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# FIBERGLASS REINFORCED STORAGE TANK SPECIFICATION

**EFI reserves the right to change this specification to improve the end product without notice to Customers.**

# FIBERGLASS REINFORCED PLASTIC STORAGE TANKS

## 1. SCOPE

This section covers the furnishing of tanks fabricated of fiberglass reinforced plastic and intended for above and belowground bulk storage of chemical solutions.

**This specification is not intended to be used in the fabrication of tanks intended for pressure and/or vacuum conditions or heating liquids above their flash points.**

When additional specifications are issued for special applications, they shall also be considered a part of this specification.

## 2. GENERAL

Tanks furnished under this section shall be fabricated and assembled in full conformity unless exceptions are noted by Customer/Engineer. When additional specifications are issued for special application, they shall also be considered a part of this specification as it pertains to the manufacturing of FRP tanks.

## 3. SUBMITTALS

Complete drawings and details covering the storage tank, connections and accessories shall be submitted for Customer review and approval.

The data shall include information on all tank fabrication, materials of construction, and data confirming chemical resistance of the proposed resins to the intended tank contents.

Drawings shall include a profile of the entire tank indicating the thickness, resin designation, reinforcement, and surfacing mat material of the structural and corrosion barrier layers.

The drawings shall also indicate the sizes of all major tank components and/or accessories.

## 4. OPERATION AND MAINTENANCE MANUALS

The operation and maintenance manual shall include project information, certified copy of the tank drawing, copies of the tank certification label, quality control inspection report, and warranty.

Data shall include handling and installation procedures, flange and tank repair procedures and accessory information.

## 5. GOVERNING STANDARDS

Materials and construction methods shall conform to the applicable provisions of the following standards:

- ASTM D3299
- ASTM D4097
- ASTM D2563
- ASTM D2583
- ASTM D2584

- ASTM C582
- ANSI B16.5

## 6. CLASSIFICATION

Tanks are classified according to type as follows, and it is the responsibility of the **Purchaser** to specify the requirements for Type II tanks, the operating pressure or vacuum levels, and the safety factor required for external pressure. Absence of a designation of type required shall imply that Type I is adequate.

***Type I:*** Atmospheric pressure tanks vented directly to the atmosphere from the tank top via a gooseneck or mushroom style vent, designed for pressure no greater or lower than atmospheric.

***Type II:*** Atmospheric pressure vented directly into a fume conservation system or from the tank top and piped "out" of tank facility and designed to withstand the specified positive and negative pressure not to exceed 14 in. of water when all tie down lugs are properly secured, in accordance with the fabricator's recommendations for FRP tanks. Tanks requiring design of pressure/vacuum greater than 14 in. water must be customer specified and reflect worst case scenario of the end-user's venting system and special consideration must be made by the fabricator.

Tanks meeting this specification are classified according to grade as follows:

***Grade 1:*** Tanks manufactured with a single generic type of thermoset resin throughout the laminate.

***Grade 2:*** Tanks manufactured with different generic types of thermoset resin in the barrier and the structural portion.

## 7. GENERAL PRODUCTS

| TANK CONFIGURATIONS | TOP DESIGNS | BOTTOM DESIGN |
|---|---|---|
| Cylindrical | Dome | Flat |
| Horizontal | Open w/Rim Flange | Dome |
| Rectangle | Flat-Bonded | Cone-30, 40& 60 Degree |
| Above and Below Ground | Flat-Bolted w/Rim Flange | Internal Slopes |

**STANDARD TANK INSIDE DIAMETER**

| | |
|---|---|
| 18" | 5' |
| 20" | 6' |
| 24" | 7' |
| 28" | 8' |
| 30" | 9' |
| 36" | 10' |
| 42" | 11' |
| 48" | 12' |
| 54" | 13' |
| 60" | 14' |
| 72" | 17.5' |

