaser. As in metal tanks, the primary method used to minimize charge accumulation inside of tanks is to limit flow rates until the filling pipe is covered. The use of conductive metallic downcomers shall also be considered. Conductive tank materials used in tank construction and properly grounded can also be used, as specified in the data sheet. All metal components in contact with the vapor space and the liquid containment portion of the tank shall be bonded. In addition, the bond cable shall be grounded so that all metal components are bonded and grounded. In severe cases the use of a suspended conductor within the tank can be used (see Figure 4).

5.18 Grounding

If specified in the datasheet, the manufacturer shall provide a means to ground the interior fluid.

NOTE The following are some of the methods currently used:

- a) conductive downcomers that are suspended from electrically bonded connections at the tank roof, and extending to the bottom of the tank floor;
- b) conductive ground rods (vertical or horizontal);
- c) carbon c-veil (embedded on the tank internal shell surface);
- d) a suspended static conductor inside the tank.

API 650, and API 2003 provide more complete guidance to address static and lightning protection issues as they relate to tank installation and operation.

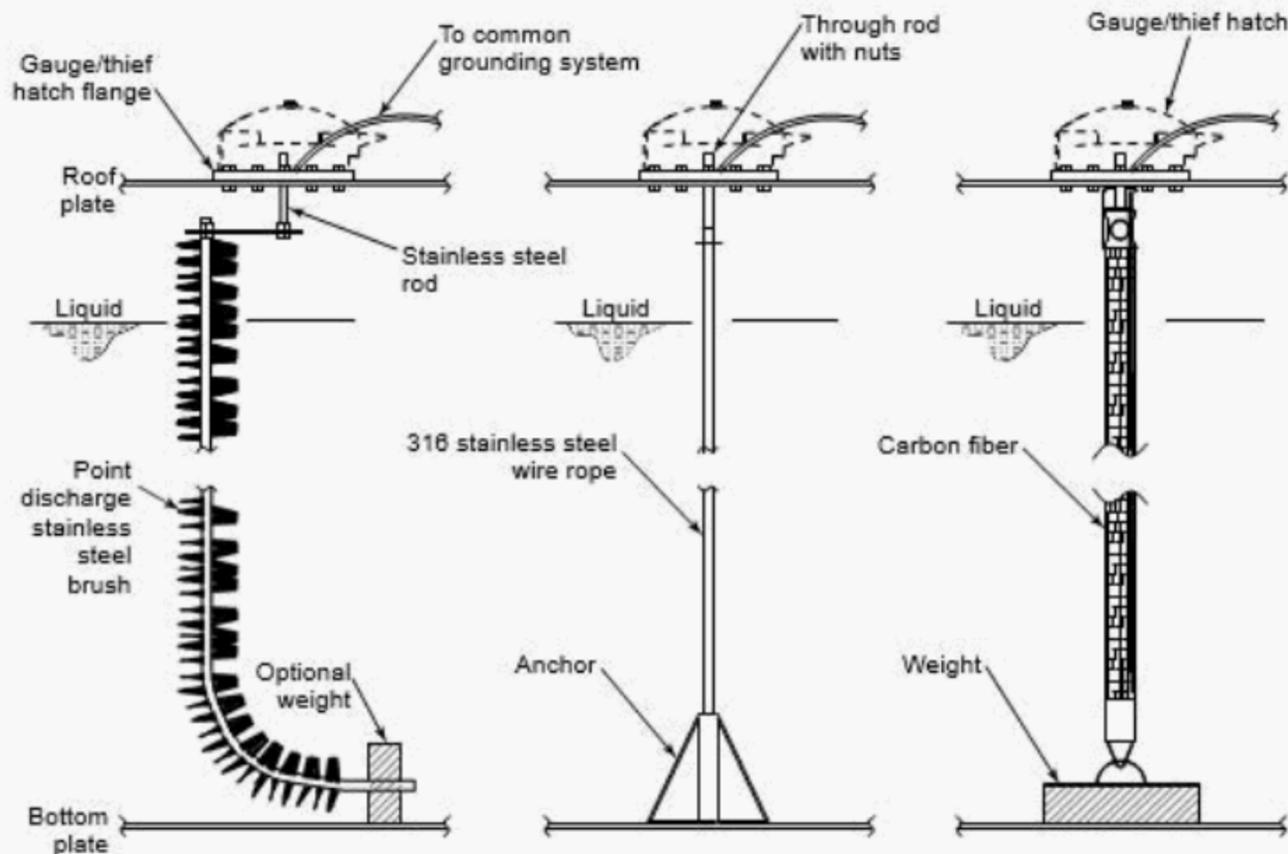


Figure 4—Example of Suspended Static Conductor Bond to Grounding System

6 Venting Requirements

6.1 Normal Venting

Top tanks shall be positively vented to atmosphere. Connection C-2 is provided for normal inbreathing and outbreathing due to temperature changes and to liquid movement into and out of the tank. The size of this connection shall be equal to, or greater than, the size of the largest outlet or inlet connection. These connections should be fitted with pressure-vacuum valves properly sized in accordance with API 2000. Gauge/thief hatches and pressure/vacuum valves shall be in accordance with the design conditions (see 5.1).

6.2 Emergency Venting

The purchaser shall consider providing emergency venting for upset conditions. This shall be addressed in the data sheet.

NOTE However, emergency venting capacity due to an external tank fire is not normally required for FRP tanks, as they will fail at temperatures in the neighborhood of 93 °C (200 °F). This temperature occurs before vaporizing sufficient amount of the liquid in the tank to create a venting problem.

7 Fabrication and Testing

7.1 Fabrication

7.1.1 General

Tanks shall be fabricated by the contact-molded or filament-wound process. Contact-molded tanks shall meet the requirements of ASTM D4097 and filament-wound tanks shall meet the requirements of ASTM D3299. Both of these methods may be used to construct the tank. Tanks fabricated using a combination of the two aforementioned methods shall meet the standard applicable to the method used for the respective part fabricated.

