Fiberspar

Engineering Guide

Spoolable LinePipe

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Introduction

Fiberspar Spoolable LinePipe has been developed to provide the oil and gas industry with a family of products to address the market requirements for a reliable, corrosion-resistant, and cost-effective solution for tubulars used during the production and transportation of oil and gas. Fiberspar Spoolable LinePipe (FS LP) is a continuously manufactured glass fiber-reinforced pipe that is designed for production gathering, transmission, distribution, and injection applications.

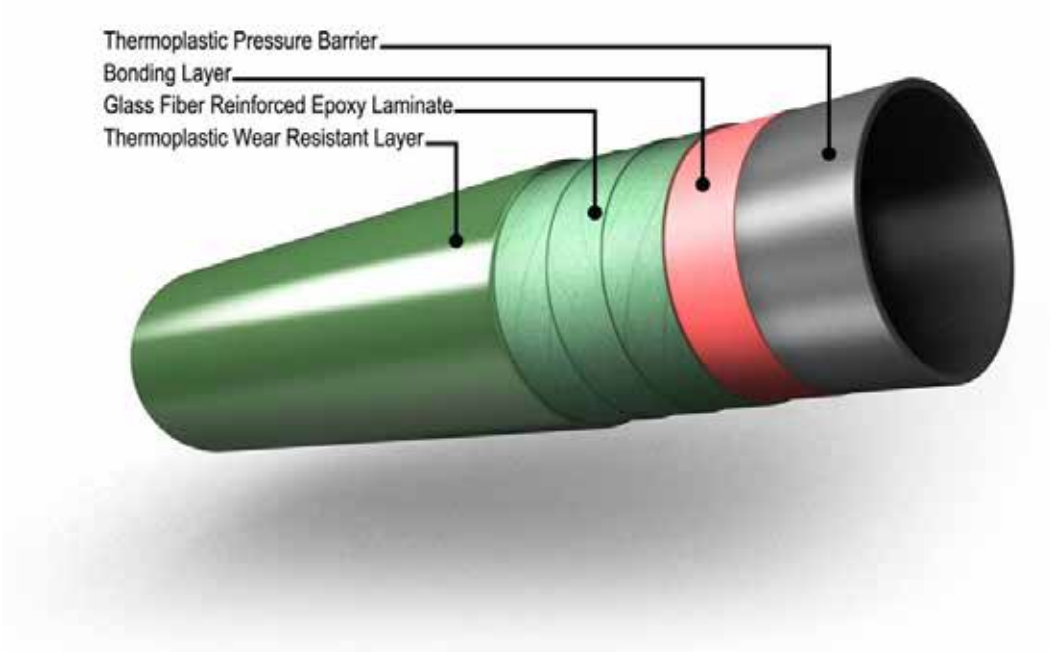
Advantages of FS LP compared to alternative pipeline systems include:

- Rapid and low-cost installation
- Improved corrosion resistance
- Long lengths without joints or connections (up to 9,000 ft, 2.7 km)
- Improved flow characteristics
- Tolerance to impact damage
- Light weight for improved safety during field installation

Fiberspar Spoolable LinePipe is manufactured in an API 15S Licensed facility. Qualification testing is performed according to the following specifications where applicable:

- API 15S – "Qualification of Spoolable Reinforced Plastic Line Pipe"
- CSA Z662 Section 13.1 – "Fiberglass Pipeline"
- ASTM D2992 - "Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.
- ASTM D2996 – "Standard Specification for Filament-Wound 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe"
- ASTM D2517 – "Standard Specification for Reinforced Epoxy Resin Gas Pressure Pipe and Fittings"

Linepipe Product Geometry



LinePipe Product Geometry

Fiberspar LinePipe

Design Overview

The patented LinePipe design consists of an inner thermoplastic pressure barrier layer that is bonded to and reinforced by high-strength glass embedded in an epoxy matrix. This reinforced structure is then jacketed using a thermoplastic material that provides additional protections from impact and abrasion.

Fiberspar Spoolable LinePipe is available in sizes between 2" and 6" with pressure ratings between 750 psi and 3,500 psi (5.2 MPa–24.1 MPa) in continuous lengths of up to 9,000 ft (2.7 km) depending on size and reel capacity. Other sizes and higher-pressure ratings are available by special order.