**Standard Nozzle and Coupling Sizes (in.)**

| | |
|---|---|
| ¼ | 4 |
| ½ | 6 |
| ¾ | 8 |
| 1 | 10 |
| 2 | 12 |
| 3 | |

All Flanged Nozzles are fabricated in accordance with ASTM 4097 Contact Mold and drilled per ANSI B16.5 and rated for 150#

**Standard Manway Sizes (in.)**

| |
|---|
| 18” |
| 24” |
| 30” |
| Custom |

Manways include 4” Rim Flange, FRP Cover and Specified Bolts. All manways are fabricated in accordance with ASTM 4097

## 8. BASIC MATERIALS

| | |
|---|---|
| **Resin** | Chemical compatible |
| **Chopped Strand** | Type “E” Glass |
| **Continuous Roving** | Type “E” Glass |
| **Woven Roving** | 60 End-Type “E” Glass—24oz per sq. yd |
| **Roving for Filament Winding** | Type “E” Glass, continuous filament strand |
| **Fillers-By Request** | UV Protection and Fire Retardance |
| **Surfacing Mat** | C-veil or Nexus whichever is suitable for chemical |
| **Metal** | CS; SS—Exotic metals not available (ie:titanium) |

**Resin:** The resin used shall be a commercial-grade, corrosion-resistant thermoset that has either been evaluated in a laminate or that has been determined by previous documented service to be acceptable for the service conditions.

The resin shall contain no pigment, dyes, colorants, or filler, except as follows:

a. A thixotropic agent that not interfere with visual inspection of laminate quality, or wit the required corrosion resistance of the laminate, may be added for viscosity control.

b. Resin pastes used to fill crevices before overlay

c. Ultaviolet absorbers may be added to the exterior surface for improved weather resistance.

d. Antimony compounds or other fire-retardant agents may be added for improved weather resistance

***Chopped Strand Mat:*** Chopped strand mat shall be constructed from chopped commercial-grade E-type glass strands bonded together using a binder. The strands should be treated with a sizing that is chemically compatible with the resin used.

***Continuous Roving:*** Continuous roving shall be a commercial-grade of E-type glass fiber with a sizing that is chemically compatible with the resin system used.

***Woven Roving:*** Woven roving shall be in accordance with ASTM D2150.

***Surfacing Mat:*** The reinforcement used for the inner surface shall be either a commercial-grade chemical resistant glass surface mat or an organic-fiber surface mat. In environments that attack glass, the use of an organic-fiber surface mat is required.

## 9. DESIGN REQUIREMENTS

**Filament Wound Laminates:** The maximum allowable stress of the total laminate shall be limited by the allowable movement of the tank wall when filled with fluid. Tanks for installation outdoors shall be designed for the effect of wind loading and other environmental factors. Tanks with significant physical loadings, other than fluid head (such as side mounted equipment or agitation) shall be given special design consideration.

The allowable strain of the tank wall shall not exceed 0.0010 in at 70F. Minimum thickness of the tank shall be 0.180 in.

**Contact Molded Laminates:** Portions of the tank such as joints, heads, nozzles, and supports may be fabricated by contact molding. Contact-molded laminates shall satisfy the minimum property requirements listed in ASTM C 582-Table 1.

***Top Head****:* The top head, regardless of shape, shall be able to support a single 250-lbf load on a 4 by 4-in. area without damage and with a maximum deflection of ½% of the tank diameter at the area the load is applied. Support of auxiliary equipment, snow load or operation personnel may require additional reinforcement or the use of stiffener ribs, sandwich construction, or other stiffening systems. Minimum thickness shall be 0.1876 in.

