Fiberglass Reinforced Thermoset Plastic Tank & Piping Standards

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I. Executive Summary

The purpose of this paper is to provide the design engineer and those responsible for purchasing tanks and piping for use in aggressive environments with an understanding of the design, material system, fabricating methods and quality control standards for the manufacture of fiberglass products. While purchasing decisions are based on quality, service and price, this paper provides guidance on how to improve the quality and safety of Fiberglass Reinforced Thermosetting Plastic (FRP) tanks and piping (i.e., pipe, fittings, and adhesives).

There are many manufacturers of commonplace plastic and fiberglass products, but only a limited number of tank and piping manufacturers are equipped to meet recognized fabrication standards for design and construction. This list is further reduced to those manufacturers who have established Quality Control and Quality Assurance programs for their manufacturing facility, fabrication process and end product. Certain of these manufacturers voluntarily submit to third party conducted Quality Assurance programs.

Two nationally recognized organizations have developed the most widely used programs for fiberglass FRP tank and piping manufacturers. American Society of Mechanical Engineers (ASME) and Underwriters Laboratories Inc. (UL) have developed standards and conduct Quality Assurance programs for aboveground RTP tanks and underground FRP tanks and piping, respectively. ASME and UL Certified tanks and piping are each labeled with a uniquely numbered "RTP-1" or "UL" stamp to signify their respective certifications. While not all fiberglass products produced by these ASME and UL qualified manufacturers (e.g., hoods, ducts, stacks, and large diameter pipes) are ASME or UL labeled, the purchaser of these other products benefits from the overall qualifications necessary to meet the third party Quality Assurance program that is in place.

The design engineer and those responsible for the purchasing of tanks and piping for application in an aggressive environment will likely place product quality high on their list of priorities. The specifying of ASME and/or UL third party qualified manufacturers should achieve this goal. Further, by specifying this level of standard, the user is more likely to receive competitive quotations for like products. Finally, the Quality Assurance programs in place relieve the buyer of the costs associated with conducting plant inspections to ensure that the products meet their purchasing specification.

II. Introduction

Fiberglass reinforced thermosetting plastic ("fiberglass") first became a viable alternative to protected steel, stainless steel and exotic materials in 1948. That year centrifugal cast fiberglass piping was first used in the crude oil production industry as a solution to corrosion problems. During the mid-50's developments in manufacturing with polyester and epoxy resins resulted in the application of fiberglass tanks and piping in the chemical industry. By the mid-60's fiberglass was accepted for the storage and handling of underground flammable and combustible liquids and industrial, municipal water, sewage and pulp and paper processing applications.

It was during the 1960's that manufacturers began to develop nationally recognized standards and test methods for fiberglass storage and fiberglass piping systems. Today, there are a number of nationally recognized standards and specifications for fiberglass tanks and fiberglass piping. While there are standards developed for military applications, e.g., MIL standards for helicopter rotor blades, following is a list of civilian organizations with published standards and specifications:

Fiberglass Tanks & Piping	**Civilian Organizations**
	API American Petroleum Institute **ASME** American Society of Mechanical Engineers **ASTM** American Society for Testing and Materials **AWWA** American Water Works Association **FM** Factory Mutual Research **NSF** National Sanitation Foundation **UL** Underwriters Laboratories Inc.

III. Background: General

Fiberglass tanks and fiberglass piping contain glass fiber reinforcement embedded in cured thermosetting resin; hence the term Fiberglass Reinforced Thermosetting Plastic (FRP) describes the fiberglass material system. This composite structure typically contains additives such as pigments and dyes. By selecting the proper combination of resin, glass fibers, additives and design, the fabricator can create a product that meets the equipment designer's performance standard. Following is a discussion on the components of a fiberglass material system.

