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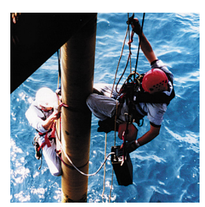


Technical assessment of spoolable fibre reinforced plastic pipe

SEPCO - Transportation of wet gas and sour water in the USA - West Texas, Wyoming and Washington State

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Technical assessment of spoolable fibre reinforced plastic pipe

SEPCO - Transportation of wet gas and sour water in the USA - West Texas, Wyoming and Washington State

by

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Summary

On the request of Shell Exploration and Production Company (SEPCO), Shell Global Solutions International B.V. has evaluated several commercially available spoolable fibre-reinforced plastic pipe systems for compliance with Shell DEP 31.40.10.20-Gen, to be used for the transport of “produced natural gas saturated with water” and “sour water”, in the USA, West Texas, Wyoming and Washington state. In this report, installation guidelines are also given for spoolable fibre-reinforced plastic pipe, for application above ground, buried, and rocky areas.

From the technical evaluation it has been concluded that the majority of the approached Manufacturers have not designed and qualified their products in compliance with DEP 31.40.10.20-Gen. however, the Manufacturers showed willingness to comply for future Shell projects.

Based on a positive outcome from an earlier assessment of Fiberspar spoolable pipe, performed by Shell Global Solutions US Inc., Fiberspar was the only manufacturer, considered “conditionally” qualified. However, to “fully” qualify for the envisaged SEPCO application, additional qualification and quality control tests were required. Burst, tensile, and 1000 hr survival tests have been performed, in compliance with DEP 31.40.10.20-Gen.

Based on successful completion of the qualification and quality control tests, Fiberspar spoolable pipe is qualified for the SEPCO envisaged application, in compliance with Shell DEP 31.40.10.20-Gen., i.e. maximum design pressure of 1500 psi (103 bar), maximum design temperature of 60 °C (140 °F), and diameter up to 4.5".

For competitive bidding, it is recommended to encourage also other manufacturers of spoolable pipe to qualify their products in compliance with DEP 31.40.10.20-Gen.

Amsterdam, March 2007

Table of Contents

1. Introduction

On the request of Shell Exploration and Production Company (SEPCO), Shell Global Solutions International B.V. has evaluated several commercially available spoolable fibre-reinforced plastic pipe systems for compliance with Shell DEP 31.40.10.20-Gen, to be used for the transport of (i) produced natural gas saturated with water and (ii) sour water, in the USA, West Texas, Wyoming and Washington state. In this report, installation guidelines are also given for spoolable fibre-reinforced plastic pipe, for application above ground, buried, and rocky areas.

2. Scope of work

The scope of work included the following:

- Compile concise specification for the envisaged application;
- Contact at least 6 suppliers of spoolable fibre-reinforced plastic pipe systems and determine interest in providing their pipe systems for the envisaged service;
- Request technical data from those suppliers who responded positively to be able to asses their product against compliance to the applicable Shell DEP 31.40.10.20-Gen.
- Perform preliminary assessment of the obtained data. Select maximum of 3 systems/ suppliers with highest potential to fulfil the requirements. Evaluation will include, responds time to request, provision of data, cooperation, track record within Shell;
- Perform detailed assessment against Shell DEP 31.40.10.20-Gen.

3. Design conditions

The design conditions specified by SEPCO for the spoolable pipe are the following:

Application 1 - Produced natural gas (95% methane, 4% CO_2) saturated with water:

- Design pressure: 103 bar (1500 psi);
- Design temperature: - 30 °C (- 22 °F) up-to +55 °C (131 °F);
- Diameter: up-to 4.5 inch.

Application 2 - Sour water (H_2S), including hydrocarbons, and CO_2:

- Design pressure: 35 bar (500 psi);
- Design temperature: - 30 °C (- 22 °F) up-to +50 °C (122 °F);
- Diameter: up-to 4.5 inch.

4. Specifications

Application of spoolable fibre-reinforced plastic pipe should comply with DEP 31.40.10.20-Gen, which includes requirements for design, qualification, and quality control for spoolable fibre-reinforced plastic pipe.

5. Results of evaluation

5.1 Evaluation of the capability of manufacturers

Several manufacturers of commercially available spoolable pipe have been approached with the request to (i) offer pipe systems, capable to meet the service conditions, as specified by SEPCO, (ii) perform qualification tests, in compliance with Shell DEP 31.40.10.20-Gen, and (iii) show track records within Shell.

The outcome of the technical evaluation of manufacturers of spoolable fibre reinforced plastic pipe, is summarized in Table 1.

Table 1 *Summary of technical evaluation of manufacturers of spoolable pipe*

Manufacturer & materials used	**Availability of product for application 1 & 2**	**Compliance with DEP 31.40.10.20**	**Track Records within Shell**
Aerosun - RTP HDPE/Aramide China	Standard product Max 4.5 "/ 106 bar/ 55 °C Applications 1 & 2	MDS (*) - provided no test data (DEP) willingness to comply	No
Airborne – RTP HDPE/glass-fibre The Netherlands	No Standard Product. Max 4"/ 103 bar/ 55 °C Applications 1 & 2	MDS - not provided no test data (DEP) willingness to comply	No
Fiberspar - GRE HDPE/GRE USA	Standard product Max 4.5"/103 bar/ 60 °C Applications 1 & 2	"Conditionally" qualified based on earlier evaluation	PDO - field trial - Shell-US, Texas
FPI - GRE HDPE/GRE USA	Standard product Max 4.5" / 100 bar / 60 °C Applications 1 & 2	MDS - not provided no test data (DEP) willingness to comply	No
Pipelife - RTP HDPE/Aramide The Netherlands	Standard product Max 5" / 65 bar / 60 °C Application 2 (sour water)	MDS - not provided no test data (DEP) willingness to comply	PDO, diameter 4" - gas/water/oil: 20 bar - effluent water: 44 bar
Polyflow - RTP liner: PPS, Nijlon 6 Aramide/PP (USA)	Standard product Max 4.5"/ 105 bar / 50 °C Applications 1 & 2	MDS - not provided no test data (DEP)	No
Technip - RTP HDPE/ Aramide France	Standard product Max. 5" / 55 bar / 60 °C Application 2 (sour water)	MDS - not provided no test data (DEP) willingness to comply	No
Wellstream – RTP HDPE/ steel strip USA	Standard product Max 4" / 103 bar/ 50 °C Applications 1 & 2	MDS - not provided no test data (DEP) willingness to comply corrosion issue - steel	No

(*) MDS: Material Data Sheet;

5.2 Conclusions

From the technical evaluation of manufacturers, the following is concluded:

- Majority of the approached Manufacturers have not designed and qualified their products in compliance with DEP 31.40.10.20-Gen. However, the Manufacturers showed willingness to comply for future Shell projects;
- Based on positive outcome from an earlier (2003) assessment of Fiberspar spoolable pipe, performed by Shell Global Solutions US, Fiberspar pipe has been accepted as “conditionally” qualified;
- To “fully” qualify the Fiberspar spoolable pipe for the envisaged SEPCO application, additional qualification and quality control tests are required, in compliance with DEP 31.40.10.20-Gen., as described in Section 6.

6. Qualification and quality control tests

Based on the outcome of (i) evaluation of the capability of manufacturers of spoolable pipe, and (ii) positive outcome from an earlier (2003) assessment of Fiberspar spoolable pipe, performed by Shell Global Solutions US, it is concluded that there is presently only one manufacturer which has performed most of the required qualification and quality control tests, as specified in DEP 31.40.10.20-Gen. However, to fully comply with DEP 31.40.10.20-Gen, additional qualification and quality control tests are required for Fiberspar spoolable pipe. The qualification and quality control tests have been performed by Shell Global Solutions, as agreed with SEPCO.

6.1 Baseline values

The Manufacturers specified baseline values for Fiberspar, 4.5”, 1500 psi, pipe, are summarized in Appendix 1, Table 1-1.

6.2 Additional qualification requirements for gas application

For SEPCO application 1, as specified in Section 3, gas tightness of the GRP spoolable pipe (+joint) should be demonstrated by performing a gas pressure test, in accordance with DEP 31.40.10.19-Gen.

6.2.1 Test procedure

The test configuration should be two connected pipes, and test pressure between 5 bar (73 psi) and 10 bar (145 psi). Compressed air or nitrogen may be used as test medium. The test duration should be a minimum of 15 minutes. The acceptance criterion is that no gas should leak from the joint or pipe wall. Any escaping gas can be detected with the aid of soapy water or similar foaming mixture.

6.2.2 Test results

Before destructive testing, the Fiberspar test samples (pipe+joint) have been air-pressure tested up to 6 bar (87 psi) for about 30 minutes. No leakages were observed.

6.3 Short-term burst tests

6.3.1 Test procedure

To verify the Manufacturers specified burst pressure strength of 414 bar (6003 psi) for the 4.5 inch diameter, 1500 psi Fiberspar spoolable pipe, short-term burst tests have been performed on two “virgin” and two 1000 hr tested pipe (+joint) samples, in accordance with ASTM D 1599, at Standard Laboratory Temperature (SLT) conditions, i.e. 23 ºC (73 ºF) +/- 2 ºC. Fresh water was used for the test fluid. A photograph showing the test pipes is presented in Figure 1.

6.3.2 Test results

The measured short-term burst strength values are the following:

- “Virgin” pipe (+joint): 411 bar (5960 psi), and 456 bar (6612 psi);
- “1000 hr” tested pipe (+joint): 479 bar (6945 psi), and 478 bar (6931 psi).

For one sample, the short-term burst pressure strength (STHP) was 3 bar (44 psi) below the Manufacturers minimum specified value of 414 bar (6003 psi), and the other three burst pressure strength values are in excess of the Manufacturers minimum specified value. Rupture of the pipe occurred at the location of the end connection, as shown in Figure 2.

The mean burst strength is calculated at 456 bar (6612 psi), and standard deviation is 32 bar (464 psi). The lower deviated STHP (mean minus two standard deviations) is calculated at 392 bar (5684 psi). Based on a safety factor of at-least 3.75, as specified in DEP 31.40.10.20-Gen, the maximum allowable design pressure is calculated at 104 bar (1508 psi).

It is concluded that the 4.5” diameter, 1500 psi Fiberspar spoolable pipe is qualified for the Manufacturers specified design pressure of 103 bar (1500 psi), in compliance with DEP 31.40.10.20-Gen.

6.4 Tensile strength tests

6.4.1 Test procedure

To verify the Manufacturers specified ultimate tensile strength of 198 kN (44600 lbs) for the 4.5 inch diameter, 1500 psi Fiberspar spoolable pipe, tensile tests have been performed on two “virgin” pipe (+joint) samples, in accordance with ASTM D 2105, at Standard Laboratory Temperature (SLT) conditions, i.e. 23 ºC (73 ºF) +/- 2 ºC. A sketch, showing the dimensions of the tensile test arrangement, is presented in Figure 3. A photograph showing the tensile test set-up is presented in Figure 4.

6.4.2 Test results

The measured ultimate tensile strength values are the following:

- Test sample 1, testing speed 2 mm per minute, failure load: 229.4 kN (51569 lbs);
- Test sample 2, testing speed 6 mm per minute, failure load: 236.4 kN (53143 lbs).

For both test samples, the ultimate tensile strength values are well in excess of the Manufacturers specified value of 198 kN (44600 lbs). The tensile failure mode of the Fiberspar spoolable pipe is shown in Figure 5.