***Bottom Head:*** The minimum thickness for a fully supported flat-bottom head shall be as follows:

3/16 in. for 2 to 6 ft diameter
¼ in. for 6 to 12 ft diameter, and
3/8 in. for over 12 ft diameter

The radius of the bottom knuckle of a flat-bottom tank shall be not less than 1 in on tanks 4 ft. or smaller in diameter and 1.5 in. on tanks larger than 4 ft. diameter. The minimum thickness of the radiused section shall be equal to the combined thickness of the shell wall and the bottom. The reinforcement of the knuckle-area shall taper so that it is tangent to the flat bottom, and shall not extend beyond the tangent line onto the tank bottom, unless methods of manufacture are used that maintain flat-bottom configuration, and shall extend up the vertical tank wall a minimum of 8 in. on tanks up to 4 ft. in diameter and 12 in. on tanks over 4 ft. in diameter. The reinforcement shall then taper into the side wall over an additional length of 4 in.

The tank bottom shall not have variations from a nominally flat plane that would prevent uniform contact of the entire bottom surface with a properly prepared flat support surface when the tank is

filled with liquid. The bottom laminate surface shall be a hand-work finish, and shall have no excessive laminate projections that would prevent uniform contact with a properly prepared flat support surface when the tank is filled with liquid. Deflection of the flat bottom when the tank is empty, commonly known as "oil canning," is permissible as long as these requirements are met.

The thickness of an elevated-dished bottom, suitable for supporting the weight of the fluid head, shall be no less than 3/16 in.

For dished heads subject to internal loading, the knuckle radius shall be externally reinforced. The reinforcement thickness shall be equal to the thickness of the head. The thickness of a joint overlay near the knuckle radius tangent line of a dished head contributes to the knuckle reinforcement.

The dished-bottom head shall have a radius of curvature that is equal to or less than the inside diameter of the tank straight shell, and knuckle radius of at least 6% of the diameter of the head.

***Open-Top Tanks:*** The top edge of open top tanks shall have a horizontal reinforcing flange or other means of reinforcement sufficiently rigid to maintain the shape of the tank after installation, such as stiffener ribs.

***Joints:*** The cured resin surfaces to be overlaid shall be roughened using 36 or courser grit abrasive media and shall extend beyond the lay-up area so that no reinforcement is applied to an unroughened surface. Surfaces shall be clean and dry before lay-up. The entire roughened area shall be coated with paraffinated resin after the joint lay-up is made.

Joints between tank-wall sections shall be over-wound to thickness, or may be overlaid by a contact-molded laminate. When contact-molded laminate joints are used to join hoop segments of the straight shell, or to join the bottom or top head to the shell, the thickness of the structural joint overlay shall not be less than 3/16 in.

The corrosion-resistant barrier component of the joint shall be formed in the same manner as the inner surface and the interior layer and the minimum overlay width shall be 4 in. This internal overlay shall not be considered a structural element in determining joint thickness.

The thickness of a joint near the bottom tangent line shall not be considered to contribute to the knuckle reinforcement, but shall be additive thereto.

***Fittings:*** The more common method of fabricating nozzles is by contact molding both the nozzle neck and flange to the dimensions shown in Specification D5421 and as listed in the table below. The corrosion-resistant barrier of the nozzle shall be at least equivalent to the inner surface and interior layer and shall be fabricated from the same resin as the tank head or shell to which it is attached.

All measurements in inches

| Nozzle Inside Diameter | Minimum Wall Thickness | Minimum Flange Thickness | Minimum Hub Thickness | Minimum Hub Length |
|---|---|---|---|---|
| 1 | 3/16 | ½ | ¼ | 2 |
| 1 ½ | 3/16 | ½ | ¼ | 2 |
| 2 | 3/16 | ½ | ¼ | 2 |
| 3 | 3/16 | ½ | ¼ | 2 |
| 4 | 3/16 | ½ | ¼ | 2 |
| 6 | 3/16 | ½ | ¼ | 2 |
| 8 | 3/16 | 9/16 | 5/16 | 2 ½ |
| 10 | 3/16 | 11/16 | 3/8 | 2 ¾ |
| 12 | 3/16 | ¾ | 3/8 | 3 |
| 14 | ¼ | 13/16 | 7/16 | 3 ¼ |
| 16 | ¼ | 7/8 | 7/16 | 3 ½ |
| 18 | ¼ | 15/16 | ½ | 3 ¼ |
| 20 | ¼ | 1 | ½ | 4 |
| 24 | ¼ | 1 1/8 | 9/16 | 4 ½ |

Nozzles 4 in and smaller shall be supported by a suitable gusseting technique, using plate gussets or conical gussets. Plate gussets, where needed, shall be evenly spaced around the nozzle and are to be added after complete assembly by the nozzle on the shell. Larger nozzles, subject to superimposed mechanical forces, require special consideration.