The selection of the thermoplastic pressure barrier liner is driven by operating temperatures and chemical compatibility with the process fluid. Materials most commonly used are high-density polyethylene (HDPE), which has excellent chemical resistance up to 150ºF (65ºC) in general water, low vapor pressure (LVP), or gas gathering applications; and high-temperature polyethylene (HTP), which is generally recommended for applications up to 180° (82°C). All of these pressure barrier materials are commonly used in the oil and gas industry, with widely published data on performance.

Connectors

Patented Fiberspar Spoolable LinePipe connectors are a full-strength, field-applied connection system with typical installation times of less than 15 minutes. The service-end connection is used to join the Fiberspar Spoolable LinePipe to flanges, T's or other fittings as required. The standard connector comes pre-welded to a flange, but customers also have the option of a threaded end, bevel end for welding or other custom configuration. Fiberspar connectors are also re-usable which allow for simple changes and modifications to systems once the line is already in operation.

Fiberspar's pipe-to-pipe connector is a full-strength connection used to join two lengths of LinePipe. The pipe-to-pipe design is similar to the service end, except a double seal carrier and two individual sets of slips are used. The tensile and burst properties of the Fiberspar connection exceed the strength of the pipe itself. Industry qualification tests are conducted using standard Fiberspar Spoolable LinePipe connectors along with the pipe, resulting in a fully qualified, complete system.

Connectors can be fabricated from various alloys depending on application and customer requirements. Commonly used materials for the end connectors include AISI 4140 L80 or A106 Grade B steel. Machining of connectors is done in house adhering to Fiberspar's strict quality control standards and welding is performed by licensed welding shops with proper QA and QC procedures only. Wetted surfaces are coated depending on customer and application requirements. For example, standard Fiberspar connectors use an Electroless Nickel Coating as specified by ASTM B733 for severe service. All welding procedures meet or exceed ASME and CSA specifications and include X-ray inspection on welds for every component. The seal rings are supplied to meet customer material specifications, with Viton and HNBR being the most common. All LinePipe connections are performed in the field by certified installers who have undergone training and are certified in the proper methods and procedures for installing Fiberspar Spoolable LinePipe connectors in accordance with requirements of API 15S, and CSA Z662 Section 13.1.

Pipe-to-pipe connector

Flanged service-end connector

Fiberspar Quality System

Overview

Fiberspar has made an extensive commitment to ensure the highest level of quality is employed in the design, manufacture, and installation of every spool of LinePipe. To that end, a four-tier quality-assurance system has been implemented to meet the needs of the oil and gas industry. The Fiberspar quality system meets or exceeds the requirements of API Q1 and is ISO 9001.

Factory hydrotests are conducted at 1.5 times Nominal Pressure Rating (NPR) on every foot of Fiberspar Spoolable LinePipe produced. Destructive testing such as burst, glass transition temperature scans, and detailed visual inspections of the laminate and liner are also part of the quality control process for each manufacturing run.

Certificate of Conformance

A Certificate of Conformance (COC) is supplied to customers prior to shipment, which summarizes the results from all quality-assurance tests required by Fiberspar's quality system. Linepipe quality control tests meet or exceed the requirements of API 15S, and CSA Z662 Section 13.1.