From the “load-displacement” curve, as shown in Figure 6, the following is concluded:

(i) Onset of non-linear behaviour occurs at approximately 95 kN (21356 lbs), i.e. well in excess of the specified tensile design load of 79 kN (17840 lbs);

(ii) Axial displacement at the specified tensile design load (79 kN) is 10 mm (0.4 inch), equivalent to 2% axial strain (based on L_0 = 450 mm);

(iii) Axial displacement at the ultimate tensile failure load is approximately 130 mm (5.1 inch), equivalent to 29% axial strain.

The mean tensile strength is calculated at 232.9 kN (52356 lbs), and standard deviation is 4.9 kN (1102 lbs). The lower deviated ultimate tensile strength (mean minus two standard deviations) is calculated at 223.1 kN (50153 lbs). Based on a safety factor of at-least 3, as specified in DEP 31.40.10.20-Gen, the maximum allowable design tensile load is calculated at 74 kN (16635 lbs), i.e. 6% lower than the Manufacturers specified value.

It is concluded that the 4.5” diameter, 1500 psi Fiberspar spoolable pipe is qualified for the Manufacturers specified design tensile load of 79 kN (17840 lbs), in compliance with DEP 31.40.10.20-Gen.

6.5 1000 hr qualification test

To demonstrate long-term pressure strength capability, 1000 hr qualification tests are required, in accordance with ASTM D1598, at a test pressure of 2.2 times pipe design pressure, at the design temperature.

6.5.1 Test procedure

Two replicate 4.5”, 1500 psi, Fiberspar pipe (+joint) samples have been 1000 hr pressure tested according to ASTM D 1598, at 227 bar (3292 psi), and 60 ºC (140 ºF), in accordance with DEP 31.40.10.20-Gen. A photograph showing the 1000 hr test set-up is presented in Figure 7.

6.5.2 Test results

The pipe (+joint) test samples successfully survived the test pressure of 227 bar (3292 psi), for 1000 hrs, i.e. the pipe samples did not leak, loose pressure, or lost structural integrity.

6.6 Quality control tests

6.6.1 Dimensions

According to DEP 31.40.10.20-Gen, the dimensions of produced spoolable pipe should meet the baseline values (qualified product), as specified by the Manufacturer.

The dimensions measured for the random selected 4.5” diameter, 1500 psi Fiberspar spoolable pipe test sample, also compared with the Manufacturers specified values, are summarized in Table 2.

Table 2 *Summary of dimension measured for Fiberspar spoolable pipe test samples*

Dimensions	Baseline value	Test sample
Outside diameter	121.7 mm 4.79 inch	122.4 mm 4.82 inch
Inside diameter	101 mm 3.98 inch	101.8 mm 4.00 inch
Thickness liner	5.3 mm 0.207 inch	5.3 mm 0.207 inch
Thickness GRE wall	5.1 mm 0.200 inch	5.2 mm 0.205 inch

The measured dimensions for the random selected test sample are within acceptable limits, when compared to Manufacturers specified values.

6.6.2 Fibre content GRE pipe wall

As specified in DEP 31.40.10.20-Gen., the fibre content (mass percentage) of the reinforced GRE pipe wall should be determined in accordance with ISO 1172, and should be within +/- 5% of the mean value quoted by Manufacturer, or within the range 70% to 82 %, as specified in ISO 14692.
The glass content of the GRE pipe samples was determined at 82% (by weight), in compliance with ISO 14692.

6.6.3 Degree of cure GRE pipe wall

As specified in DEP 31.40.10.19-Gen, the degree of cure (T_g) should be determined by one of the following methods:

- Differential Scanning Calorimetry (DSC) according to ISO 11357-2;
- Thermal Mechanical Analyses (TMA) according to ISO 11359-2;
- Heat Distortion Temperature (HDT) according to ISO 75-1.

The T_g should be at-least 30 °C above the design temperature of the pipe. If the T_g is less than the minimum value (minus 5 °C tolerance) specified by the manufacturer, the component should be rejected.

The degree of cure (T_g), specified by Fiberspar for the anhydride cured “modified” (proprietary) Bisphenol-A Epoxy resin of the GRE pipe wall, is 115 ºC (239 ºF).

The degree of cure (T_g) for the Fiberspar test pipe has been determined by Thermal Mechanical Analyses (TMA), and was found at 110 ºC (230 ºF), see Figure 8.

It is concluded that Tg is within 5 °C tolerance of the Manufacturers specified value, and more than 30 °C above the Fiberspar design temperature of 60 °C (140 ºF), i.e. in compliance with the Shell DEP requirements.

6.6.4 Adhesion strength liner-GRE

A strong bond between the thermoplastic (HDPE) liner and GRE wall is desirable in order to (i) provide maximum liner collapse strength, e.g. when vacuum occurs, and (ii) prevent liner disbonding during small radius bending, e.g. during spooling operation.

6.6.4.1 Shear strength

The shear strength between the HDPE liner and GRE wall for the 4.5” diameter, 1500 psi Fiberspar spoolable pipe has been measured in accordance with DIN 53796, Method A and Method B.

For DIN 53796 - method A, the shear strength is determined using a ring section cut from the Fiberspar pipe, height 20 mm (0.79 inch) and measuring the maximum axial shear load, required to disbond the complete “liner-ring” from the GRE wall. A photograph, showing the surface after shear failure has occurred for the ring shape test specimen, is presented in Figure 9. From Figure 9, it is observed that there are a significant amount of fibres, still bonded to the HDPE surface, indicating a strong bond between the HDPE liner and GRE pipe wall.

For DIN 53796 - method B, the shear strength is determined using again a ring section cut from the Fiberspar pipe, height 20 mm (0.79 inch) and measuring the maximum axial shear load, required to disbond a “segment” of the liner from the GRE wall, see Figure 10. Again it is observed that there are a significant amount of fibres, still bonded to the HDPE surface.

The measured shear strength values, compared with the strength, as specified by DIN 53796, are summarized in Table 3.

Table 3 *Summary of “liner-GRE” shear strength for Fiberspar spoolable pips*

Test procedure	**Measured**	**Specified strength DIN 53796**
DIN 53796 - method A	8.4 MPa (1218 psi)	3.0 MPa (435 psi)
DIN 53796 - method B	7.8 MPa (1131 psi)	2.5 MPa (363 psi)

It is concluded that the shear strength between the HDPE liner and GRE pipe wall of the Fiberspar spoolable pipe is in excess of the value, specified by DIN 53796, i.e. strong bond between the liner and GRE pipe wall.

6.6.4.2 Pull-off strength

To determine the pull-off adhesion strength, tests have been performed in accordance with ASTM D4541, using a self-aligning adhesion tester, and 20 mm (0.79 inch) diameter dolly (Figure 11). After the pull-off tests, the fracture surface was inspected visually to determine type of failure, i.e. adhesive failure (interface), or cohesive failure (within the composite). A photograph showing the typical “cohesive” type fracture surface is presented in Figure 12.

From the experiments (seven), the average pull-off strength is calculated at 3.6 MPa (522 psi), and standard deviation 0.7 MPa (102 psi). Generally adhesion strength between HDPE, and other polymer materials, including GRE, is poor, typically lower than 1 MPa (145 psi), and therefore it is concluded that the bond between the HDPE liner and GRE wall for Fiberspar pipe is relatively strong.

6.6.5 Microscopic investigation

Samples were cut from the burst and 1000 hr tested Fiberspar pipes, and inspected using an optical microscope. The cross section of the pipe wall after burst and 1000 hr testing is shown in Figure 13, and Figure 14, respectively, and shows voids, which are uniformly distributed.

The average void content of the GRE structural wall is 5% to 6%, typical for filament wound pipe. Detail of the GRE pipe wall, showing voids, and minor matrix cracking, is presented in Figure 15. Significant micro cracking, as expected in the GRE wall of burst tested pipes, could not be observed (Figure 13), indicating the use of a relative high-flexible resin for Fiberspar spoolable pipe.

6.6.6 Materials identification

Materials used for the Fiberspar spoolable pipe are the following:

- Resin: proprietary blend (FS111), a modified Bisphenol A Epoxy resin, and anhydride hardener;
- Reinforcement fibres (roving): continuous electrical grade glass-fibres (E-glass), in a single tow, and 0.45% sizing (by weight). More details about the glass-fibre material, are given in Appendix 2;
- Liner: high-density polyethylene, L-HDPE, density 0.941 to 0.959 g/cm^3, grade Novapol HD-207-H, or Solvay Fortiflex HDPE K44-15-122. More details about the HDPE liner material, are given in Appendix 2.

7. Installation

7.1 General

For installation of spoolable fibre-reinforced plastic pipe, experienced and qualified installation contractors should be used. General guidelines on installation, and qualification of non-metallic pipe joiner, supervisor, and inspector, are given ISO 14692-4.

Installation guidelines, given by the Manufacturer should be followed. Manufacturers guidelines for the installation of Fiberspar GRE spoolable pipe are given in Appendix 1.

7.2 Above ground (surface) systems

For above ground (surface) installation, external protected, e.g. HDPE jacketed spoolable pipe should be used to protect against impact, sharp objects, abrasion, etc. According to the Manufacturer, it should not be allowed for vehicles to drive over Fiberspar spoolable pipe, and consequently crossing points may be required.

7.3 Buried systems

7.3.1 Trenches

The trench depth should be sufficient to provide a minimum depth of cover, including the thickness of pre-padding. In cold climate regions, the trench depth should be deeper than the lowest 'frost' level of the soil.

Changes in direction, in the vertical as well as the horizontal plane, may be achieved by bending providing the bend radius is greater than the Manufacturer’s specified minimum bending radius.

Wherever possible the pipe should be installed on undisturbed soil to avoid potential problems with differential settlement. Where this is not possible, e.g. at excavations for boring equipment at cased crossings, attention should be given to compacting the trench bottom using backfill material. In this case it is recommended to backfill in small amounts, compacting each layer before further back-fill in order to maintain sufficient trench depth, and to provide the minimum specified depth of cover.

Before the pipe is laid in the trench, sharp objects e.g. rocks, bricks etc., should be removed and pre-padding laid, as discussed in Section 7.3.3.

7.3.2 Excavation

The trench should be excavated in order to provide the minimum specified depth of cover. Minimum depth of cover should be measured from the top of the pipe to the top of the undisturbed surface of the soil, or top of graded working strip which ever is smallest. Fill material in the working strip should not be considered to add to the depth of cover. However, the surface of fill material placed to fill low points to accommodate pipe bending limitations may be used to determine depth of cover, to be agreed by the Principal.

Excavation and grade of the trench should be sufficiently deep and wide to provide a minimum of 500 mm (20 inch) working space on both sides of the pipe (where jointing is done in the trench) and space for a minimum of 150 mm (6 inch) of padding material after compaction all around the pipe and for the continuous length of the pipeline.

The trench profile after excavation should be such that the radius of curvature in any plane is greater than the minimum allowable bending radius specified by the pipe Manufacturer, and local high and low points in the trench bottom should be levelled off to provide a smooth continuous profile.

The trench bottom and sides should be kept free of rocks, projections and other hard objects at all times before and after stringing of the pipe. Any such items encountered should be removed prior to pre-padding operations so that the pipe is not damaged.

Where the pipe crosses other piping, pipelines, sewers, water lines, cables, conduits or other underground structures of any kind, the trench should be excavated and graded to such a depth and in such a manner that the top of the pipeline will be minimum 500 mm (20 inch) below the bottom of the underground structure crossed.