IV. Background: Glass Fibers

Glass Fiber Types: All glass fibers begin as individual filaments of glass drawn from a furnace of molten glass. Many filaments of glass are formed simultaneously and gathered into a "roving" and a surface treatment "sizing" is added to maintain fiber properties. Glass fibers are designed for several applications, some of which are shown as follows:

Types	Applications
E or E-CR	Acid Environment
E	Alkali Resistance
C	Chemical Resistance

Glass Fiber Forms: Glass fibers are manufactured for use by the tank and piping fabricator in the following forms:

- *Continuous Roving*: Supplied as strands of glass fiber on a cylindrical spool. Typically used in filament winding and chop-gun spraying applications.
- *Reinforcing Mats*: Supplied as chopped strands held together with a resinous binder. Typically used for hand lay-up applications.
- *Surface Veils*: Supplied as light weight reinforcing mats to provide a resin rich smooth surface which increases corrosion resistance without the crazing that would occur in non-reinforced resin.

Glass Fiber Reinforcement: The mechanical strength of a fiberglass product depends upon the amount, type and arrangement of glass fiber reinforcement within the material system. Strength increases proportionally with the amount of glass fiber reinforcement and is highest in the fiber directions. Following are three general types of fiber orientation:

- *Uni-directional*: Glass fibers are oriented primarily in one direction. Such arrangements are obtained when continuous roving is wrapped around a cylinder or when fabrics with the fibers all in one direction are applied.
- *Bi-directional*: Fibers are positioned in two directions 90 degrees apart. Such arrangements are obtained with woven or stitched fabrics.
- *Multi-directional*: The fibers are positioned randomly with equal amounts of fibers in all directions. Such arrangements are obtained with the use of chop-gun applications and reinforcing mats.

V. Background: Resins

The second major component of fiberglass tanks and piping is the thermosetting resin system. Thermoplastic resin is one of two basic groups of resin systems, but is not used with glass fiber reinforcing. A comparison of the two resin systems is shown below:

- Thermoplastics are resins that are normally solid at room temperature, but are softened by heat and will flow under pressure. Typical applications include household kitchenware, children’s toys, bottles and other common items.
- Thermosetting plastics are resins that undergo an irreversible reaction when cured in the presence of a catalyst. They cannot be re-melted and are insoluble.

Fiberglass products use only thermosetting resin systems of which there are two generic types, epoxy and polyester resins. The resin system is chosen for its chemical, mechanical and thermal properties. Epoxy resins are used primarily for the manufacture of small diameter piping, whereas polyester resins are commonly used for large diameter piping and storage tanks. Polyester resins come in many variations with different properties to resist acids, caustics and high temperatures.

Additional compounds are added to resins such as pigments, monomers (e.g., styrene, vinyl toluene) catalysts (e.g., organic peroxides), hardeners and accelerators. For example, catalysts are typically added to polyester resins to accelerate the curing action, whereas epoxy resins do not use catalysts.

VI. Resistance to Aggressive Environments

Resistance to corrosion in aggressive environments is one of the primary reasons for specifying fiberglass tanks or piping. Typical types of corrosion do not affect fiberglass. This would include galvanic, aerobic, pitting and inter-granular corrosion which harms metals but not fiberglass. Although fiberglass resists a wide range of chemicals and temperatures, it requires the right design, fabrication and installation to match the appropriate application. For example, fiberglass may be subject to chemical attack from hydrolysis, oxidation, pyrolysis or incompatible solutions. The proper resin/glass matrix will minimize chemical attack.

VII. Industry Standards and Specifications

Industry Segments: Certain industry trade organizations have developed fiberglass tank and/or piping standards and specifications that are specific to their industry. In addition, certain third party organizations have developed standards and specifications that are applicable to several industries with similar corrosive environments. Following is a discussion of civilian fiberglass standards and specifications and their applications:

A. Trade Association Standards & Specifications:

a. Potable Water Pipelines and Tanks

The American Water Works Association (AWWA) maintains the following standards for small and large diameter pressure piping for potable water pipelines and tanks.

