Fiberglass Pipe
Past, Present and Future

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I. Purpose and Scope

Today Fiberglass Reinforced Thermosetting Plastic ("FRP") is being used in many industrial product applications, including the storage and transfer of corrosive materials or the handling of other materials in corrosive environments. While FRP piping has a 65 -year history, it is considered a modern day product material with many new emerging applications that take advantage of its corrosion resistance, strength-to-weight ratio, low maintenance and life cycle cost. This paper discusses the history of FRP piping, current applications of FRP pipe and emerging future technological advances for new applications in petroleum storage and handling facilities.

II. Introduction

Don't confuse FRP piping with ordinary thermoplastic piping like 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 material. By contrast, FRP piping materials are manufactured by winding processes that employ epoxy resins reinforced with continuous glass filaments. The resins used are thermosetting i.e., they 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. 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 which typically specialize in consumer products, such as bathroom vanities or pleasure boats. However, there are relatively few machine made pipe manufacturers. These are large manufacturers that mass produce on-the-shelf or custom piping for petroleum, commercial, industrial and municipal applications for both domestic and overseas markets. Machine made FRP can have a higher glass loading i. e., denser glass fiber filament/resin product which is more reproducible in a quality controlled environment. Therefore, this paper is limited to advancements made in machine made pipe and fittings that will have applications in the petroleum industry.

III. Early Days

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

While FRP technology was developed during World War II, it was later when the first pipe was made from FRP by applying a glass fiber cloth and resin over a male mandrel by hand. This “hand lay-up” method was suitable for some chemical industry applications, but did not have the combination of strength and cost-effectiveness necessary to replace steel in the petroleum industry.

IV. Machine Made Piping

In the late 1940’s centrifugal casting was the first machine made method to produce pipe suitable for chemical and commercial applications and oil field gathering lines. Next a filament winding process was developed to manufacture pipe with tensioned glass fibers oriented to bear the combination of hoop and axial forces. Filament winding with a dual angle construction called for layers of glass fibers in a near axial orientation and resulted in developing high pressure (up to 2,000 psi) down hole tubing for producing wells. Some of these earlier FRP tubing strings remain in service after more than 35 years of production.

In the 1960’s an efficient high volume continuous pipe production process was developed for small diameter pipe rated for pressures (up to 450 psi). Large scale use of this pipe began in 1964 and was primarily installed in two inch crude oil gathering lines.

V. Codes and Standards Development

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

In 1968 the American Petroleum Institute ("API") published their first FRP pipe standard. This first API standard was 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.

VI. Today

Today the use of FRP machine made piping has grown from its original major use in oil field gathering lines to applications ranging from handling flammable and combustible liquids at retail consumer facilities to sewer and water mains in the municipal and industrial markets. Following are examples of current FRP piping applications:

In the oil and gas production industry, high pressure applications include up to 4,000 psi. In environments as cold as above the Arctic Circle to the deserts of the Middle East. FRP piping is used both above ground and buried and is found in systems from Production to Enhanced Oil Recovery techniques, including hydraulic fracturing to salt water and CO_2 injection.

Flammable and combustible liquid handling includes the underground piping of motor vehicle fuels, including high concentrations of alcohol (ethanol) and aviation and marine fuels at most of the nation’s retail and commercial vehicle refueling facilities. Since FRP piping was Underwriters Laboratory Listed in the late 1960’s, over 150 million feet have been successfully installed and serve the nation’s motoring public.

While sewer and drainage piping continues to be dominated by concrete, there are many areas where FRP is the preferred choice. For example, concrete pipe deteriorates rapidly in sewage due to hydrogen sulfide attack. Hydrogen sulfide erodes the upper surface of the pipe and will eventually cause a cave-in. FRP is unaffected by hydrogen sulfide or purging with caustic or hypochlorite to suppress sulfide odor. As a result, FRP pipe has been used as a liner in large diameter (48 to 60 inches) concrete pipe.

VII. The Future

Architectural and engineering firms are now able to use computer software programs developed to enhance the design of FRP piping systems. The program includes liquid flow analysis, gas flow analysis, free span analysis, thrust block design, chemical composition and installation information. The program makes it easy to step through complicated calculations and analysis when designing a new FRP piping system or for troubleshooting an existing FRP piping system.

Oil & Gas Production Industry:

The oil and gas production industry will be requiring higher pressure rated and larger diameter piping to control corrosion problems in produced fluid lines (It is not uncommon to "produce" and treat seven barrels of water for each 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 to reduce flame spread for non-critical areas or in critical areas, be coated with an intumescent paint or insulated with an intumescent material i. e., the paint and coating expands to form incombustible foam insulation. This latter system will maintain the serviceability of the piping for a minimum of three hours under flow conditions. FRP firewater protection piping is solving weight problems when designing 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). In areas classified as hazardous, FRP piping can be made with conductive fibers, co-mingled with the glass fibers, to provide electrical conductivity of the material to ground the system and prevent potential build-up of static charge.

Municipal and Industrial Pipe Applications:

Trenchless Piping: Trenchless piping is a rapidly growing technology where micro-tunneling for new piping and slip-lining for rehabilitating 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 the cutter head through the substrata. It takes hundreds of tons of jacking pressure to push large diameter piping distances of hundreds of feet. For example, 18 inch diameter FRP pipe can be jacked at pressures up to 90 tons and nine foot diameter FRP pipe at pressures up to 1,750 tons.

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

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

Slip-lining: Slip-lining 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 technology has advanced and yields a machine-made pipe with close outside diameter tolerances in diameters up to 120 inches. The light weight and smooth outer surface permits jacking the pipe inside an existing pipe, thus rehabilitating leaking concrete sewer pipes. This system of rehabilitation minimizes the jacking pressures required to push the FRP pipe through the existing concrete pipe and is done even as sewage flow continues. For example, a trench-less project is underway to rehabilitate 6,000 feet of 102 inch sewer in Los Angeles with a minimum of excavation by using nine foot diameter FRP pipe.

Industrial Applications: Chemical processing typically involves piping exposure to such chemicals such 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 are prohibitively expensive. However, resin selection such as furan based materials are extremely solvent resistant and cost-effective.

Petroleum Marketing Facility Applications

Traditionally petroleum marketing facilities used steel piping which was low in cost and met the 2 hour 2,000° F fire code requirement for the handling of flammable and combustible materials. While retail facilities have adapted to new material advancements e. g., FRP underground tanks and 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 Laboratory has UL 971 Listed FRP piping for flammable and combustible service in diameters of 2, 3, 4 and 6 inches. The 2012 edition of NFPA 30 references UL 971 and permits using these FRP pipe diameters in distribution terminals. While terminal designers prefer to locate steel piping aboveground for ease of environmental testing i.e., visual inspection rather than periodic pressure testing, the Uniform Fire Code revised their rule in 1995 and now require the installation of piping underground. Underground steel piping will require cathodic protection systems and its inherent periodic testing requirement. Therefore, a cost effective alternative to 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 because of the high leakage rate in the pipe joining methods available and steel piping will corrode underground. Large diameter FRP piping is available up to twelve 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 are corrosive to traditional carbon steel. With blending systems located at the truck loading rack, underground piping is common 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 systems require continuous maintenance. Even then, it is questionable how much of a metallic system is in an effective operating condition at a given moment. FRP fire resistant material systems have been developed and are proving to be cost effective in many fire protection applications.

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