In the case of a single pipeline to be laid in the trench, the minimum trench width should be at least the minimum outside diameter of the pipe plus 300 mm (i.e. 150 mm on each side of the pipe) unless otherwise agreed with the Principal. In the case where more than one pipeline is to be laid in the trench, the separation between each pipeline should be a minimum of 150 mm (6 inch), with a further 150 mm required between the trench sides and first and last pipelines.

7.3.3 Pre-Padding

The bottom of all trenches should be fully pre-padded throughout their length before lowering in or jointing in the trench. The pre-padding should provide a minimum compacted padding thickness of 150 mm (6 inch) below the invert of the pipe.

The installed padding material should be free of sharp rocks, stones, metal parts, roots, clods, etc., and without sharp edges, which could damage the pipe.

Base materials from which pre- and post-padding material will be produced should consist mainly of sandy material. More than 75 % by weight of the screened material should have a grain size between 0.06 mm (0.0024 inch) and 3.0 mm (0.12 inch) and no more than 25 % by weight should have a grain size between 3.0 mm and 5.0 mm.

Near residential areas and roads, padding material should be dust free, e.g. 'coarse sand' with a minimum grain size of 0.6 mm (0.024 inch) in order to avoid inconvenience or danger to the environment.

7.3.4 Post-padding

Prior to back filling, the pipe should be covered with a layer of post-padding material to provide a thickness of 150 mm (6 inch) over the pipe.

7.3.5 Backfilling

The pipeline trench should be backfilled prior to the system hydro test except for the test-ends and joints. These exposed sections should be kept as short as possible.

The material used for initial backfill should be loose material not greater than 50 mm (2 inch) in diameter. The fill material should be placed in such a manner as to cause minimum disturbance to the sand padding and to avoid excessive penetration (more than 150 mm) of rocks into the sand layer. The initial backfill should be placed in the trench to a level slightly above the surrounding ground.

Where the trench has been excavated through or along driveways, walks, roads, at live stock passageways, etc, the initial backfill should be thoroughly compacted by mechanical tamping of the material into place. The surface of such areas should be stabilized and/or restored to its original condition, to be agreed by the Principal, and the responsible authorities.

7.3.6 Cased crossings

If a section of pipe is to be installed in a casing (e.g. at a road or rail crossing), it should be subjected to a leak tightness test prior to installation. During insertion of the pipe into the casing, care should be taken to ensure that the pipe does not contact the outer casing to avoid scraping and external damage.

Three insulators/spacers per pipe joint should be securely attached to the pipe section before it is inserted into the casing. Following installation in the casing, any bends required to bring the pipe elevation up to the normal pipeline elevation should be installed together with at least one full pipe length on either side. This complete section should then be subjected to a full hydrostatic pressure test.

Following successful completion of the hydro test, the ends of the annular space between the carrier pipe and casing should be sealed by a rubber manchet or plug. Filling the entire annular space with e.g. polyurethane foam may also be considered.

7.4 Minimum bend radius

The bend radius during installation shall not be less than the manufacturer's specified minimum value. The minimum allowable bend radius for Fiberspar spoolable pipe, as specified by the Manufacturer, is based on a maximum bending strain of 3.5%, regardless of pressure rating, and summarized in Table 4.

Table 4 *Minimum specified bend radius for Fiberspar spoolable pipe*

Pipe size	Minimum bend radius
< 2.5 inch	0.5 - 1.0 meter (1.6 - 3.3 feet)
2.5 - 4.5 inch	1.0 - 2.0 meter (3.3 - 6.6 feet)
4.5 - 5.5 inch	2.0 - 2.5 meter (6.6 - 8.2 feet)

8. System hydro testing

8.1 General

Upon completion of installation, the spoolable pipe should be hydrostatically pressure tested. Preferably, the system should be installed such that smaller parts of a system can be pressure tested separately and at the earliest opportunity during installation.

8.2 Preparation

A formal risk assessment should be carried out prior to the system hydrotest. All supports, guides, etc, should be in place prior to pressure testing. Temporary supports and restraints should be added if required. Pipe systems containing check valves should have the source of test pressure located on the downstream side. Threaded connections and the bolts of flanged joints should be made up to the correct torque prior to pressure testing.

8.3 Pressure testing

Water should be admitted at a suitable point in the pipe system and provision should be made for bleeding the air at high(er) points (e.g. loosening of flange connection). Any compressed air in the system may give erroneous results and all necessary measures should be taken to remove air during filling, including control of back-pressure, a steady, controlled filling rate, the use of a break tank and of at least two foam pigs with water in front and in between. If possible, the line should be filled from the lower end. Venting should be carried out repeatedly at points in the test section where air might accumulate. The filling pig speed should be controlled at approximately 0.6 m/s (2 feet/s) and should not exceed 1.8 m/s (6 feet/s).

After filling, temperature stabilization is required before commencing pressurization. This may take anything between 6 and 48 hours, depending on the temperature difference between the fill water and the soil surrounding the pipe, the type of soil, air temperature etc.

Once the temperature has stabilized, a strength (integrity) test should be carried out at a pressure equal to 1.5 times the pipe(line) design pressure and held for a minimum of 4 hours, and no longer than 6 hours. The rate of pressurization should not exceed 2 bar per minute.

Following successful conclusion of the strength test, a leak tightness test should be carried out at a pressure equal to 1.1 times the system design pressure. The test pressure should be held for a minimum of 24 hours during which time no water should be added to or removed from the pipeline. During the test, the pressure should be recorded continuously and deadweight tester readings should be recorded every 30 minutes.

In the event of a pressure drop during the leak tightness test, a "step-test" should be performed. In this test, the test section should be re-pressurized to the leak tightness test pressure (i.e. 1.1 times design pressure) and after each hour the pressure should be recorded and the section re-pressurized by adding water. The quantity of water required to bring the section back up to test pressure should also be recorded. This should continue for a further period of 24 hours. If the quantity of water added each hour shows a decreasing trend, then it may be considered that the pipeline is tight. If the quantity of water added remains constant, then it must be assumed that the pipeline is not leak tight.

Any leaking should constitute a defect and the test should be terminated and a repair effected. The test procedure should then be repeated.

Over-torque of threaded joints, or flanges to stop leaks should not be permitted. Leaking joints, or flanges should be remade and retested. If leakage still occurs, threaded joints, or flanges must be replaced.

8.4 After completion of tests

After controlled depressurization, all remaining vent and low point drain valves should be opened and the system thoroughly drained. Temporary blinds and other equipment installed for testing should be removed on completion of the test. Test pressure gauges should be removed and any temporary vent and drain facilities installed for testing are to be removed.

9. Discussion

It is rather disappointing to conclude that majority of the approached Manufacturers of spoilable pipe have not designed and qualified their products in compliance with DEP 31.40.10.20-Gen, and that only one Manufacturer, i.e. Fiberspar, was considered “conditionally” qualified. However, it was positive that the Manufacturers showed willingness to comply for future Shell projects.

Based on the successful completion of the qualification and quality control “confirmation” tests, Fiberspar spoolable pipe is now qualified for the SEPCO envisaged application, in compliance with Shell DEP 31.40.10.20-Gen., i.e. qualified for maximum design pressure of 1500 psi (103 bar), maximum design temperature of 60 ºC, and diameter up to 4.5".

Based on (i) microscopic investigation of the GRE pipe wall, (ii) measurement of the adhesion strength between the HDPE liner and GRE pipe wall, and (iii) exceeding most of the minimum requirements, as specified in DEP 31.40.10.20-Gen, it is concluded that the quality of the Fiberspar spoolable pipe product is high.

For competitive bidding, it is recommended to encourage also other manufacturers of spoolable pipe to qualify their products in compliance with DEP 31.40.10.20-Gen.

10. Conclusions

(a) Majority of the approached Manufacturers have not designed and qualified their products in compliance with DEP 31.40.10.20-Gen. However, the Manufacturers showed willingness to comply for future Shell projects;

(b) Based on successful completion of qualification and quality control confirmation tests, Fiberspar spoolable pipe is qualified for the SEPCO envisaged Applications 1 and 2, in compliance with Shell DEP 31.40.10.20-Gen., i.e. maximum design pressure of 1500 psi (103 bar), maximum design temperature of 60 ºC, and diameter up to 4.5".