7.1.2 Joints

Joints between the hoop sections of tanks formed separately shall be formed by overlay to at least the minimum widths appearing in ASTM D4097, Table 2, with an overlay thickness equal to the required design shell thickness. The overlay shall be tapered back from this minimum thickness to become flush with the adjoining section over a minimum width of 75 mm (3 in.). The inner surface of the joint shall be sealed in accordance with 5.4.3.

7.1.3 Dimensional Tolerances

Tanks shall be fabricated to the dimensions in Table 1b and within the tolerances listed. The shell, bottom, and roof thicknesses shall not be less than those specified in Section 5. In addition, there shall be no abrupt visual transition or bulging on the shell outside surface.

7.1.4 Defects

The tank shall be free of visual defects such as foreign inclusions, dry spots, air bubbles, pinholes, and delaminations.

- a) The internal surface of the tank shall be smooth, free of cracks and crazing and shall contain no more than two pits per 0.1 m² (1 ft²) area. Acceptable pits are those less than 3 mm ($\frac{1}{8}$ in.) in diameter and less than 0.8 mm ($\frac{1}{32}$ in.) deep. Acceptable pits shall be covered with sufficient resin to ensure coverage of the inner surface reinforcement. Pits of larger dimensions are not acceptable and shall be repaired. Some waviness is permissible as long as the surface is smooth and free of pits.
- b) The exterior surface of the tank shall be smooth and free of exposed fibers.

7.2 Hydrostatic Testing

7.2.1 The tank shall be hydrostatically tested in the manufacturer's shop.

NOTE If the purchaser elects to have a second hydrotest performed in the field after installation, this test is outside of the scope of this specification. See the Annex D for the specific requirements.

7.2.2 Testing shall be conducted with clean, fresh water to which a surfactant has been added.

7.2.3 The test shall be held for a minimum period of one hour unless a longer period is specified by the purchaser. If there is a sign of cracks or excessive deformation, then the test period shall be at least four hours long.

7.2.4 The tank shall be tested by filling through use of a temporary standpipe 300 mm (12 in.) above the top crown of the tank.

7.2.5 All connections shall be plugged or blinded during the test, using the type and size of fittings intended for use after installation, to verify thread or flange sealing integrity.

7.2.6 All leaks and defects found shall be repaired by the manufacturer and the tank retested for a minimum of two hours. If the tank shows a consistent defect(s), it shall be rejected.

7.3 Quality Control Tests

7.3.1 The tests described in this section shall be conducted by the manufacturer or his subcontractor on the completed tank to confirm that this specification is met. These tests include thickness, degree of cure, dimensional tolerances, and surface cure.

