Fiberglass Pipe: Past, Present And Future

From the early 1950s through the present, the use of machine-made piping has grown tremendously. Sullivan D. Curran, P.E. gives an overview of the last 45 years.

Today, Fiberglass Reinforced Thermosetting Plastic (FRP) is being used in many industrial product applications, including the storage and transfer of corrosive materials and the handling of other materials in corrosive environments. While FRP piping has a 30-year history, it is a modern day product material with many emerging applications that take advantage of its corrosion resistance, strength-to-weight ratio, low maintenance and life cycle cost. This article discusses the history of FRP piping, its current applications and the emerging technological advances for new applications of FRP piping in petroleum storage and handling facilities.

What exactly is FRP piping? Don't confuse it with ordinary thermoplastic piping, such as PVC and polyethylene. Those thermoplastic systems typically employ non-reinforced, extruded pipe and injection-molded fittings and flanges. What strength they have comes from the sheer bulk of the material.

By contrast, FRP piping materials are manufactured by winding processes that employ epoxy resins, reinforced with continuous glass filaments. The resins used undergo irreversible chemical reactions as they cure, resulting in superior temperature capabilities, while the filament reinforcement makes the piping components mechanically far more capable than ordinary non- reinforced thermoplastics. This process is called thermosetting. The result is enhanced performance and lighter weight.

Also, don't confuse hand lay-up with machine-made FRP products. Hand lay-up manufacturers number in the thousands, and include small shops that typically specialize in consumer products, such as bathroom vanities or pleasure boats. However, there are relatively few manufacturers of machine-made pipe. These are typically large companies that mass produce on-the-shelf and custom piping for petroleum, commercial, industrial or municipal applications for both domestic and overseas markets.

Machine-made FRP can have a higher glass loading content (i.e., a higher density glass fiber filament to resin ratios) than hand lay-up products. Also, machine made products are more reproducible since they are typically in a quality controlled environment. This article will focus on the advancements made in FRP machine-made pipe and fittings, as well as their applications in the petroleum industry.

Over a wooden barrel

In the early days, just after Colonel Drake's discovery of oil near Titusville, Ohio in 1859, no pipe was used at all! The oil was pumped directly into wooden barrels for shipment. The first pipes were made from wood and later replaced with steel. However, the steel pipe was rapidly corroded by the combination of salt water and sour, high sulfur crude.

Although FRP technology was developed during World War II, it was more than a decade later when the first pipe was made from FRP by a hand lay-up method. This was done by applying a glass fiber cloth and resin by hand over a male mandrel (a rotating cylindrical mold that can be collapsible to remove the pipe). Although this hand lay-up method was suitable for some chemical industry applications, it did not have the combination of strength and cost-effectiveness needed to compete with steel in the petroleum industry.

In the 1950s, centrifugal casting was developed to produce pipe suitable for chemical and commercial applications and oil field gathering lines (piping between producing wells and storage tanks).

Also in the 1950s, a filament winding process was developed to manufacture pipe with tensioned glass fibers, which were oriented to bear the combination of hoop and axial forces. The process called for layers of glass fibers in a near axial orientation, and resulted in the development of down hole tubing able to withstand high pressure (up to 2,000 psi) for crude oil producing wells. Some of these earlier FRP tubing strings remain in service after more than 35 years of production. Tubing strings include threaded joints that connect the drill pipe together in "strings" as long as 1500 feet.

In the 1960s, a very efficient high-volume continuous-pipe-production process was developed for small diameter pipe that was rated for pressure up to 450 psi. The process was both efficient and capable of producing the high volume of pipe necessary to compete with steel. Large scale use of this pipe began in 1964; it was primarily installed in 2 inch crude oil gathering lines.

Developing the standards

In 1959, the American Society for Testing Materials (ASTM) published the first nationally recognized standards and test methods for FRP pipe: ASTM D1694, Standard Specification for Threads for Glass Fiber Reinforced Thermosetting Resin Line Pipe. This specification was developed by a group of representatives from fiberglass pipe manufacturers, oil companies and other industries.