Long-term Hydrostatic Strength

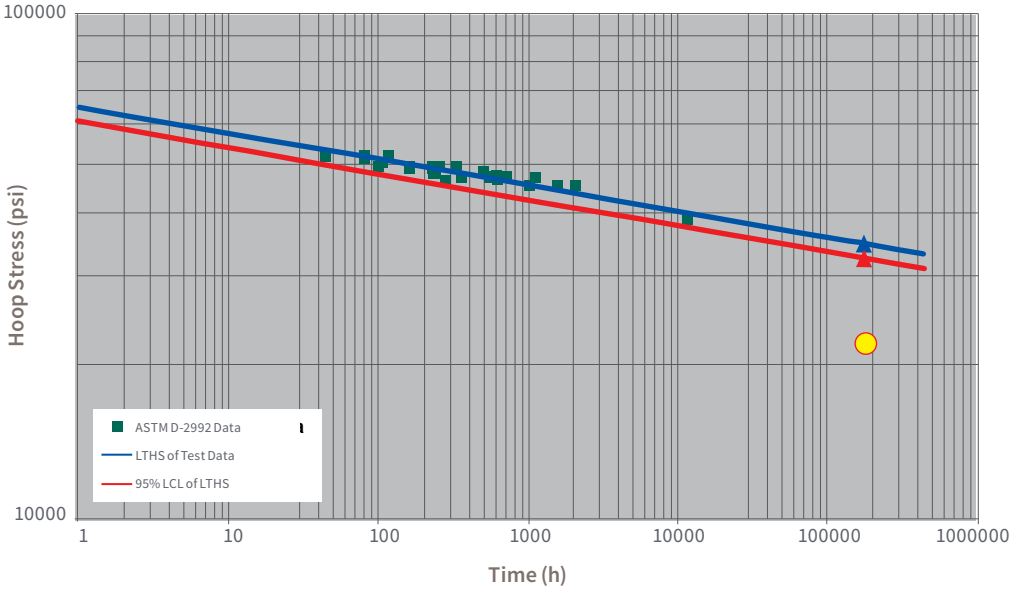
ASTM D2992 Testing

The hydrostatic design basis (HDB) of the Fiberspar Spoolable LinePipe is determined in accordance with ASTM D2992, Procedure B (static), at the maximum rated temperature of the Fiberspar Spoolable LinePipe. The maximum allowable design pressure for static pressure service for the linepipe is determined by the formula stipulated in the applicable pipe design specification. API 15S specifies that Nominal Pressure Rating (NPR) calculations are based on a 20-year regression curve reference time, and a 0.67 design factor is applied to the extrapolated data to determine maximum operating hoop stress.

The graph below is an example of a regression curve with calculated values for Fiberspar Spoolable LinePipe per ASTM D2992, Procedure B.

The API 15S nominal pressure rating (NPR) for Fiberspar LinePipe is calculated based on qualification temperature, test fluid, static loading, and installation recommendations. For operating and service conditions outside of these baselines, especially when large pressure and temperature fluctuations are anticipated, additional analysis and design is recommended to ensure safe, reliable operation.

Regression Curve for Fiberspar LinePipe ASTM 2992 Procedure B



Operational and Design Considerations

Chemical Compatibility and Pressure Barrier Selection

Fiberspar Spoolable LinePipe can be designed to contain a wide range of fluids. Pressure barrier liner selection is based on the specific anticipated service conditions. Due to the almost limitless number of combinations, concentrations, temperature and pressure conditions that are possible in the field, Fiberspar Engineering can provide guidance on a case-by-case basis for specific applications, and can also undertake compatibility testing upon request.

The composite nature of Fiberspar makes it naturally resistant to the types of internal and external corrosion mechanisms typically encountered when using metallic materials. Chemical compatibility of the exterior surface of Fiberspar Spoolable LinePipe is generally not of concern since the epoxy resin and glass fiber outer surface typically is inert in the environments encountered in most buried applications. An external thermoplastic jacket is provided for further protection to the laminate from unusual external conditions, and provides protections from abrasion and impact.

Vibration, Pulsation and Flow Cycling

Applications that use pumps or include pressure cycling may require additional steps to prevent long-term pipe damage or degradation. Systems subject to severe pressure cycling or pulsation may require higher design pipe safety factors per applicable design codes. Applications that will operate on a high-pressure pump, which also cycles several times a day, must be reviewed to determine if any additional service factors need be applied. All pumps produce pulsation, and pulsation dampeners need to be properly sized and maintained to prevent service failures. Positive displacement pumps are particularly prone to vibration and pulsation. Movement of the pipeline due to pulsation or vibration may result in localized abrasion damage if the line is in contact with something sharp and hard. This eventually may lead to a premature failure. Fiber Glass Systems Engineering can provide application-specific guidance where vibration, pulsation or cycling is a concern.

Pressure Drop Calculations and Abrasive Flow

Fiberspar Spoolable LinePipe has a smooth internal thermoplastic pressure barrier that improves flow by reducing frictional losses when compared to steel pipe. The smooth interior surface generally does not deteriorate in service, and improved flow properties are maintained over time. Since the inner liner of Fiberspar is made of polyethylene, an absolute roughness coefficient of 0.00006 inches (0.0015 mm) can be used for friction loss calculations.

Each of the thermoplastic pressure barrier materials used by Fiberspar have good flow abrasion properties and will normally show less abrasive wear than steel pipe under the same abrasive flow conditions. Where highly abrasive flow is expected, tests are recommended to determine the level of abrasion under the specific operating conditions.