7.3.2 Tank shell thickness shall be measured and recorded at all cutouts to verify specified minimum thickness is met or exceeded. Readings shall be taken using a micrometer, calipers, ultrasonic measurement, or any other equally sensitive method capable of producing repeatable data. Measurements shall be taken at two locations ~180° apart and aligned in the circumferential direction at each cutout.

7.3.3 Degree of cure of the laminate shall be determined to meet the resin manufacturer's standards by measuring Barcol hardness in accordance with ASTM D2583.

7.3.4 Tank dimensions and standard nozzle locations shall be verified on the finished tank to meet the tolerances stipulated in Table 1b and locations specified in Figure 2.

7.3.5 An acetone test shall be used to detect surface inhibition on external surfaces and secondary bond surfaces exposed to air during cure (non-mold surfaces). The following procedure shall be used: wipe surface with clean acetone for 30 seconds, allow to dry (typically for 10 to 20 seconds), and check for tackiness. If the surface is tacky, it failed the test. Tackiness is an indication of incomplete cure. If tackiness is determined to be present, the Barcol hardness test shall be performed to verify incomplete cure. If an incomplete cure is evident, the tank shall be either repaired and then retested, or scrapped at the purchaser's option.

7.4 Optional Tests

If specified by the purchaser, other tests shall be conducted such as: tensile strength (ASTM D638), flexural strength (ASTM D790), glass content (ASTM D2584), temperature resistance of resin (ASTM D790), and acoustic emission examination (SPI E-1067). If the purchaser specifies destructive testing requirements, the destructive tests shall be conducted on nozzle and manway cutouts. The manufacturer is responsible for retaining cutouts of sufficient size for testing.

7.5 Painting

External surface paint (see 4.2.2), if used, may also be used to provide the finishing color. The exterior coating system shall consist of surface preparation, primer, and finish coating. The surface preparation shall be per SSPC-SP1 solvent cleaning to remove dirt, grease, and oil by solvent washing or washing with a good detergent, followed by rinsing with potable water. Uniformly and lightly abrade the surface to remove the gloss and provide an etch or anchor profile without reducing the design thickness. This shall be done with abrasive blasting using a fine (40 to 100 mesh) abrasive or by sanding with 100 grit sandpaper or abrasive pads. Polyamide epoxy may be applied as a primer and aliphatic polyurethane for finishing. The application shall follow the coating manufacturer's product data sheet.

8 Marking

8.1 The tank shall be identified with a metal nameplate located as shown in Figure 2 and marked according to Figure 5. The nozzle configuration shall be denoted on the nameplate as either "Standard" or "Modified" and the reference to API 12P shall be shown on the nameplate. The API monogram shall also be shown on the nameplate if applicable to the tank manufacture. See 5.11 and Annex A.

8.2 If the purchaser specifies requirements that conflict with this specification, then the tank shall not be monogrammed, and the nameplate shall not refer to API 12P.

NOTE If there is any exception made to a requirement in API 12P, the nameplate should be marked to refer to the purchaser's specification.

8.3 The nameplate shall be affixed with bolts and nuts or by other suitable means.

Annex A

(informative)

Use of API Monogram by Licensees

The information in this annex has been intentionally removed.

See API Specification Q1, Annex A or the API website for information pertaining to the API Monogram Program and use of the API Monogram on applicable products.

Annex B (informative)

Recommended Installation and Handling

B.1 Installation

Vertical flat bottom tanks should be installed on a base providing continuous support for both the tank bottom and knuckle radius and having sufficient bearing strength to support the weight of the tank full of liquid, and with negligible settlement. The following materials are recommended for use, when possible, for tank grades:

- compacted gravel with a top clean sand layer to provide a smooth uniform support;
- smooth surfaced concrete, or a concrete grout.

Per API 12R1, the tank support base should be elevated and the outer grade should be sloped down to allow drainage away from the tank bottom. Retaining rings are highly recommended for tank gravel pads to help prevent wind and water erosion around the tank base. The use of rock riprap, large diameter gravel, or other coarse material around the base of the tank after installation will mitigate tank grade erosion.

B.2 Handling

During installation of the tank, several methods of handling are recommended. Tanks may be handled with a crane utilizing the lifting lugs laminated to the tank.

CAUTION Do not attempt to lift by attaching to a fitting.