Amsterdam, March 2007
wk

Figure 1 *Photograph showing the Fiberspar test pipes "as received*

Figure 2 *Photograph showing rupture of the Fiberspar pipe after burst test*

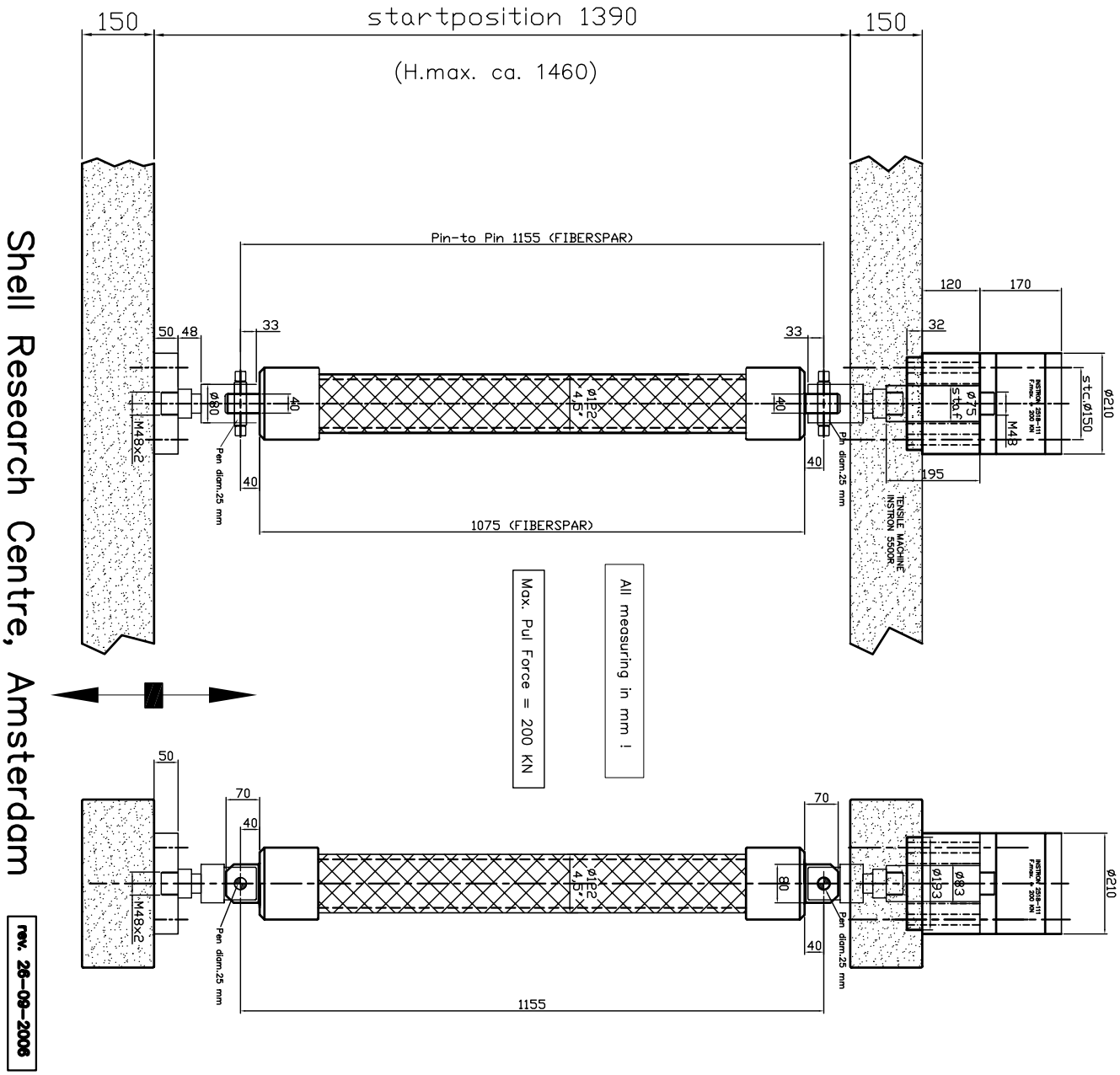


Figure 3 *Sketch showing the dimensions of the tensile test arrangement*

Figure 4 *Photograph showing the tensile test set-up*

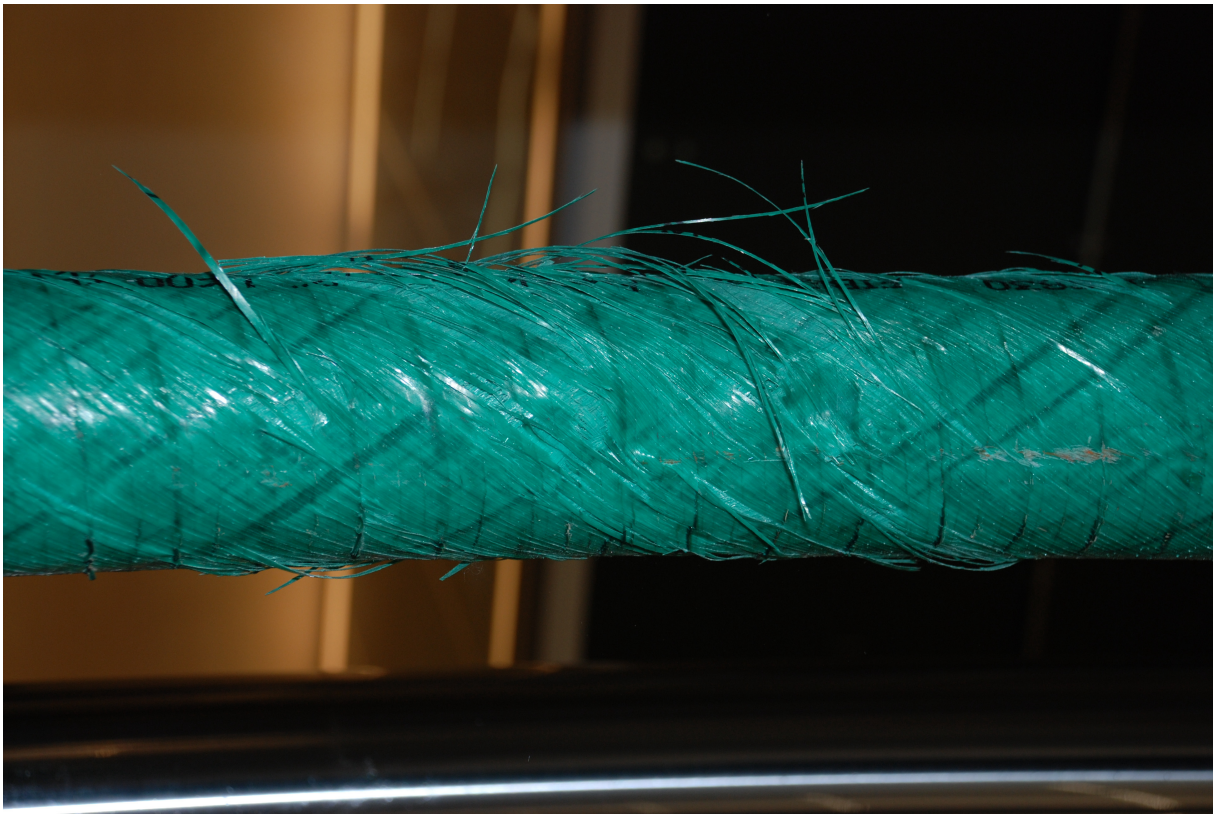


Figure 5 *Photograph showing the failure mode of Fiberspar pipe during tensile test*