Pigging

Pigs can be run through Fiberspar Spoolable LinePipe to remove deposits and blockages. However, because the thermoplastic pressure barriers in Fiberspar Spoolable LinePipe are softer than steel, sharp-edged, scraper-type pigs should be avoided, and soft pigs should be used. Typical high-density foam pigs or soft urethane cup-type pigs are suitable. Fiber Glass Systems engineers can provide information and support for the selection of pig types and sizes to avoid damage to Fiberspar Spoolable LinePipe

Hot Oiling

Intermittent hot oiling of Fiberspar Spoolable LinePipe can be employed up to a maximum hot oil temperature of 82ºC or 180ºF and up to 50% of the pipe nominal pressure rating. Because of the reduced thermal conductivity of Fiberspar Spoolable LinePipe as compared to steel, lower hot-oiling temperatures can be employed while maintaining the exit temperature from the line.

Asphaltenes, Paraffins and Hydrates

Formation of asphaltene or paraffin in hydrocarbons is driven by a change in fluid conditions. Build-up of these deposits inside the tubular occurs when precipitated solids adhere to the pipe wall, and can lead to reduced flow or blockages. Precipitates can adhere to thermoplastics, although this tendency depends on the specific thermoplastic. In most cases the smooth thermoplastic internal pressure barrier material provides improved flow characteristics that generally helps reduce build-up.

Since hydrate crystals tend to originate in cracks and crevices in the inner pipe surface, the smooth thermoplastic inner surface of Fiberspar Spoolable LinePipe can have the effect of delaying the onset of hydrate formation, and can be very beneficial in preventing any build-up of hydrates.

External Jacket and UV Protection

Fiberspar Spoolable LinePipe is externally coated with a continuous thermoplastic material using a custom extrusion process. This provides additional resistance to damage from point loads, abrasion, or impact. This external jacketing comes standard on Fiberspar Spoolable LinePipe products as an added layer of protection. The pigments used in the reinforcing layer and external jacket of Fiberspar Spoolable LinePipe include a UV-absorbing additive that protects the pipe. Any effect on Fiberspar Spoolable LinePipe from UV rays is cosmetic, and the pipe can continue to be used to the full rating for the designed service life.

Static Discharge

Fiberspar Spoolable Linepipe is an electrical insulator, and in applications that involve transport of non-polar liquids and gases, especially at high velocities, a static charge may be generated on inner pipe surfaces. If a line requires repair or purging, or if a new connection is needed, grounding and static control procedures should be employed during the intervention. Static electric discharge can ignite a flammable gas or a combustible atmosphere. Where a flammable gas or combustible mixture may be encountered and static electric charges may be present, observe all company (operator, contractor, etc.) and industry (OSHA, PPI, etc.) procedures for static electricity safety and control, including procedures for discharging static electricity and for personnel protection.

Fire Resistance

The Flammability Classification of Fiberspar products is as follows: “Non-flammable under specified operating conditions. Material will not burn unless exposed to direct flame.”

Fiberspar LinePipe is not resistant to fire. If exposed to direct flame for a period of time causing any damage to the exterior of the pipe, it is recommended that the section is removed and replaced.

LinePipe Installation

Fiberspar Spoolable LinePipe can be installed using construction practices commonly employed for jointed fiberglass pipe. However, given the flexibility, continuous lengths and axial strength of Fiberspar Spoolable LinePipe, specialized techniques can be employed that can reduce installation time and costs. Fiberspar's General Installation Guide, available upon request, summarizes general best practices, as well as some of the specialized techniques that may be used to install Fiberspar Spoolable LinePipe.

Fiberspar Installation Manual

Fiberspar Spoolable LinePipe or connectors should be installed in compliance with the Fiberspar Installation Manual. The Fiberspar Installation Manual is a controlled document with detailed procedures and work instructions that is only available to Fiberspar Certified Installers.

Fiberspar connectors must be installed pursuant to API 15S and CSA Z662 standards by Fiberspar-trained and authorized personnel pursuant to Fiberspar's Connector Installation Procedure. Fiberspar is able to train customer personnel or contractors in these procedures for safe installation.

Pull-through Remediation

Fiberspar Spoolable LinePipe is ideally suited to repair leaking or failed steel lines by pulling the Fiberspar pipe in a continuous length inside of existing pipelines. This technique is possible because of the continuous, flexible, smooth OD and the high axial tensile strength and lightweight nature of the product. Fiberspar has developed installation processes that allow continuous lengths of up to 9,000 ft (2.7 km) to be used to rehabilitate damaged or failing pipelines. This process provides a full-strength, corrosion-resistant repair while minimizing ROW disturbance and excavation requirements for installation. Because of the improved flow characteristics of Fiberspar Spoolable LinePipe as compared to steel, the reduction in flow area from the pull-through remediation is generally offset by the better flow characteristics of Fiberspar Spoolable LinePipe.