When using cranes for handling, care should be taken to prevent damage to the knuckle radius or to connections by dragging the tank. A tank skid should only be used with a bottom plate to protect the knuckle radius, ensuring the base of the tank is setting solidly on the base of the tank skid and is securely fastened to the tank skid by chains or web belting. Care should also be taken when tail boarding with a tank skid that there is sufficient ground clearance for maneuvering the tank onto the grade and that the tank is not severely dropped when set into place. After the tank is installed on the grade, a final inspection is recommended to ensure that there are no fractures in the base, knuckle, sidewall, or connections, either in the interior or exterior of the tank. Because the majority of problems with fiberglass tanks tend to occur during handling and shipping, it is strongly recommended that the manufacturer's special instructions be followed in all cases.

B.3 Fire Protection

FRP tanks should be remotely located from any obvious ignition source and/or so located that any spill resulting from the failure of these materials could not unduly expose persons, buildings, or structures.

Annex C (normative)

Walkways, Stairways, and Ladders

C.1 General

Walkways and stairways furnished to this specification shall be constructed in accordance with API 12R1.

Annex D (normative)

FRP Tank Data Sheet

This annex provides a tool for Purchasers (owners, engineering contractors, and other designated agents) to aid in conveying information to a tank manufacturer. The FRP Tank Data Sheet (Figure D.1) shall be used in conjunction with the FRP Tank Nozzle Location Guide (Figure D.2). The data sheets shall be prepared in conjunction with this specification such that comprehensive proposals (bids) may be made, and subsequent contracts may be placed for the fabrication of tanks.

General Information

Company _____
 Lease _____
 Field _____ Approx. Location _____
 Estimate No _____ Inquiry No _____
 Requisition No _____
 Contact _____ Phone No _____
 Cost Estimate Only _____ [] For Purchase _____ []
 Inquiry Date _____ Required Date _____

Specifications

API 12P: [] Yes [] No, [If "No" is checked, then Purchaser Specification must also be checked "Yes"]
 Apply API Monogram: [] Yes [] No, [If "Yes" is checked, then API-12 P must also be checked "Yes"]
 Purchaser Specification: [] No [] Yes _____

Number of Units Required _____
 Capacity _____
 Diameter _____ Height _____
 Style of Top [] Cone [] Dome [] Flat [] Other
 Style of Bottom [] Flat [] Cone [] Other
 Type of Fluid _____
 Specific Gravity _____ Design Vacuum _____
 Maximum Operating Pressure _____
 Design Pressure _____
 Minimum and Maximum Operating Temperature _____
 Testing Requirements: Standard [] Other _____

Wind Load [] No [] Yes, Wind Speed _____ mph or [] Per ASCE -7-16 /IBC
 Seismic Load [] No [] Yes _____ (Specify Spectral acceleration, or per ASCE 7-16
 Snow Load [] No [] Yes _____ IBC) (Specify load in PSF, or per ASCE 7-16 /IBC)

Resin Temperature Rating [] 150°F [] 170°F [] 190°F Plus [] Other _____
 Liner [] _____ Mil. C-Veil [] _____ Mil. Nexus [] Other _____
 UV Protection [] UV Inhibitor [] Pigmenting [] Gelcoating
 [] Painting [] Other _____
 Tank Color [] Natural [] Other _____
 Fire Retardants [] No [] Yes _____

Grounding [] No [] Yes Ground Rod [] No [] Yes Type _____ Carbon C-Veil
 Other _____

Downcomer Pipe [] No [] Yes Type _____
 Nozzle Location [] Per Figure 3 of API 12P or [] "Modified"
 Nozzle Ends [] Threaded [] Grooved [] Flanged [] Gusseted Flanges
 Manway [] 18 in. (45.7 cm) [] 20 in. (50.8 cm) [] 22 in. (55.9 cm) [] 24 in. (61 cm) Quantity _____
 Walkway Brackets [] Painted Steel [] Galvanized Steel
 Lifting Lugs [] Painted Steel [] Galvanized Steel
 [] Fiberglass [] Stainless Steel

Gauge/Thief Hatch Model
 Pressure _____ Vacuum _____
 Plastic Trim [] No [] Yes Type _____
 Pipe Support Brackets [] No [] Yes Quantity _____
 Insulation [] No [] Yes Type _____
 Heat Tracing [] No [] Yes [] _____
 [] No [] Yes [] _____
 Tie Down Lugs [] No [] Yes [] Painted Steel [] Galvanized [] Fiberglass [] Stainless Steel _____

Interior Top Seam Laminated [] No [] Yes *
 Striker Plate [] No [] Yes Specific size _____
 Stairway Required [] No [] Yes

Walkway Required Length _____ Units _____ Width _____ Units _____
 [] No [] Yes [] Galvanized [] Painted
 Length _____ Units _____ Width _____ Units _____

Enclosed Walkway/Stairway/Ladder Drawing [] No [] Yes
 Nozzle Orientation Drawing [] No [] Yes

*Suggested if tank is to have a gas blanket.