Manways installed in top heads may be of the flanged or nonflanged design, as agreed upon between the fabricator and purchaser.

***Vents:*** Tanks that discharge freely into the atmosphere must be provided in all Type I closed-top tanks. Minimum vent size shall be sufficient to handle the flow displacement of all combined inlet or outlet nozzles without creating any pressure above atmospheric, or any vacuum condition.

Special vent sizing consideration should be given to the numerous operating situations that could otherwise cause a positive or a negative pressure in a closed tank. Since overfilling a closed tank with the vent on the top can cause the tank to be over-pressured, a suitably sized overflow, properly located, or other appropriate protection, may be required to prevent over-pressurizing the tank.

Type II tanks shall be designed to withstand the specified positive or negative pressures not to exceed 14 in. of water. Special design consideration must be given to buckling of tank wall and heads, the hold-down lug system, and top and bottom knuckle requirements. Fluid level in the tank is an important consideration in the analysis.

Flat-bottom Type II tanks must have all hold-down lugs properly secured to the foundation, in accordance with the fabricator's recommendations for the design of the lugs used and for the tank installation and operation.

***Hold-Down Lugs:*** Hold-down lugs shall be a requirement on all tanks for outdoor service, on all Type II tanks, and on tanks subject to seismic loads or vibrations. The design number and

attachment of such lugs is the responsibility of the fabricator, based on wind, seismic, and other loads specified by the purchaser.

Hold-down lugs shall be placed on the tank in such a way that they do not protrude below the bottom surface of the tank.

***Lifting Lugs:*** Lifting lugs or other provisions for lifting tanks shall be provided for tanks over 500 lbs. in weight.

## 10. LAMINATE CONSTRUCTION

Tanks shall be hand lay-up, spray-up, or filament wound construction in accordance with the applicable governing standards. The finished laminate shall be constructed using either a single or dual resin system and shall not contain colorants, dyes, fillers or pigments.

***Structural Tank:*** The laminate comprising the structural tank (bottom, shell, top head) shall consist of a corrosion-resistant barrier comprised of an inner surface, interior layer, and a structural layer.

***Inner Surface:*** The inner surface exposed to the chemical environment shall consist of a resin rich layer 0.010 to 0.020 in. thick, reinforced with a suitable chemical-resistant glass fiber surface mat or with an organic fiber surface mat.

***Interior Layer:*** The inner surface layer exposed to the corrosive environment shall be followed with a layer composed of resin, reinforced only with non-continuous glass-fiber strands applied in a minimum of two plies of chopped-strand mat. As an alternative, a minimum of two pass of chopped roving of minimum length of 0.5 in. to a maximum length of 2.0 in. shall be applied uniformly. Each ply of mat or pass of chopped roving shall be well-rolled prior to the application of additional reinforcement. The combined thickness of the inner surface and interior layer shall not be less than 0.10 in.

Glass content of the inner liner and the interior layer combined shall be 27 +/- 5% by weight.

The degree of cure of the laminate shall be such as to exhibit a Barcol hardness on the inner surface of at least 90% of the resin manufacturer's minimum specified hardness for the cured resin.

***Structural Layer:***

***Filament Wound:*** Subsequent reinforcement shall be continuous-strand roving. The thickness of the filament-wound portion of the tank shell may be varied with tank height (tapered-wall construction). If additional longitudinal strength is required, the use of other reinforcement such as woven fabric, chopped-strand mat, or chopped strands, may be interspersed in the winding to provide additional strength. Glass content of this filament-wound structural layer shall be 50 to 80% by weight.