Piping	*C950*	Fiberglass Pressure Pipe
Tanks	*D120*	Thermosetting Fiberglass-Reinforced Plastic Tanks

b. Petroleum Production & Exploration

The American Petroleum Institute (API) maintains the following standards for high and low pressure crude oil and gases, and produced water (e.g., saline solutions) line piping, well drilling tubulars and oil field non-potable water tanks:

Piping	Spec. 15HR	Specification for High Pressure Fiberglass Line Pipe
	Spec. 15LR	Specification for Low Pressure Fiberglass Line Pipe
	R.P. 15TL4	Recommended Practice for Care and Use of Fiberglass Tubulars
Tanks	Spec. 12P	Specification for Fiberglass Reinforced Plastic Tanks

B. Third Party Standards & Specifications:

a. Flammable and Combustible Liquids Storage and Handling Applications

Underwriters Laboratories Inc. (UL) is a nationally recognized third party testing laboratory that maintains performance standards. *UL testing and approval also involves the labeling of the product and a listing service.

The listing service includes the periodic inspection of the manufacturing facilities as part of a quality assurance program. UL testing standards for fiberglass piping and tanks are shown below:

Piping	**UL 971*	Nonmetallic Underground Piping for Flammable Liquids
Tanks	**UL 1316*	Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products

b. Chemical, Industrial and Pulp & Paper Applications

The American Society for Testing and Materials (ASTM) maintains standard specifications for the testing of fiberglass materials and the fabrication of fiberglass tanks and piping. The most commonly used standards are listed below:

Piping	*D 2997*	Centrifugally Cast “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
	D 2996	Filament-Wound “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
Tanks	*D 4097*	Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks
	D 3299	Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks
	D 4021	Glass-Fiber-Reinforced Polyester Underground Petroleum Storage Tanks

The American Society of Mechanical Engineers (ASME) maintains standards for certain applications of fiberglass piping and storage tanks as shown below. In the case of the tank standard, ASME conducts a manufacturing facility and *tank certification program. This program includes the application of an ASME stamp on the tank and periodic quality assurance inspections by ASME inspectors.

Piping	B31.3	Chemical Plant and Petroleum Refining Piping
Tanks	*RTP-1	Reinforced Thermoset Plastic Corrosion Resistant Equipment

VIII. Quality Control & Quality Assurance

Quality Control: The manufacture of fiberglass tanks and piping requires the control of materials and processing parameters to ensure consistency and reliability of the end product. Manufacturers maintain control by implementing a quality control program which includes raw materials inspection, vendor certification, in-process inspection, finished product inspection and testing.

Quality Assurance: There is a second level of quality control known as a quality assurance program. This program may be conducted by a qualified outside party and should include the outside party evaluation of the quality control program in place to ensure that it will perform as intended. Finally, the outside party should conduct periodic unannounced plant inspections to verify the performance of the quality control program.

A. Certification Programs

a. General: Typically a certification program includes the assignment of a unique identification number to each product manufactured. The manufacturer records all manufacturing, inspection and testing data for each unique number and maintains a filing system for possible future retrieval. There are two methods of certification, self and third-party certification.

b. Self-Certification: Self certification is when the manufacturer certifies that the product meets a certain standard or specifications cited in the purchase order. The validity of the certification is based on the quality of the manufacturing process when the product was produced.

c. Third-Party Certification: Third party certification is when a qualified third party participates in the certification process and shares in the control of the unique numbers assigned to each product. Two examples of such programs for fiberglass tanks and piping are the UL "Labeling" and the ASTM "Stamp" quality assurance programs. UL labels are laminated onto each fiberglass tank, pipe and fitting for underground flammable and combustible liquid service. ASME RTP stamps are laminated onto aboveground tanks for chemical or other industrial service applications.

The manufacturer pays for the third party certification service by first paying a fee to have the production facility and product approved or certified. Then there is an ongoing fee for the periodic plant inspections and the purchasing of UL labels or ASME stamps to certify that each product meets the standard setting organization's standard. As a result, there is an added cost to the manufacturer for the third party quality assurance program and product certification. However, the added product cost represents an overall savings to the end user. In terms of user costs, there are savings by minimizing design engineering, purchasing specifications, plant inspections and the longer trouble free life of a quality product.