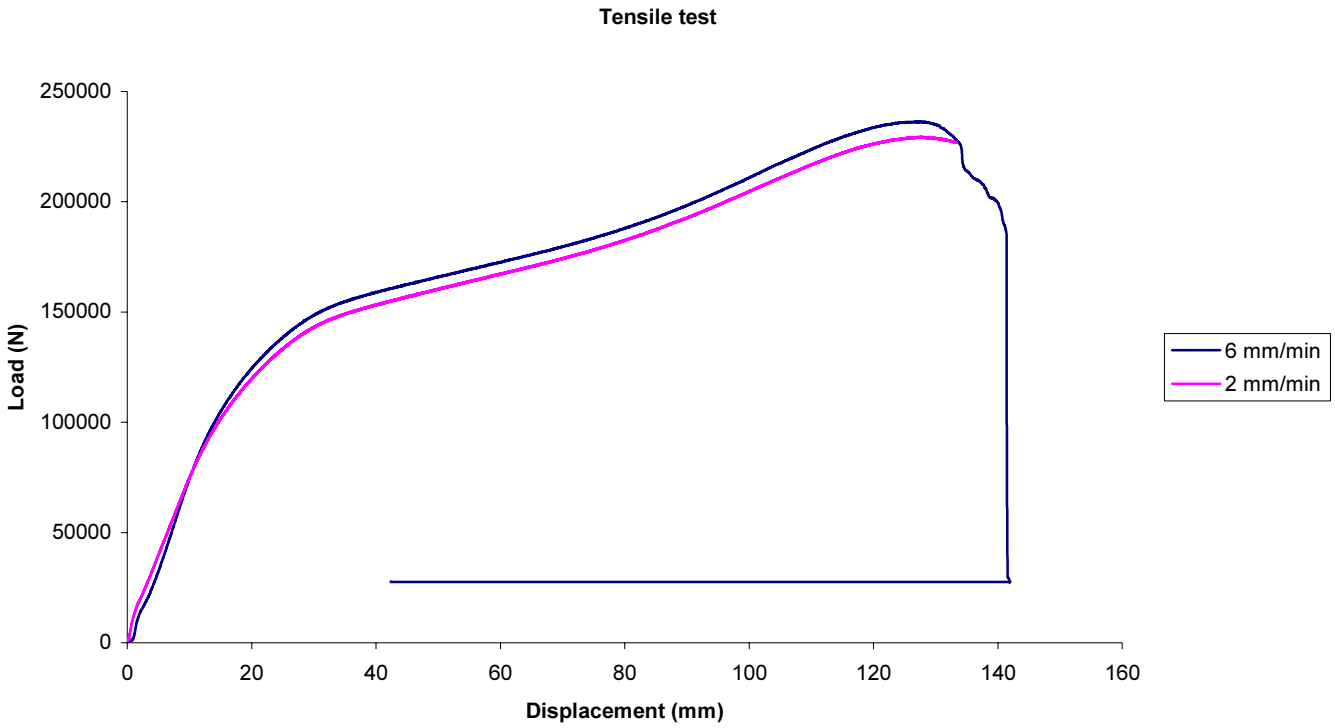


Figure 6 *Tensile load versus displacement curve for Fiberspar pipe*

Figure 7 *Photograph showing the 1000 hr test set-up for Fiberspar pipe*

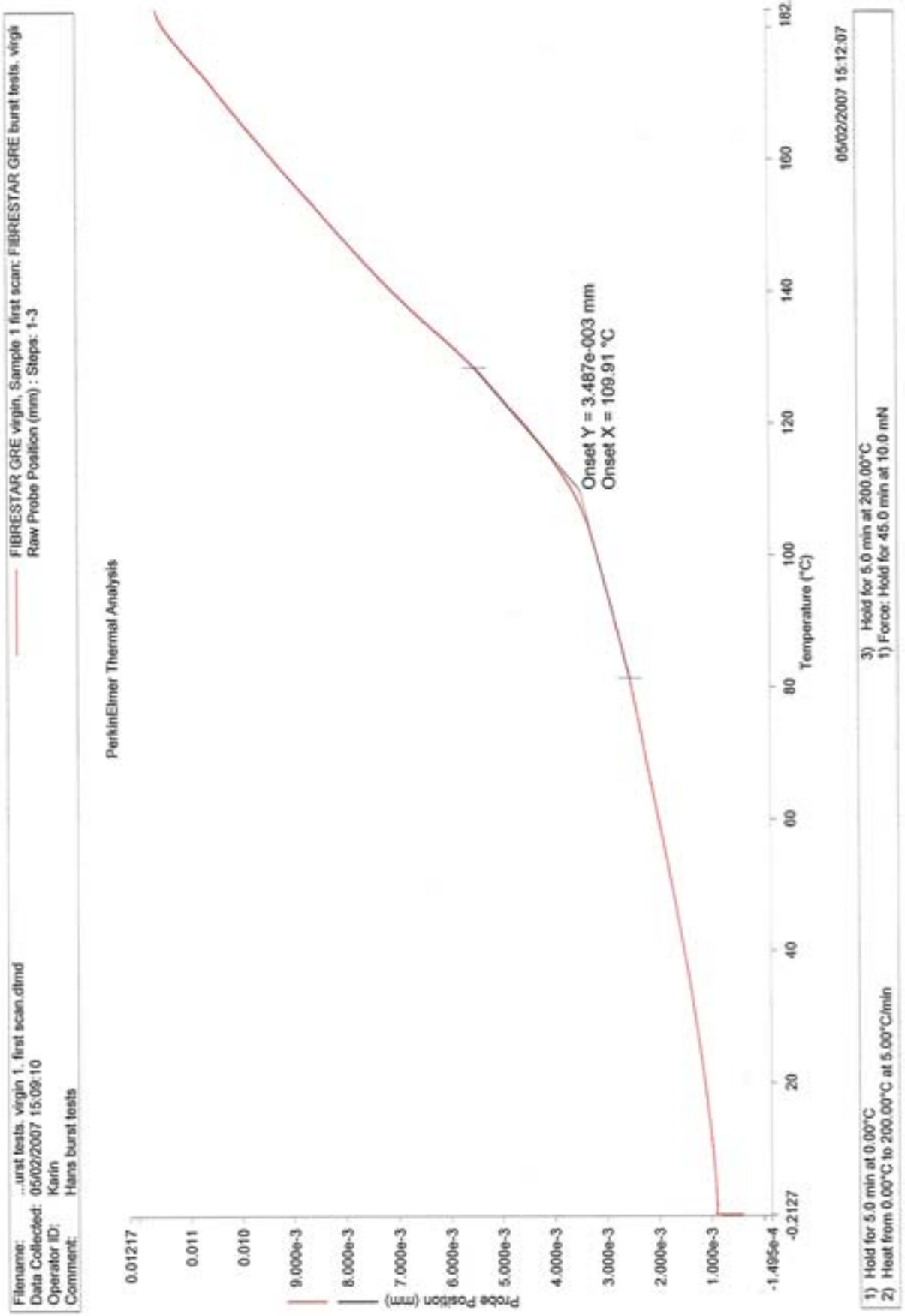


Figure 8 *Thermal Mechanical Anaylses (TMA) graph for GRE wall, Fiberspar pipe*

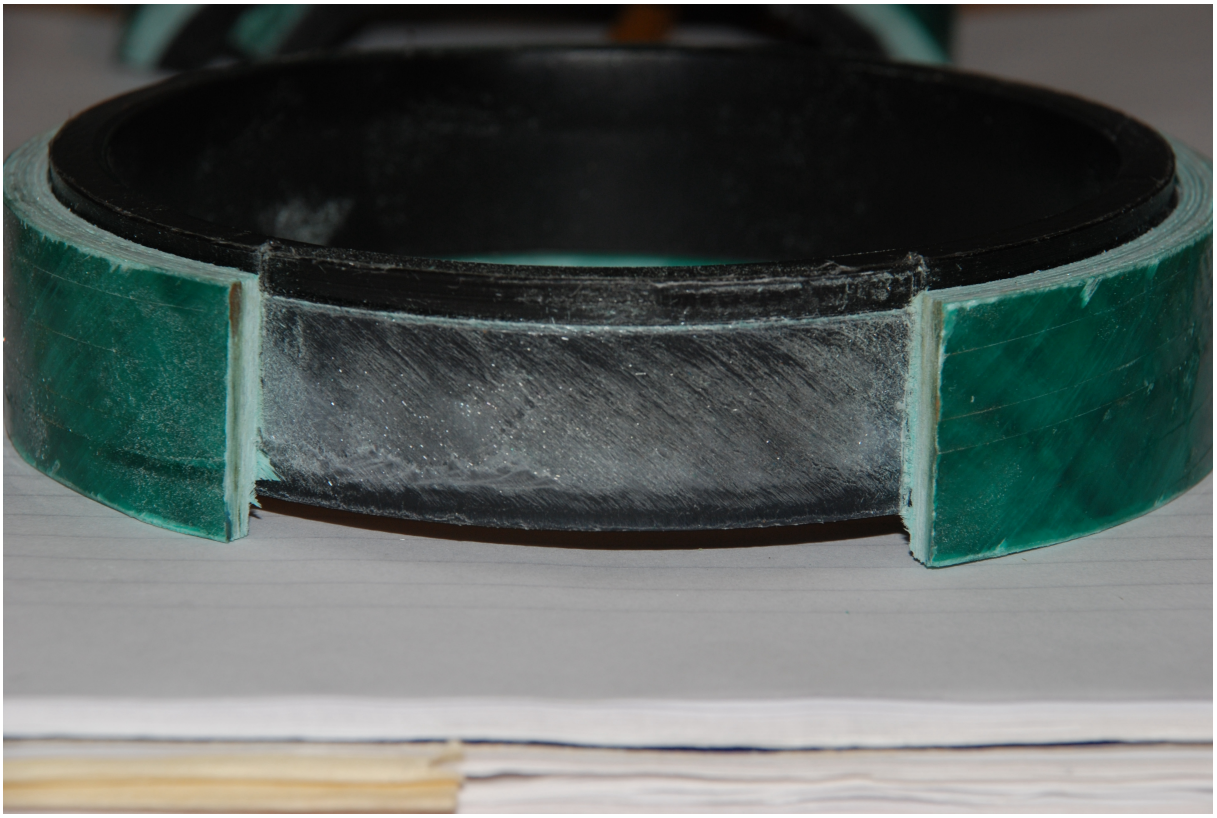


Figure 9
Photograph showing the liner surface after shear failure of Fiberspar ring specimen

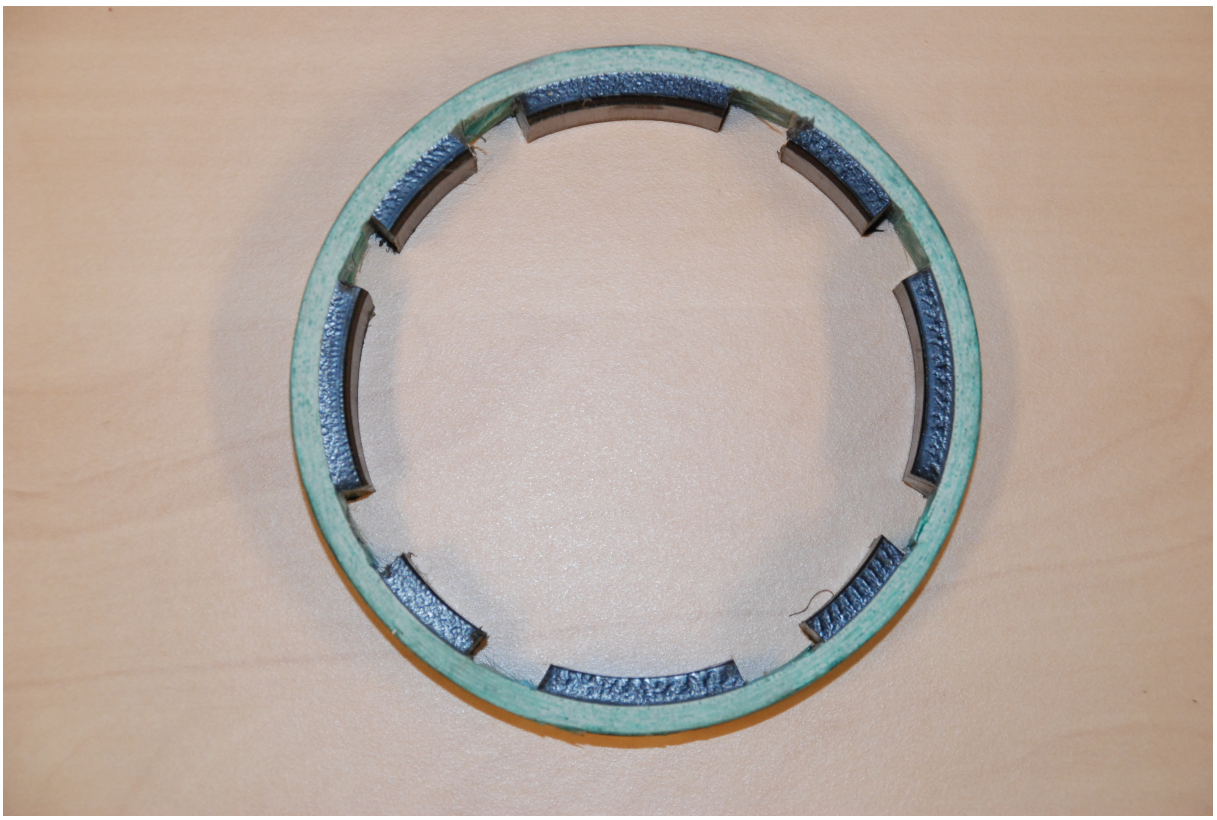


Figure 10 *Photograph of Fiberspar segmented liner specimen*

Figure 11 *Photograph showing the adhesive bonded dollies, used for pull-off test*

Figure 12 *Photograph showing the fracture surface after pull-off test*

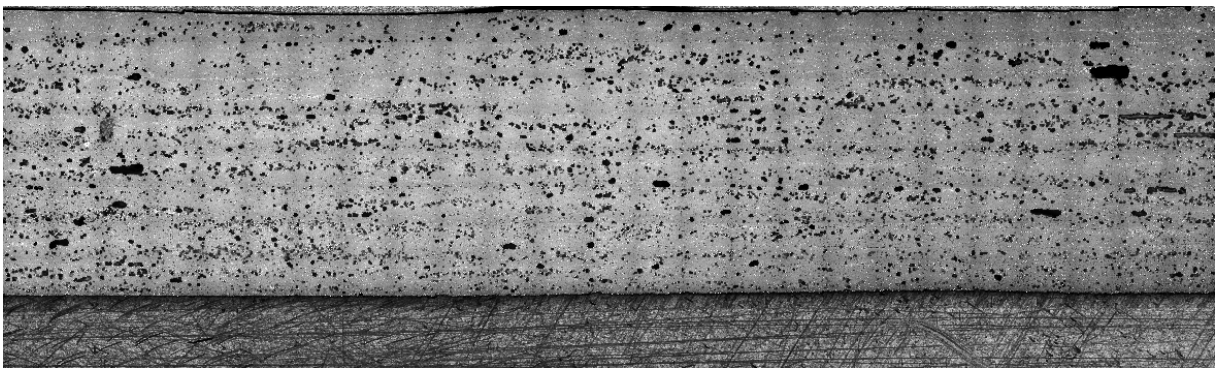


Figure 13 *Cross-section of Fiberspar pipe wall, after burst test*

Figure 14 *Cross-section of Fiberspar pipe wall, after 1000 hrs test*

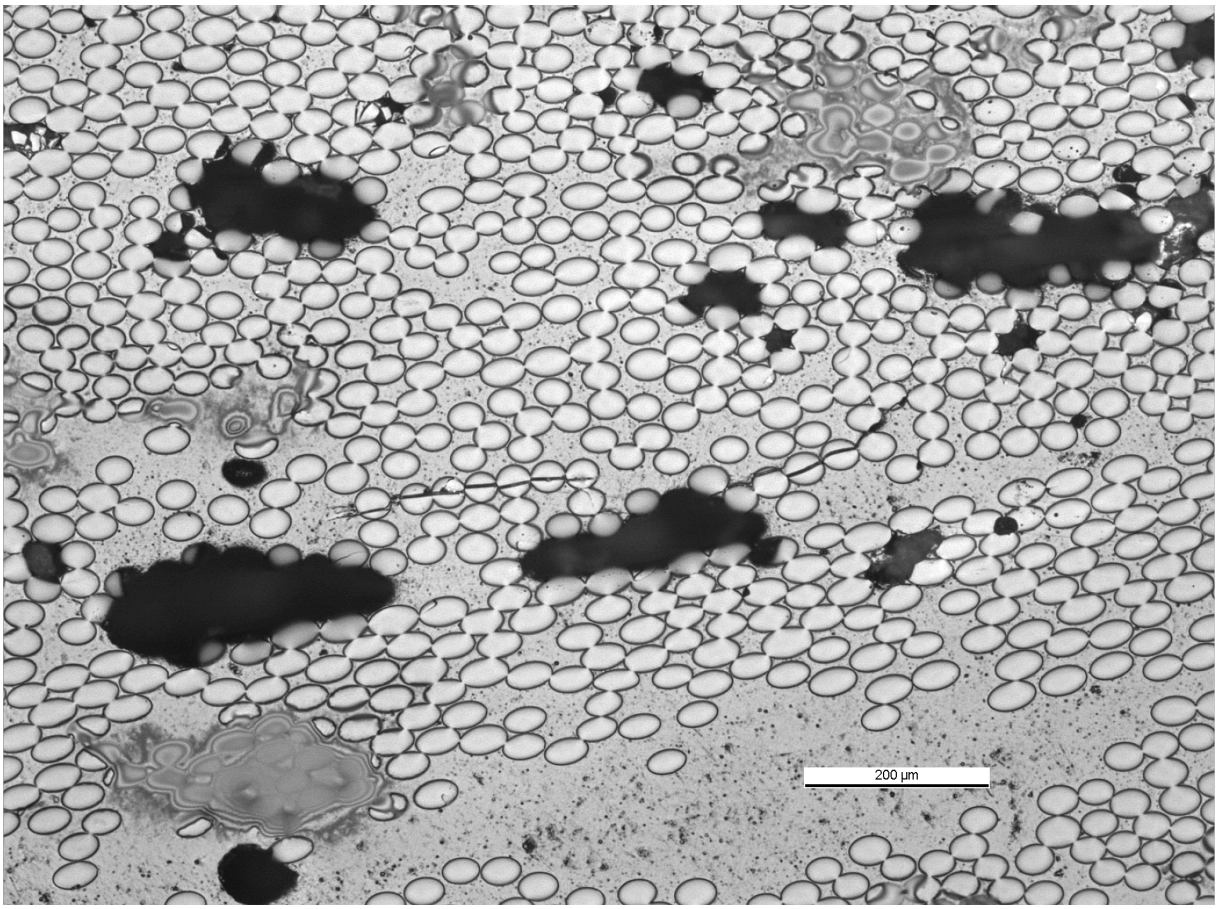


Figure 15 *Microstructure of GRE wall of Fiberspar pipe wall, after burst test*

Appendix 1 Fiberspar product datasheet and installation guide

FIBERSPAR

FS LP 4 1/2" 1,500 (E)