***Contact-Molded Structural layer in Top and Bottom Heads:*** Subsequent reinforcement shall be comprised of 1.5 oz/ft chopped-strand mat or equivalent weight of chopped roving, or shall be comprised of chopped-strand mat or chopped roving and such additional number of alternating plies of 24 oz/yd woven roving 18 oz/yd non-woven biaxial fabric to a thickness as required to meet the physical properties that are used for the design. Each successive ply or pass of

reinforcement shall be well-rolled prior to the application of additional reinforcement. Where woven roving is used, chopped-strand glass reinforcement shall be used as alternating and final layers. All woven roving and surfacing mat shall be overlapped. Laps in subsequent layers shall be staggered at least 2.25 in. from laps in the preceding layer.

When the outer surface of this structural layer is to be subject to spillage or a corrosive environment, a resin-rich layer, shall be applied over the final layer of reinforcement.

Tanks used for outdoor service shall incorporate provisions to minimize ultraviolet degradation. A suitable method includes the use of a 5 mil thickness of exterior gel coat. The entire tank shell shall be lightly sanded to allow the gel-coat finish to adhere properly. Since pigmentation makes inspection difficult, the gel-coat shall be applied after the structural layer has cured and a visual inspection is performed.

Where air-inhibited resin is exposed to air, full surface cure of the inner surface shall be obtained by coating such surface with a coat of resin containing 0.2 to 0.6% paraffin wax. The acetone sensitivity test is used to check surface cure.

***Joints:*** The width of the first layer shall be 3 in. minimum. Successive layers shall uniformly increase in width to form a smooth contour laminate that is centered on the joint +/- ½ in.

A highly filled resin paste shall be placed in the crevices between joined pieces, leaving a smooth surface for lay-up.

The cured resin surfaces of parts to be joined shall be roughened using 36 or coarser abrasive media to expose glass fibers. This roughened area shall extend beyond the lay-up areas so that no reinforcement is applied to an unprepared surface. Surfaces shall be clean and dry before lay-up. The entire roughened area shall be coated with paraffinated resin after joint overlay is made.

The interior overlay of a joint shall consist of a minimum of two plies of 1.5 oz/ft chopped strand mat reinforcement, followed by a resin-rich layer reinforced with surfacing mat.

The outer structural overlay of a joint shall be centered on the joint and shall be finished.

***Fittings and Accessories:*** The surfaces of fittings, tank accessories, and the laminates required for their installation that are exposed to the corrosive media shall be constructed in accordance with this specification except for those fitting surfaces which are made by manufacturing processes other than contact molding.

The cut edges of all laminates exposed to the chemical environment shall be sealed with a laminate. Where shape, thickness, or other restrictions preclude covering the edges with laminate, such cut edges and any machined flange faces shall be at least coated with resin. In either case, the resin used shall be the same used in the equipment laminate.

***Nozzle and Manway Installation:*** Flanged nozzles may be installed with the pipe stub flush inside the tank shell or projecting inside the tank.

***Nozzle Projection:*** The installed nozzle shall maintain a clearance of 3in. between the back of the flange and the exterior of the cutout opening reinforcement. In addition, this clearance shall not be less than the shear distance required for proper installation of the nozzle.

***Cutout Reinforcement Laminate:*** When a vessel shell or head is cut in an area bearing hydrostatic pressure, the cutout shall be reinforced on a circular area concentric with the cutout.

***Cutout Reinforcement Diameter:*** The outer diameter of the cutout reinforcing laminate, shall not be less than two times the nominal nozzle diameter. For nozzles less than 6 in. in diameter, the minimum cutout reinforcement diameter shall be the nominal nozzle size plus 6 in.

***Cutout Reinforcement Thickness:*** The thickness of the cutout reinforcement laminate for nozzles installed in cylindrical shells or dished heads shall be determined by nozzle and tank size.