Plowing with Fiberspar Spoolable LinePipe

Plowing methodology, which was originally developed for fast and less-disruptive installation of cables and fiber optics, has been adapted to installation of continuous pipeline systems using advanced and high-capacity plowing equipment. Such plowing equipment can be used with Fiberspar Spoolable LinePipe and in some situations can be a very high-productivity and economical installation method. Since plowing equipment usually has relatively high deployment costs, viable use of plowing requires a large project, good ground conditions and relatively long, uninterrupted runs with few line crossings. Many Fiberspar installations have been completed successfully using plowing equipment, but not all plowing equipment designs are compatible with Fiberspar Spoolable LinePipe. More information on plowing techniques and guidelines can be found in the Fiberspar General Installation Guide.

Road and River Crossings

Fiberspar Spoolable LinePipe is ideally suited for road and river crossings. Techniques are similar to the pull-through techniques described in the Pull-through Remediation Section. While most crossings will involve the use of a casing or conductor pipe, Fiberspar Spoolable LinePipe has also been successfully used with the slick-bore method, where pipe is inserted directly into a recently drilled horizontal bore without a conductor pipe. For advice or details on crossings and directional drilling (slick bores), contact Fiber Glass Systems Engineering.

Thermal Movement

The axial thermal expansion coefficient for Fiberspar Spoolable LinePipe is approximately 12.5x10–6 in./in.-°F (2.26x10–5 mm/mm-°C), and the hoop-wise thermal expansion coefficient is approximately 7.14x10–6 in./in.-°F (1.28x10–5 mm/mm-°C).

Because the Fiberspar Spoolable LinePipe has low axial stiffness compared to steel, forces exerted on end fittings from temperature changes will in almost all cases be negligible. Nonetheless, it is good pipeline design practice to calculate these loads and make sure that sufficient margins are provided to accommodate this loading. For surface installations, it is necessary to properly support and anchor the LinePipe to restrict movement and damage.

The following formulas can be used to calculate the change in length of Fiberspar Spoolable LinePipe due to temperature fluctuations, or axial force exerted over a given length.

Given a length of flowline, L, the pipe will extend or grow due to a temperature change of ΔT:

$$\Delta L = L \times \alpha_1 \times \Delta T$$

Where:

α_1 = **coefficient of thermal expansion in the axial direction**

The non-mechanical loads, $P^{non\text{-}mechanical}$, that arise from thermal expansion of Fiberspar Spoolable LinePipe in the case of fully restrained ends (or segments) can be written as:

$$P^{non\text{-}mechanical} = \varepsilon_1^{non\text{-}mechanical} \times E_1 \times A = \alpha_1 \times \Delta T \times E_1 \times A$$

Where E_1 is the axial modulus of elasticity of Fiberspar Spoolable LinePipe and A is the cross-sectional area of the linepipe. Thermal expansion curves for any specific Fiberspar product are available upon request, or Fiberspar engineers can supply calculations for specific cases.

Shrinkage from Pressure Fluctuation

As in the case of thermal expansion, changes in pressure can result in changes in length or axial forces, but again these forces are generally negligible when compared to forces that can be exerted on end components from higher stiffness steel pipeline materials.

Fiberspar Spoolable LinePipe is fabricated with a unique combination of materials and designed with glass fibers oriented such that the Poisson's ratio is greater than 0.5, so the axial hoop strain will induce, through Poisson's effect, an axial contraction that is greater than the axial extension resulting from the pressure-induced axial load. Physically, this means that Fiberspar Spoolable LinePipe will often contract (or get shorter) when under pressure. This contraction needs to be considered while preparing for testing and designing final tie in points.

Marine Installations and Weighting

Fiberspar Spoolable LinePipe is buoyant when not completely full of water and should be weighted in applications with high water tables or where the backfill is not sufficient to keep the pipe in place. In marine pipeline pull-throughs, it is not necessary to weight linepipe, as the steel pipe conduit provides sufficient weighting. If LinePipe is pulled into position during the installation process, care must be taken to avoid damaging or snagging the pipe on rocks, sharp surfaces or other objects. Fiber Glass Systems should be consulted in applications involving weighting of linepipe.

Fiberspar Spoolable LinePipe is not recommended in new construction in marine environments where there is significant risk of damage to the linepipe from construction or fishing activity.

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