4 1/2 Inch Nominal, 1,500 Series Fiberspar LinePipe w/HDPE Pressure Barrier

Product Data Sheet (Imperial Units)

ASTM 2996 Designation: RTRP-11HZ1-4112

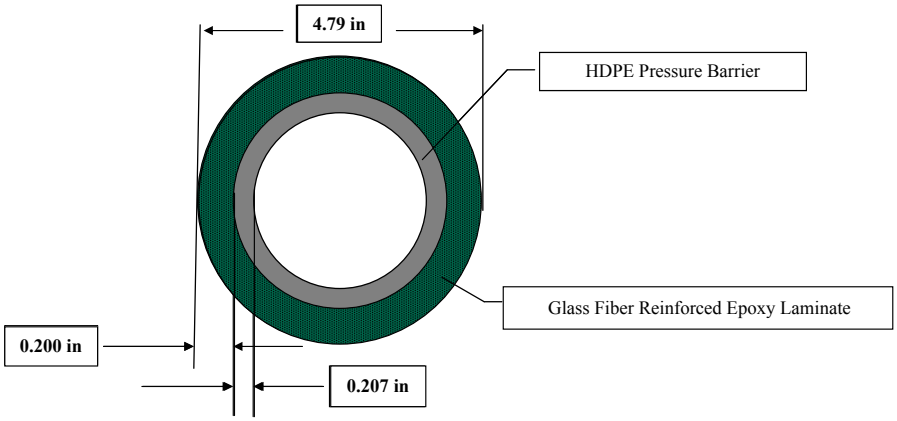
Fiberspar s/n: LEEN045024

Physical Properties:

Geometry		**Tensile Modulus**	
Outside Diameter (in)	4.79	Axial (psi)	8.69E+05
Inside Diameter (in)	3.98	Hoop (psi)	1.12E+06
Inside Flow Area (in^2)	12.43	**Poisson's Ratio**	
Total Wall Thickness (in)	0.41	Major	0.49
C/S Area (in^2)	5.61	Minor	0.63
Linear Weight		**Thermal Exp. Coeff.**	
Linear Weight - Air (lb/ft)	3.61	Axial (in/in -°F)	1.26E-05
Linear Weight - Water (lb/ft)	1.18	Hoop (in/in -°F)	7.33E-06
Net Density (lb/in^3)	0.054	**Thermal Conductivity**	
Flow Coefficients		(BTU/hour/ft^2- in/°F)	1.92
Hazen - William's	150	**Resin T_g**	
Darcy-Wiesbach	0.0004	(°C)	125°
Manning	0.009	(°F)	257°

Mechanical Performance:

Maximum Operating Temperature	**140 °F**	
Minimum Operating Temperature	**-29 °F**	**78 °F**	**140 °F**
Max. Recommended Operating Pressure (psi)	1,500	1,500
Nominal Ultimate Burst Pressure (psi)	6,000	5,100
Maximum Recommended Tensile Load (lbs)	17,840	15,000
Nominal Ultimate Tensile Load (lbs)	44,600	37,500
Nominal Ultimate Compressive Load (lbs)	-50,100	-41,000
Nominal Ultimate Collapse Pressure (psi)	750	750
Minimum Operating Bend Radius (in)	80	80
Minimum Spooling Diameter (in)	136	136



Fiberspar LinePipe LLC www.fiberspar.com Rev: 1.0
(713) 849-2609 February 23, 2006

Table 1-1 *Product datasheet for 4.5", 1500 psi Fiberspar spoolable pipe*

FS LP 4 1/2" 1,500 (E)

4 1/2 Inch Nominal, 1,500 Series Fiberspar LinePipe w/HDPE Pressure Barrier

Product Data Sheet (Metric Units)

ASTM 2996 Designation: RTRP-11HZ1-4112

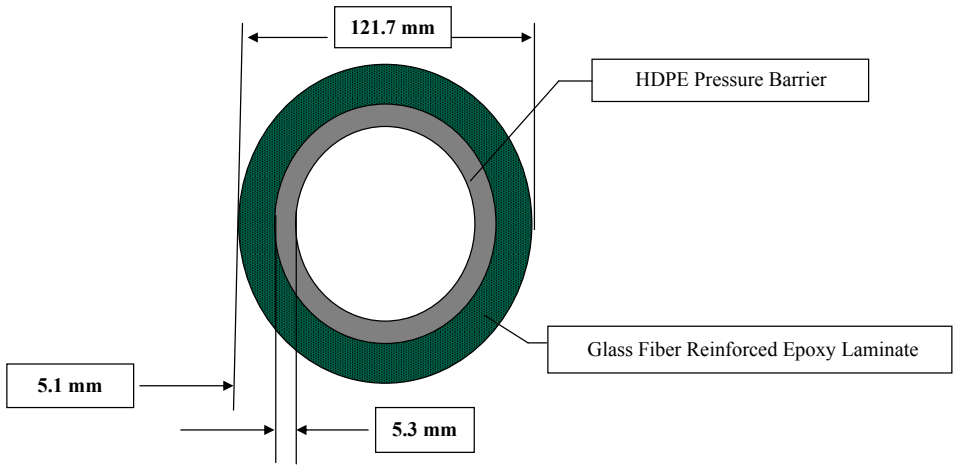
Fiberspar s/n: LEEN045024

Physical Properties:

Geometry		**Tensile Modulus**	
Outside Diameter (mm)	122	Axial (MPa)	5,991
Inside Diameter (mm)	101	Hoop (MPa)	7,734
Inside Flow Area (mm^2)	8,018	**Poisson's Ratio**	
Total Wall Thickness (mm)	10.3	Major	0.49
C/S Area (mm^2)	3,617	Minor	0.63
Linear Weight		**Thermal Exp. Coeff.**	
Linear Weight - Air (kg/m)	5.37	Axial (mm/mm -°C)	2.27E-05
Linear Weight - Water (kg/m)	1.76	Hoop (mm/mm -°C)	1.32E-05
Specific Gravity (g/cm^3)	1.49	**Thermal Conductivity**	
Flow Coefficients		(W/(m -°K))	0.273
Hazen - William's	150	**Resin T_g**	
Darcy-Wiesbach	0.0004	(°C)	125°
Manning	0.009	(°F)	257°

Mechanical Performance:

Maximum Operating Temperature	**60 °C**		
Minimum Operating Temperature	**-34 °C**	**26 °C**	**60 °C**
Max. Recommended Operating Pressure (MPa)		10.34	10.34
Nominal Ultimate Burst Pressure (MPa)		41.4	35.2
Maximum Recommended Tensile Load (kg)		8,090	6,800
Nominal Ultimate Tensile Load (kg)		20,230	17,000
Nominal Ultimate Compressive Load (kg)		-22,730	-18,600
Nominal Ultimate Collapse Pressure (kPa)		5,100	5,100
Minimum Operating Bend Radius (cm)		203	203
Minimum Spooling Diameter (cm)		345	345



FIBERSPAR® LinePipe™

General Installation Guide

Table of Contents
General Installation Guide

A. Introduction to Fiberspar

Fiberspar is the world's leading innovator and manufacturer of spoolable, fiber-reinforced pipe and tubing. The company's proprietary technology (more than 25 US and international patents related to spoolable products) is incorporated into product lines used in a variety of oil and gas field applications.

Fiberspar® LinePipe™ is used in production gathering, injection, and disposal applications. More than 5 million feet of LinePipe have been installed for a wide range of customers in North America, including almost every major operator.

Fiberspar production lines capable of producing 4 million feet of pipe per year

Fiberspar LinePipe is manufactured using an inner thermoplastic pressure layer reinforced with high-strength glass and/or carbon fibers embedded in an epoxy matrix. The result is high-pressure pipe immune to corrosion, with few joints, and rapid deployment potential. In 2002, the manufacturing plant was moved from Wareham, Massachusetts, to its current location in Houston, Texas.

The Company now has Sales offices in Houston, Texas, and Calgary, Alberta, and Field Operational Centers in most of the active oil and gas locations in North America, including Central Texas, South Texas, Rocky Mountains, Alberta and South Saskatchewan.

LinePipe inventory at plant

Fiberspar uses proprietary technology to manufacture on a continuous, linear processing line. All key operations are carried out in house, including, liner extrusion, pipe fabrication, testing and pipe jacketing. An ISO 9001-compliant quality system with complete testing laboratories and expert staff support new product development and quality assurance testing.

Today, Fiberspar is the leading designer and manufacturer of continuous-length, spoolable fiber-reinforced pipe used in the oil and gas industry. And, with seventeen years in the business, Fiberspar is one of the most experienced.

More information on Fiberspar's products and services can be found at the company's website: **www.fiberspar.com.**

LinePipe ready for transport to Alberta, Canada.

B. Product Information

This manual is applicable to the installation of FIBERSPAR® LinePipe™ (FS LP) family of products. FS LP products are advanced composite line pipes produced in continuous lengths of up to 5 miles. They are designed for storage, delivery and deployment from spools.

This General Installation Guide provides is intended for general information on application and installation of systems using Fiberspar LinePipe. It is not an Installation Manual.

The *"FIBERSPAR LinePipe Engineering Guide"* provides engineering and design data applicable to the FS LP products and is available on application at www.fiberspar.com.

1. Product Identification

A Product Identification Number or PIN identifies FIBERSPAR® LinePipe™. The PIN takes the form:

FS LP BB b/b CCCC (D)

Where:

FS = FIBERSPAR®

LP = LinePipe™

Note: The letter "J" which designates jacketed product may follow the "LP."

BB = Nominal Outside Diameter (in whole inches)

b/b = Nominal Outside Diameter (in fractional parts of an inch)

CCCC = Maximum Allowable Operating Pressure (MAOP), psi

(D) = Pressure Barrier Material Code

Current Material codes are "E" for HDPE and "X" for PEX (cross-linked PE)

2. Connector Identification

The primary connectors are available in two basic types, the Service-End Connector and the Pipe-to-Pipe Connector. (See Figures A.1 and A.2 These are identified with a Product Identification Number that takes the form:

CHEXxYZz

Where:

C = Connector

H = Design Revision

E = Series
- B = B Series
- C = C Series
- D = D Series
- E = E Series
- G = G Series

Xx = Size (Nominal Outside Diameter)
- X= whole inches
- x = decimal parts of an inch

Y = End Termination:
- W = Flanged Assembly
- L = NPT Threaded Assembly

Zz = End Termination Size
- Z = Nominal Pipe Size in Inches
- z = ANSI Flange Rating
  - 0 = 150#
  - 1 = 300#
  - 3 = 900#
  - 4 = 1500#

Service-End Connector Components

Pipe-to-Pipe Connector Components

3. Certified Installers

FIBERSPAR requires that a Fiberspar Certified Installer supervise all installations of Fiberspar LinePipe. To attain certified status, installers are required to attend a Fiberspar training class, and work under direct supervision of a Certified Installer for a number of installations. To maintain Certified Installer status, the installer must install Fiberspar LinePipe on a frequent basis, maintain an updated manual and attend refresher courses as required. Certified Installer status will lapse for any individual who has not installed Fiberspar LinePipe in the preceding 6 months.