In 1968, the American Petroleum Institute (API) published its first FRP pipe standard: API 15LR, Specification for Glass Fiber Reinforced Thermosetting Resin Line Pipe. Today ASTM and API publish numerous standards, specifications and test methods for FRP piping.

FRP machine-made piping today

The use of FRP machine-made piping has grown tremendously. From its original and major use in oil field gathering lines, FRP piping is now used in applications ranging from handling flammable and combustible liquids at retail consumer facilities to sewer and water mains in the municipal and industrial markets.

Here are some examples of current FRP piping applications in the oil and gas production industry:

(1) 4,000 psi 4 inch pipe in oil field service;

(2) 2 to 16 inch pipes for water filtration projects in climatic conditions as cold as Alaska and as hot as the Persian Gulf; and

(3) a salt water/crude oil 12 inch pipeline operating at 290 psi at temperatures up to 120 degrees Fahrenheit.

The handling of flammable and combustible liquids includes the underground piping of gasolines, gasoline-alcohol mixtures and alcohols at most of the nation's retail and commercial vehicle fueling facilities. FRP piping was Listed by Underwriters Laboratories in the late 1960s. Since that time, more than 60 million feet of pipe has been successfully installed in gasoline refueling stations serving the nation's motoring public.

While concrete sewer and drainage piping continues to dominate, there are many situations where FRP is the preferred choice. For example, concrete pipe deteriorates rapidly in decomposing sewage due to a hydrogen sulfide (H2S "rotten egg" gas) attack.

Hydrogen sulfide erodes the upper surface of the concrete pipe and will eventually cause a cave-in. However, FRP is not affected by either hydrogen sulfide or purging with caustic or hypochlorite to suppress sulfide odor. As a result, FRP pipe is frequently used as a liner in large diameter (48 to 60 inches) concrete pipe.

Future of FRP piping systems

• Computer software

Many architectural and engineering firms are now able to fully utilize the computer software program developed to enhance the design of FRP piping systems. The program makes it easy to step through complicated calculations and analysis when designing a new FRP piping system or when troubleshooting an existing FRP piping system. The software program typically includes: an analysis of liquid flow, free span (i.e., distance between pipe supports) and gas flow; thrust block design (i.e., lateral pressure capacity); chemical composition; and installation information.

• Bigger and better pipes

The oil and gas production industry will be requiring higher-pressure rated and larger-diameter piping to control corrosion problems in produced fluid lines (i.e., water contaminated with salt, sulphur and other corrosive elements). It is not uncommon to "produce" and treat seven barrels of water for each one barrel of crude oil brought out of the ground.

In addition to solving corrosion problems, FRP piping can be designed with a flame-retardant additive. This additive reduces the spread of flames in non-critical areas or in critical areas. Coated with an intumescent paint or insulated with an intumescent material, the paint and coating expand to form an incombustible foam insulation. This latter system will maintain the serviceability of the piping for a minimum of three hours under flow conditions (i.e., the piping remains in active service, such as a fire main.).

FRP firewater protection piping is solving weight problems when used in offshore oil production platforms. Weight savings in the design of a platform can save the owner from $2.00 to $4.00 per pound in construction costs by reducing the weight of the support structure (e.g., savings up to 750 tons). (See the next issue of PE&T for more information on FRP and fire protection.)

• Trench-less piping
This is a rapidly growing technology in which micro- tunneling for new piping and slip lining for the rehabilitation of existing piping do not disturb roadbeds or other aboveground structures.

Micro-tunneling: While tunnel boring has been used on large tunnel projects, micro-tunneling is a new application for trench-less piping. In micro-tunneling the FRP pipe is hydraulically jacked, and pushes a machine-operated cutter head through the substrata.

It takes hundreds of tons of jacking pressure to push large diameter piping hundreds of feet. For example, 18 inch diameter FRP pipe can be jacked at pressures up to 90 tons, and 9 foot diameter FRP pipe at pressures up to 1,750 tons to push lengths of pipe and their coupling joints hundreds of feet.

In the past, stainless steel sleeves have been used as a reinforcement around concrete pipe joints to withstand hydraulic jacking pressures. However, FRP sleeve joints are proving to be a cost-effective replacement for the stainless steel used in concrete pipe jacking.