Figure D.1—FRP Tank Data Sheet

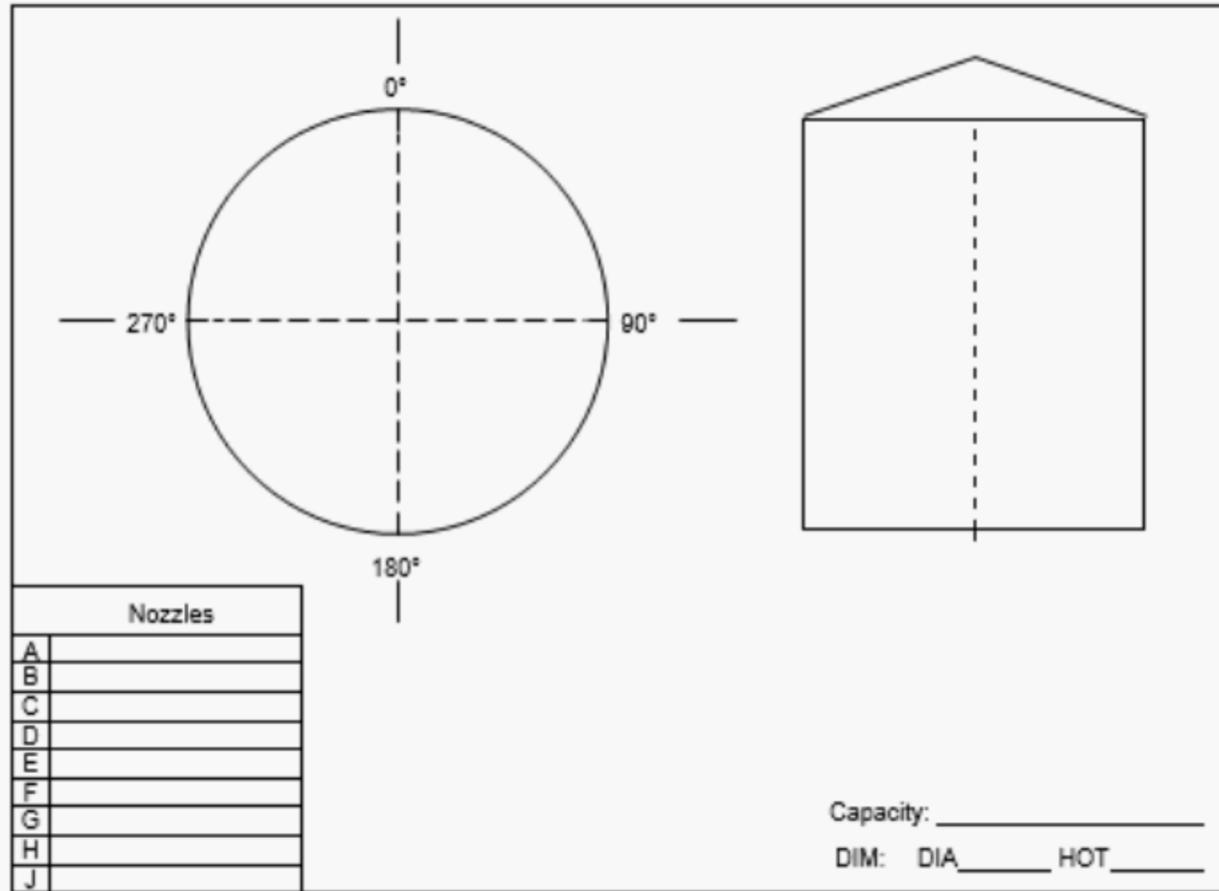


Figure D.2—FRP Tank Nozzle Location Guide (Used with Data Sheet)



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