C. Storage and Handling

1. Packaging

FS LP is packaged on spools for transport, storage and deployment. The spools are fabricated from steel or wood and often weigh more than the FS LP product which is on the spool.

Pipe is wrapped around the spool drum and in layers to the desired length. The outermost layer should be at least 1 inch below the spool flange. All pipe is hydro-tested on the spool at the factory and although care is taken to remove water, spools of pipe may contain small amounts of water that is not practical to remove.

CAUTION: FS LP wound on spools has some stored energy. Ensure that the pipe end is restrained during all operations to avoid rapid release of this energy and potential injury to personnel and damage to pipe and equipment.

Spools of FS LP Ready for Transport

2. Handling

Most jobs staged from local deployment areas do not require the handling and lifting of full spools at location. Specialized equipment is used which allows the technician to deploy the LinePipe directly from the transport vehicle. However, on larger projects its may be necessary to swap spools out of the deployment equipment directly on location. In these cases, care must be taken because spools of pipe tend to be top-heavy loads and must be handled with care to avoid overturning causing harm to surrounding personnel or damage to the pipe and/or spool.

On rare occasions it will be necessary to upright the spools after unloading in order to place them in an upright spooling frame. The preferred method for uprighting a Fiberspar spool is to use a crane equipped with a second line.

CAUTION: Improper handling of spools of FS LP can result in personnel injury as well as damage to the product. Ensure that the lifting equipment used, including straps, slings and spreader bars are in good working condition and are rated for the load and conditions.

The use of a spreader bar and slings is strongly recommended when moving spools with a crane.

In the absence of a crane, two forklifts can be used. The bar is placed through the center hole and a forklift is positioned on each side of the spool. The forks are used to lift the bar raising the spool.

When two forklifts are used to unload a truck, it is recommended that the spool be raised and the truck driven out from under it. Movement of the forklifts must be coordinated to avoid accidents.

CAUTION: Attempting to move the spool by "rolling it" is never recommended. Spools tend to be top heavy and may tip sideways if rolling is attempted. Rolling the spool of FS LP may also damage the pipe that is on the spool.

3. Storage

Spools of product should be stored on level flat surfaces with no protruding objects that might contact and damage the pipe on the outermost layer. It is also recommended when spools are placed on soft surfaces such as dirt or gravel that they be placed on suitable support to prevent the spool flanges from sinking into the ground. The use of 6" X 6" timbers is recommended for this purpose. Block, or otherwise ensure, that the spool cannot roll. **Do not store on slopes**.

If storage is to be for an extended period of time, the pipe should be protected from freezing. Spools of FS LP may contain some water from hydro testing or condensation that can freeze and damage the pipe.

4. Field Transport

When transported in the field for deployment, the spool must be mounted in a suitable spooling frame. Transport should be on a trailer that is as close to the ground as practical. Be aware of any overhead power lines or other overhead obstructions that may come in contact with the spool.

Spool of FS LP on Trailer for Transport and Deployment

CAUTION: Spools make top-heavy loads that are easily overturned. The spool and frame should be mounted as close to the ground as practical and the frame securely chained to the trailer. During transport, speed should be reduced and turns must be negotiated with care.

D. Installation Tools

1. Introduction

FS LP is designed for storage, handling and deployment from spools. The tools and equipment required for any job is somewhat dependent on the method selected for deployment of the FS LP. The following discussion of tools considers the basic tools/equipment required for all installations. Special installations may require additional tools/equipment.

2. Spools

Spools are used to transport and deploy the pipe. Spools are typically 12 ft, 14 ft or 16 ft in diameter, and can be manufactured from steel

or wood. The core diameters of Fiberspar spools are selected to ensure that the bending strains are within allowable limits. Only Fiberspar supplied spools should be used to store, transport or deploy Fiberspar LinePipe. Hydro testing of Fiberspar LinePipe is carried out on specially reinforced spools at manufacturing locations. Fiberspar LinePipe should never be subjected to pressure on a shipping spool.

3. Spooling Equipment

Fiberspar has designed and manufactured spooling equipment suitable for deploying and re-spooling Fiberspar LinePipe. Approved equipment must be used for these operations. Fiberspar engineers should be consulted where any equipment not designed by Fiberspar is to be used for deployment. Fiberspar spooling equipment safely supports the LinePipe during spooling operations, and has speed control and powered braking to ensure that back tension is kept on the spooled pipe at all times.

Fiberspar currently uses three types of spooling frames for field deployment of LinePipe products.

Rim Drive A-Frame. These handle the spools in a vertical position. Smaller diameter spools are typically deployed on this equipment, which consists of an “A-frame” with an integrated drive mechanism that controls the rate of deployment through a hydraulically driven rubber tire in contact with one of the flanges or rims of the spool. It is capable of handling spools from 143” to 147” in diameter and pipe sizes up to 3 ½”-1500, and sufficiently low profile to allow deployment with a loaded reel. One or two of these types of frames can be loaded on a double-drop trailer, transported to location and the pipe deployed without requiring a crane on location. Rim drive A frames are not suitable for re-spooling operations.

Rim-Drive Spooling Frame

Carousel. These are typically used for larger spools. The spool is loaded in the horizontal position. It uses two hydraulically driven rubber tires to control the rate of deployment and also has two level-wind arms which contain the Fiberspar LinePipe on the reel to support the pipe wraps during deployment.

Horizontal Carousel Spooling Frame

This frame is capable of handling reels from 12' up to 19' in diameter and pipe sizes up to 4 ½"-1500. Two of these types of deployment frames can be carried on a step-deck trailer, allowing the installer to deploy up to 9,000' of FS LP 4 ½" – 1500 product without the necessity of a crane being on location. Carousels are not suitable for re-spooling operations.

Chain Drive A Frame. This frame is generally used for larger diameter spools and for re-spooling operations. This type of frame usually requires a crane on location for assembly and is not generally suitable for deployment from a truck trailer. It is a typical "a-frame" type that has a chain and sprocket drive mechanism along with integrated "drive dogs" that engage in the flange of the spool, providing a positive drive system. The spool has to be fitted with a shaft to be fitted into these frames.

Chain-Drive Spooling Frame

All three styles of frames require a hydraulic power supply for operation of the hydraulic drive control motors and the level wind arms on the carousel frames. The hydraulic power supplies are either gasoline or diesel driven and connect to the deployment frames via high-pressure hoses and quick connect couplings.

4. Pulling Devices

For most installations, a suitably powered device is required for pulling the pipe off of the spool. Fiberspar does not normally supply this device, as suitable devices, such as a backhoe, are normally available at location. The pulling device must be selected to provide sufficient pulling force under the prevailing conditions, but not excessive pulling capability, to ensure that the pipe cannot be damaged from over pulling. Pulling capability should not exceed the recommended maximum tensile load of the FS LP product being installed. This maximum recommended tensile load varies with different FS LP designs. Shear loops are other tension limiting devices can be used to prevent accidental over-pulling of the pipe.

For some installations, a winch or wire-line type of device with sufficient pulling capability is required. If the maximum pulling capacity could not exceed the recommended maximum tensile load of the FS LP being installed, a tension-limiting device, such as a shear loop should be used. Fiberspar can supply suitably sized shear loops.

a. Pulling Heads

Pulling heads are the preferred method of attachment of FS LP to the pulling device. Fiberspar can supply pulling heads sized and designed for the various sizes and pressure ratings of FS LP. The pulling head is attached to the end of the FS LP by setscrews through a number of holes drilled through the side of the pipe. The pulling head is then attached to the pulling device through a pulling eye preferably with a nylon sling or strap to avoid "shock" during the installation process.

b. Multi-Grip Pulling Assembly

The multi-grip pulling assembly (Chinese finger) is another device that is used to pull the FS LP. The device slips over the pipe and tightens up on the pipe as you pull on it. It has a reinforced eye on the end for attachment to the pulling strap or cable. Fiberspar can supply suitably sized multi grip pulling assemblies.

5. Load Indicating System

A pulling load indicator system is recommended during all pulls. The system should provide a real-time indication of the tensile load being applied to the FS LP. It should also be capable of maintaining a record of the maximum force applied to the FS LP. A print out of force versus time is desirable but not mandatory. The system should be calibrated and rated for the ultimate tensile strength of the FS LP being installed.

6. Miscellaneous

The following tools will generally be required for all installations:

- Fiberspar Liner Reaming Tool. This tool is required for sizing the ID of the FS LP prior to attaching the Fiberspar connector. Also used in conjunction with this tool is a suitable power device. Fiberspar recommends a ½"-drive right angle drill.
- Cutting Mean. A tool is required for cutting the FS LP. A SawsAll or hacksaw is recommended. The blade should be bimetallic, 14 to 24 toothed or abrasive. As Fiberspar LinePipe cuts relatively easily, care must be exercised to avoid damaging adjacent pipe.
- Tie Down. A method for restraining any FS LP remaining on the spool is required. The pipe on the spool must be restrained at all times. The preferred method is to either use a metal clamp that is bolted to the spool flange, or to cut the pipe at an angle and drill two holes through the exposed half of the pipe into the flange wall, and fit two bolts to hold the pipe. For temporary restraint, for example when moving the spool on location, a strap or sling can be used.
- Hand Tools. Miscellaneous hand tools are required.
- Pipe Cradles. In some installations that require the Fiberspar LinePipe to "bend" around corners, it may be necessary to use "pipe cradles" to facilitate the installation. The pipe cradles are used in the bends to prevent the Fiberspar LinePipe from exceeding the minimum recommended bending radius during installation. The pipe cradles are designed with a fixed radius that is greater than the minimum operating bend radius of the Fiberspar LinePipe. These cradles are attached to a fixed or stationary point in the bend and the Fiberspar LinePipe is then pulled around the cradles during installation.

In addition to the tools listed, additional tools may be required for specific types of installations and for the attachment of connectors and fittings. Fiberspar can supply these tools.

E. Installation Techniques

The following is a description of the most common installation techniques that are encountered in the oil and gas industry.

1. Stationary Spool - Surface & Buried

In a stationary spool installation the spool and spooling frame serves as an anchor point. The FS LP is deployed by pulling it from the stationary spool. This is the normal method for installation for applications in areas with soil that is not excessively rocky.

CAUTION: Since the FS LP will be pulled off the stationary reel when using this installation method, care should be exercised to avoid dragging the pipe over anything that will create excessive wear or damage to the OD of the pipe.

For surface or buried lines, a truck, backhoe or other piece of construction equipment is used to pull the pipe into the trench. Ensure that the pulling device is properly sized, but not oversized, for the product being installed.

2. Moving Spool Installations

When the soil is excessively rocky or abrasive, it is sometimes possible to move the spooling frame/spool to install the FS LP. This approach reduces the abrasion damage to the pipe. However, it may involve moving a trailer with the spooling frame/spool and pipe mounted on it under off-road conditions.

If the spool is to be moved to affect installation, it is first necessary to connect and anchor the pipe end. Connecting is accomplished using the appropriate joining system. Anchoring is accomplished by installing a thrust block or anchor post and clamping or otherwise securing the pipe in place. The anchor must be strong enough to resist loads up to the recommended tensile load of the FS LP being installed.

The equipment required for moving spool deployment is the same as for stationary spool deployment.