FRP pipe and joint systems are proving to be more cost effective than their concrete counterpart. This is because FRP’s smoother outside surface and lighter weight significantly reduce the jacking pressure required, and permit jacking of longer piping runs than concrete, thus reducing installation costs and time.

Slip-lining: This is a trench-less method of rehabilitating an existing pipe with a minimum of excavation. New and rehabilitated sewer and drainage pipes are no longer limited to relatively small diameter FRP slip-lining methods.

Centrifugal-cast FRP pipe may be used since it is machine-made on a female mandrel rather than a male mandrel as is filament-wound FRP pipe. Centrifugal-cast FRP pipe technology has advanced and yields a machine-made pipe with close outside diameter tolerances in diameters up to 96 inches. The light weight and smooth outer surface permits jacking the pipe inside an existing pipe, thus rehabilitating leaking concrete sewer pipe up to 102 inches (i.e., nine feet in diameter).

This system of rehabilitation minimizes the jacking pressures required to push the FRP pipe through existing concrete pipe, and it is done even as sewage flow continues. For example, a trench-less project is underway to rehabilitate 6,000 feet of a 102-inch sewer in Los Angeles with a minimum excavation by using 9 foot diameter FRP pipe.

• New chemical processes This typically involves piping exposure to such chemicals as acetone, methylene chloride, hydrochloric acid, ethylene dichloride, phenol, toluene, xylene, ethyl acetate, and methyl acetate. Specialty metals such as titanium are typically used for resistance to such chemicals, but they are prohibitively expensive. However, resin selection such as furan based materials are extremely solvent-resistant and a cost effective alternative to titanium.

Petroleum marketing facilities

Traditionally petroleum marketing facilities used steel piping. It was low in cost and met the 2 hour 2,000 degree Fahrenheit code requirement for the handling of flammable and combustible materials. While retail facilities have adapted to new material advances (e.g., FRP underground tanks, piping and flexible connectors), distribution terminal designers and contractors have been slow to apply non-steel technologies. Following are several areas where the terminal facility designer should consider FRP piping applications:

Underground piping:

Underwriters Laboratories has UL 971 Listed FRP piping for flammable and combustible service in diameters of 2, 3, 4 and 6 inches. The 1996 edition of NFPA 30 references UL 971, and permits using these FRP pipe diameters in distribution terminals.

While the terminal designers prefer to locate piping aboveground for ease of environmental testing (i.e., visual inspection rather than periodic pressure testing), the Uniform Fire Code (UFC) revised its rule in 1995. UFC now requires the installation of piping underground. This will require cathodic protection systems and the ever-present requirement for periodic testing. Therefore, a cost effective alternative to both underground steel piping and cathodic protection is FRP pipe consistent with UL Listed diameters.

Sewer and drainage:

Pollution prevention-related projects include containment, recycling, discharge reduction and sewage treatment. Concrete piping is not suitable for the handling of petroleum-related effluent for two reasons: (1) because of the high leakage rate in the pipe joining methods available; and (2) steel piping will corrode in an underground environment.

Large diameter FRP piping is available up to 9 feet in diameter, and designed with leak free joints. As described above, trench-less new or slip-lining rehabilitation piping methods are cost effective and provide a minimum of disruption in operations.

Corrosive chemicals:

Today, it is becoming more common to blend motor fuel additives at the terminal. Many of these additives (e.g., gasoline detergent additives) are corrosive to traditional carbon steel. With blending systems located at the truck loading rack, underground piping is commonly installed under the driveway areas and lends itself to FRP piping.

Firewater protection:

Scale from internal corrosion of steel piping in a firewater protection system is known to plug nozzles and sprinkler heads. To combat the effects of corrosion and internal scaling, metallic firewater systems using untreated water require continuous maintenance. In untreated or “non-neutral” (i.e. controlled pH) firewater systems, it is questionable how much of a metallic system is in an effective operating condition at a given moment.

FRP fire-resistant material systems are being developed and should prove to be cost effective in certain fire protection applications where firewater is corrosive to steel, such as marine vessels and off-shore drilling platforms.

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