When reinforcing materials are cut to facilitate placement around and installed nozzle, joints in successive reinforcing layers should be staggered to avoid overlapping and (on cylindrical shell installation) shall not be placed so they are parallel the axis of the tank. The intent of this requirement is to avoid orienting joints in reinforcing layers perpendicular to the maximum load-bearing direction.

***Nozzle Installation Laminates:*** The all interior installation laminate placement is used only when the nozzle being installed has an integral conical gusset preventing application of an exterior laminate.

***Installation Laminate Thickness:*** The inside and outside installation thicknesses combined shall be at least as thick as the nozzle neck.

***Inside Installation Laminate Construction:*** The inside installation laminate shall be constructed using only noncontinuous glass reinforcements, except that when woven roving is included to strengthen the laminate, it shall be preceded and followed by a layer of 1 ½ oz mat and then covered with a laminate. When the inside laminate consists only of a corrosion barrier, the length of the laminate shall be a minimum of 3 in. or the nominal radius of the nozzle.

***Installation Laminate Lengths:*** The length of the outside laminate and the inside laminate shall each be equal to the shear length, based on the thickness of the individual laminates.

In the nozzle installations where the installation overlay is installed before the cutout reinforcement has fully cured, that portion of the overlay which extended into the tank shell may be considered to become a part of the cutout reinforcement laminate if the installation laminate length is extended to the required cutout reinforcement diameter.

***Monolithic Installation:*** The total bond thickness shall be the greater of either the cutout reinforcement thickness or the outside bond thickness.

***Gussets:*** If plate or conical gussets are used to stiffen the installed nozzle, gusset installation laminates are in addition the nozzle installation laminates.

***Location of Cutouts on the Shell:*** For cutouts made within 6 in. of the knuckle radius area of a head or within 6 in. of a shell-to-head joint, additional hole-cutout reinforcement is required, unless the area of installation is at a point within the vessel that is not exposed to hydrostatic pressure.

All nozzles and manways shall be installed in accordance with ASTM specification. The interior overlay shall present the same corrosion resistance to the fluid.

## 11. DIMENSIONS AND TOLERANCES

Standard tank diameters are based on internal measurements with the tank in the vertical position.

Tolerance on the inside diameter, including out-of-roundness, shall be +/- 1%.

Shell taper shall be additive to the figure used for the tank diameter. Shell taper shall not exceed ½ degree per side.

Tolerance on overall tank height shall be ½%, but shall not exceed +/- ½ in.

Nozzle flange faces shall be perpendicular to the axis of the pipe and shall be flat within +/- 1/32 in. through 18 in. nozzle size and 1/16 in. for large nozzle sizes.

The standard orientation of flanges shall provide bolt holes straddling the normal centerlines of the tank. Bolt holes of flanges located on the tank top or bottom, shall straddle the principal centerline of the vessel or lines parallel to it.

## 12. WORKMANSHIP, FINISH and APPEARANCE

The minimum acceptable for workmanship and finish of the finished laminate shall conform to the requirements specified in Section 9 of Specification C 582.

## 13. REQUIRMENTS

***Degree of Cure:*** Degree of cure of the laminate shall be found by determining the Barcol hardness.

A useful technique to check the cure of a non-molded surface of a polyester resin is as follows: Rub a few drops of acetone on the laminate surface until it evaporates. If the surface becomes softened or tacky, it is indication of under cure.

The use of organic reinforcing materials may reduce the Barcol readings without necessarily indicating under cure.

Barcol hardness values may vary upon temperature.

## 14. PRODUCT MARKING

The tank shall be marked to identify the producer, date of manufacture, capacity, all resins used, inner surface reinforcements, specific gravity, design temperature, and the words “Pressure-Atmospheric,” or the operating pressure and vacuum, shall be imprinted on the tank.

Additional marking requirements may be needed for compliance with local codes. It is the responsibility of the purchaser/user to specify additional labeling requirements for the vessel, such as liquid content, operating and safety instructions, and any other warnings necessitated by local codes.

**END OF THIS SECTION**