IX. Third Party Certification of Aboveground Storage Tanks

The ASME RTP-1 Reinforced Thermoset Plastic Corrosion Resistant Equipment standard applies to Reinforced Thermoset Plastic (RTP) vessels in corrosive and otherwise hazardous material service operating at pressures not to exceed 15 psig external and /or 15 psig internal above any hydrostatic head. The RTP-1 standard addresses the following requirements a fabricator must meet to be certified and manufacture tanks with a RTP-1 stamp.

a. Shop Qualifications: Each fabricating facility is surveyed by a team of ASME Inspectors who will conduct an inspection of the following capabilities:

1. *Fabricator's Facility and Equipment:* The qualification survey includes the general shop area and certain specific are i.e., raw material storage areas, resin mixing and dispensing, molds (e.g., tank heads) and laboratory equipment.
2. *Personnel:* The fabricator's organization shall include specific personnel designated for each of the following functions:
    - Design and Drafting
    - Quality Control

- Material Control
- Fabrication
- Laminators (i.e., a person who makes laminates)
- Secondary Bonders (i.e., a person who joins & overlays subassemblies)

3. *Quality Control Program and Record System:* The fabricator shall establish and maintain a Quality Control Program for all phases of the fabricating process. This program includes a procedure that assures current designs and specifications are in place. A record keeping system shall be in place to provide a paper trail for all fabricating phases.

4. *Materials Inspection Requirements:* The fabricator is required to conduct minimum inspections and testing of reinforcing material i.e., glass-fiber and resins and curing agents when received. These minimum procedures are cited in the standard.
5. *Qualifications of Laminators and Secondary Bonders:* The Inspector will qualify laminators and secondary bonders based on their ability to produce demonstration laminates to meet all provisions of the standard. They shall be re-qualified every three years.
6. *Demonstration of Capability:* The fabricator is required to produce demonstration laminates for each type of laminate the shop will use on vessels fabricated to the standard. This would include the production and testing of a filament wound vessel and hand lay-up and/or spray-up laminates using all glass-fiber mats and/or glass-fiber roving in the chopper-gun process. The latter two laminates are required for the fabrication of heads or when joining the subassemblies of vessels together.
7. *Demonstration Vessel:* To complete this requirement the fabricator must have a comprehensive understanding of the standard. It involves the fabricator's ability to design, execute drawings, qualify demonstration laminates, establish design values, qualify Laminators and Secondary Bonders and follow an effective Quality Control Program.
   After vessel testing, it shall be sectioned to reveal the details and integrity of laminates and secondary bonds.
8. *Materials Specifications:* The fabricator must use resins and glass-fiber reinforcements that meet the standard and were used in the qualification laminates.
9. *Test and Analytical Methods:* The standard includes accepted test and analytical methods for physical mechanical properties. These include stress analysis methods and examination by using acoustic emissions in conjunction with a hydrostatic test.

b. Accreditation: An accredited fabricator is one who holds a current ASME RTP-1 "Certificate of Authorization." The certificate is issued for a three year period for each shop location, after which time the shop must be re-certified. After initial accreditation, ASME will conduct a continuing audit program of the Quality Control Program i.e., a Quality Assurance program.

X. Third Party Certification of Underground Storage Tanks & Piping

Underwriters Laboratories Inc. (UL) is an independent testing laboratory established to investigate materials, products, equipment, constructions and systems with respect to hazards affecting life and property. UL certification i.e., "Listing" is the largest nationally recognized testing laboratory and is often required by local and regional building codes for the storage and transfer of flammable and combustible liquids.

A. Underground Storage Tanks UL 1316 "Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products" standard applies to spherical or horizontal cylindrical atmospheric-type Reinforced Thermoset Plastic (RTP) tanks that are intended for the underground storage of petroleum-based flammable and combustible liquids, alcohols and alcohol-blended fuels. The UL 1316 standard addresses the following requirements a fabricator must meet to be certified and manufacture tanks with a UL Mark.

The manufacturer must submit a representative tank to UL's testing facility for an engineering evaluation of the following components:

1. *General Standards:* Lift lug strength, pipe connections, man-ways and other fittings are standardized for the installer.
2. *Significant Performance Requirements:* Following is a summary of major performance requirements included in the UL testing protocol:
3. *Internal Pressure:* Two internal pressure tests are performed on the demonstration tank. First, the tank is placed aboveground on a sand bed with no other support. It is then filled with water to capacity for one hour and shall show no damage. Second, the tank shall withstand without rupture an internal pressure 25 psig for 10 foot and 15 psig for 12 foot diameters, respectively.
4. *External Pressure:* The demonstration tank is to be buried in a pit, filled with water and then subjected to an internal vacuum of 17.9 psig without failure.
5. *Aged Properties:* Coupons are cut from the demonstration tank and are aged at 158 degrees F in an oven for up to 180 days and must retain 80% of the original flexural and impact strength.
6. *Impact and Cold Exposure:* Coupons are conditioned for 16 hours at 20 degree F and must retain 80% of their original flexural and impact strength.
7. *Material Compatibility:* Coupons are cut from the demonstration tank and immersed in 100 degree F test liquids for up to 180 days and must retain 50% of their flexural and 30% of their impact properties. The immersion liquids include gasolines, heating fuels and gasoline blends up to 100% ethanol and methanol.

B. Underground Piping UL 971 "Underground Piping for Flammable Liquids" standard applies to primary and secondary containment non-metallic pipe and fittings (piping) intended for use underground to transfer petroleum-based flammable and combustible liquids, alcohols, and alcohol-blended fuels. The UL 971 standard addresses the following requirements a fabricator must meet to be certified and manufacture piping with a UL Mark.

The manufacturer must submit a representative samples to UL's testing facility for an evaluation of the pipe, fittings and adhesives:

1. *Internal Pressure:* Primary Piping Test samples are subjected to 1.5 million cycles at a rate of 25 cycles per minute. Following this test, the samples are subjected for five minutes to a hydrostatic pressure of two times the rated pressure and then for one minute at five times the rated pressure.
2. *Bending:* Bending moment and bending load tests are conducted on pipe fittings threaded or bonded to the pipe and then tested for leaks.
3. *Aged Properties:* Samples are tested essentially the same as for fiberglass tanks.
4. *Impact and Cold Exposure:* Piping is tested before and after 16 hours of conditioning at minus 20 degrees F by dropping from a six foot height onto pavement and by dropping a steel ball on the piping. The piping then must then pass a leakage test.

5. *Material Compatibility*: Immersion tests with test fluids essentially the same as for fiberglass tank coupons are performed on pipe samples.
6. *Permeability:* Eighteen inch lengths of pipe are filled with the test fluids and sealed with end caps using the test adhesive or screwed fitting. The primary pipe and containment pipe are weighed over a 180 and 30 day period respectively, to determine if the test fluids permeate the materials.

Accreditation: An accredited (i.e., Listed) fabricator with Underwriters Laboratories has submitted a demonstration product to UL engineers who have conducted an investigation of the product for compliance with the UL 1316 or UL 971 standard. The registered UL Mark on a product is a means by which a manufacturer can show that UL approves the product as having met the standard test protocol and that the manufacturer participates in a third party quality assurance program. This program typically includes quarterly unannounced UL representative plant inspections of the manufacturer's quality control program.

X. Summary

1. Since the 1950's Fiberglass Reinforced Thermosetting Plastic (RTP) has developed as a proven material for tanks and piping applications in an aggressive environment.
2. The fabricator has many different glass-fiber, resin and additive RTP matrices from which to design the appropriate material system for the intended application.
3. Fiberglass standards and specifications are generally industry and/or application specific. An exception may be found with certain ASTM standards.
4. Product quality is an important factor when making a purchasing decision for the storage and transfer of aggressive materials.
5. Product quality assurance is attainable by:
   - Buyer's tight specifications and plant inspections
   - Industry standards and self-certification by the fabricator, or
   - Third Party Standards and Quality Assurance Program
6. American Society of Mechanical Engineers (ASME) and Underwriters Laboratories Inc. (UL) are the two nationally recognized organizations that have developed standards and conduct Quality Assurance programs for the manufacture of aboveground RTP tanks and underground tanks and piping, respectively.
7. Third party Quality Assurance Programs:
   - Provide an objective standard
   - Require management dedication to the quality process
   - Result in a higher level of overall service and product quality for all fiberglass products produced at a qualified facility.
8. In the absence of third party quality programs the next best option is to know your fabricator.

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