CAUTION: While this method of installation can be both rapid and avoid damage to the Fiberspar Pipe, it should only be carried out where the access for the moving vehicle is good, flat and secure. The spool of pipe represents a top-heavy load that is prone to overturning. This type of installation should be used only with experienced truck drivers and should be done slowly and with caution. An overturning load can result in injury to personnel and damage to equipment and the FS LP.

3. Trenches

All certified installers should have attended a recognized safety course on preparation and working in trenches before being qualified to work on trench installations of Fiberspar products. No Fiberspar installer should enter a trench that is not properly prepared or deemed unsafe.

Trenches must be prepared for accepting the pipe. Preparation involves ensuring that the bottom is reasonably smooth and level. Bedding, if required, should be in place.

For narrow trenches slightly wider than the pipe, the FS LP must be deployed alongside the trench and lowered into the trench manually after any necessary connections have been made. See handling instructions on how the pipe should be supported during this operation. FS LP can be pulled directly into trenches when they are wide enough for personnel to perform joint make-up in the trench.

Fiberspar LinePipe can be installed in a continuous length even where the trench is not straight, but all bends should have as large a radius as possible and certainly not less than the minimum bend radius quoted in the pipe data sheet for each size of pipe.

The installer should inspect the installed pipe before testing or covering to ensure that it is not lying on any sharp surfaces such as large rocks, or in contact with other pipes. Where there are pipe crossings, the Fiberspar pipe should if possible pass under the other pipe and good padding or sandbags placed between the two pipes to ensure that there is no possible direct contact when settlement takes place. Direct contact can result in rapid wear where there is even minor movement due to pulsations, fluid movement or vibration.

Any road or river crossings in trenched installations are installed in a similar manner to pull through installations – see below .

4. Pipeline Remediation Applications

Pipeline remediation involves pulling an FS LP pipe inside an existing pipeline to effect repairs to that existing line. The installation requires generally the same tools as for a surface or buried stationary spool installation except that only the ends of the pipe that will be repaired are uncovered. In addition, a pigging operation

and pulling unit are also required for this method of installation.

When installing FS LP in a pipeline remediation application, a wireline, from a winch or wireline unit, is normally pumped through the existing pipeline and used to pull the FS LP through. Only a single wireline can be used for a given run of pipe. The winch/wireline should be capable of pulling to the recommended tensile load of the FS LP. A plastic or rubber guide bushing is required at the entrance of the parent pipe to prevent damage to the FS LP.

A 20-foot length of the FS LP being used should be pulled through the existing line to ensure that there are no obstructions in the line before initiating the installation. It is also recommended that a sizing pig be pumped through the parent line prior to pulling the FS LP in place.

CAUTION: When installing FS LP in a pipeline remediation application, the condition of the existing line should be determined. If the corrosion is excessive it may be necessary to utilize centralizers or sacrificial wear pads to prevent pipe damage from occurring. Fiberspar recommends jacketed pipe for many pull through applications (see section on Jacketed pipe).

If the tension limitations of the FS LP or winch will be exceeded, there are three methods for making the installation:

- The existing line can be filled with fluid to allow the FS LP to “float” and thus reduce the loading.
- An injector, such as a coiled tubing injector, can be used to push the FS LP into the pipeline. In a push-pull operation the units must work together to avoid buckling or over tensioning the FS LP.
- The FS LP can be cut and a pipe-to-pipe connector installed, and the balance of the pull can be made keeping the tension loads during installation within operating limits.
- Connector Make-up. In most installations, the FS LP should be left 1.5 feet longer than would normally be done with conventional piping to allow for contraction after pressurization due to relaxing of tensile force during the installation process.

5. Plow-In

Fiberspar LinePipe can be plowed in using a high capacity plow. The plow used must have sufficient capacity to bury the FS LP to the required depth and a shoe with an installation radius that is equal to or greater than the minimum-bending radius of the FS LP.

Soil Conditions – The buried condition of the pipe can never be inspected with a plough – in installation, so these installations must be restricted to predictable and good soil conditions. Poor soil conditions to be avoided include rocky ground, frozen ground and severe elevation changes. In general, ground would be considered unsuitable for plough- in if an additional pulling force is required to move the plough, the plough cannot maintain reasonably consistent plough in speed and is stop/starting, large rocks are being pushed to the surface, or the chute or guide is being sharply moved either laterally or vertically due to encountering obstructions.

Plow-In Operation with FS LP Laid Out in the Right-of-Way

Deployment Method - The straight line deployment method (as shown above) shall always be used, where the pipe is laid out on the proposed line of installation and in line with the deployment guide, passing straight over the top of

the plough without twisting or lateral strain. Always check in advance that the plough is capable of this method of the deployment. Laying the pipe on one side of the plough and deploying by creating a moving loop that is not vertical puts twist on the pipe, and this method must not be used in the future. The orientation and location of the spool and feeding of the pipe should minimize bending of the pipe and eliminate bending that reverses the direction of curvature.

Guides and Chute – the design of guides and chute on the plough must have no sharp edges that could contact the pipe or expose the pipe to kinking or a bend radius less than the design bend radius of Fiberspar Line Pipe.

Supervision – Although good planning and job selection can avoid most problems, there should always be a Fiberspar certified installer present during plow–in deployment.

6. Surface Installations

Techniques for surface installation of Fiberspar LinePipe are very similar to trenched installation, but some special consideration should be given to pipe protection. Jacketed pipe will normally be used for surface installation for extra protection. The pipe should not be installed on rocky ground or on pipe supports at intervals as often used for steel pipe surface installation. The pipe should be supported on smooth ground. Vehicles should not be driven over Fiberspar LinePipe, so crossing points may have to be provided. Since the pipe will not be restrained during hydro test, it will possibly shrink in length during the test. Fiberspar Engineers can advise on the amount of shrinkage, but care will have to be taken to ensure that the pipe cannot move and tighten against pinch or kink points.

It can be difficult to move the unrestrained pipe around planned bends in the right of way, and pipe rollers and anchor points may have to be used to route the pipe. Fiberspar Field supervision should be consulted in advance for advice on the route and equipment required if a surface installation is planned.

7. Crew Size & Organization

A Fiberspar Certified installer should be present to supervise overall installation operation, provide specific training to local helpers, and fit all connectors. The Fiberspar Certified installer should be present during the hydraulic test.

Crew size will be dependent on the specific installation, skill level of the work force, as well as industry practice, but typically the Fiberspar Certified installer will require assistance from a back hoe or similar to pull the pipe, and one additional helper to assist with handling.

In all operations, crew sizes will be dictated by terrain, environmental and other conditions.

F. Joining

1. Introduction

Only Fiberspar Certified Installers will install fittings for service.

The FS LP Compression Slip Connector is a mechanical fitting that attaches to the pipe by application of compression forces. Two general types of connectors are used, Service End and Pipe-to-Pipe.

2. Service End Connectors

- Service-End Connectors are used at the end of a pipe run to connect the pipe to another system or another fitting. (See Figure E.1)
- The Service-End Connector is available with a variety of end configurations that are commonly used in pipeline applications. Fiberspar standard configuration is an ANSI RF Flange. Other configurations supplied on request are RTJ flange, NPT Pipe thread, hammer unions, or other configurations specific to end user specifications.
- Pipe-to-Pipe Connectors are used to connect two lengths of LinePipe™ together. (See Figure E.2)

Forces are typically applied through wedge loading of a slip between two body halves. The Fiberspar LinePipe Engineering Guide provides the required formulas to calculate axial forces generated in a pipe line with Fiberspar LinePipe based on changes in pressure or temperature.

The effect of internal pressure and changes in temperature on axial forces in the Fiberspar LinePipe shall be taken into account when making up fittings.

Service-End Connector Components

Pipe-to-Pipe Connector Components

In preparing for attachment to another system or fitting, the needs of the customer and system must be considered and the proper end configuration ordered. Planning should consider the application and the connection means to be used. The assembly procedure may vary slightly depending upon the type of end connection involved.

In summary the attachment procedure for a Service End involves the following general steps:

- The pipe end is cut square.
- The FS Reaming Tool is used to size the inside diameter of the pressure barrier.
- A chamfer is cut on the exposed end of the pressure barrier.
- The slip nut and slip are positioned on the end of the pipe.
- The Service End is fitted with “O” rings and lightly lubricated and inserted in the pipe end.
- The Service End and slip nut are threaded together and the threads tightened

CAUTION: In attaching Compression Slip Connectors to the FS LP or the system, the pipe must not be rotated or subjected to torque. “O” rings should be installed and lubricated just prior to final assembly to avoid damage.

3. Pipe-to-Pipe Connectors

The Pipe-to-pipe Compression Slip Connector is used to join two lengths of FS LP. Attachment is the same as attachment of the Service End Connector except there are two pipe ends to be prepared and the connector has two slips and two slip nuts.

4. Connector Selection

In order to ensure that the proper connector is used on the LinePipe product, measurements of the ID and OD of the pipe are used to determine which connector components are installed. Components are then selected based on the range they are designed to fit and how the LinePipe measurements fit into that range.

G. Testing

1. Introduction

All pipe is tested to 1.5 times rated operating pressure before being shipped, and following installation procedures properly, and a first time successful field test should be the routine result. But the field test is the last line of defense, the point where anything that slips through the net should be caught before it becomes a damaging service failure. When

field test procedures are adhered to and a successful test achieved, service failure is very rare.

The correct procedure for testing involves two separate steps. The pipe should be tested first in the open ditch to a relatively low pressure to find any obvious leaks or damage. The ditch should then be backfilled before final testing at full test pressure. There are two reasons for this:

- Backfilling is one of the most common sources of pipe damage and would not be detected if the pipe is tested only before backfilling
- Fiberspar LinePipe will contract in length at pressures above normal rated pressure, and backfilling will prevent any movement.

2. Filling

The system should be filled by pumping a pig (poly or squeegee) in front of the fluid to help force the air out of the system. In systems containing tees and branches, it may not be suitable to use a pig as the pig may get caught in one of the side branches. Fluid should enter the system at the lowest point and air must be vented from the highest point or points. Allow fluid to flow through the vents until there is no evidence of air coming from the system. When all air is removed, seal the vents and prepare for testing.

CAUTION: Entrapped air will cause testing problems and may result in over pressurizing the system. Use care to ensure all of the air is removed.

3. Test Procedure

- Fill pipe in the open ditch with water taking reasonable steps to remove air or gas.
- Raise pressure slowly (less than 20% rated pressure per minute) to around 50% system rated pressure in the open ditch, check for leaks. The purpose of this test is to find any obvious connector leaks, or gross damage before backfilling.
- Reduce pressure to around 200 psi and back fill the ditch. See backfilling guidelines.
- When backfilled, raise pressure slowly (max 20% rated pressure per minute) to 50% of full agreed test pressure and hold for 15 – 30 minutes. Check for leaks. Then raise pressure slowly to full test pressure and hold.
- Fiberspar representative will be present during the test if requested.

Following these steps will guarantee a safe test, demonstrate whether leaks are due to a pipe problem or back fill problem and prevent problems from shrinkage stress, which takes place when pressure exceeds pipe rated pressure.

Complex piping systems should be broken into smaller runs for testing when practical. The following guidelines and warnings must be followed carefully to avoid personal injury and/or damage to equipment.

CAUTION: Testing with fluids under pressure can be hazardous. Personnel injury and/or equipment damage is possible. Exercise care and follow safety precautions. Never attempt to tighten a connector while pressurized.

Testing with air or gas is extremely dangerous and should not normally be done. Gas is compressible and the stored energy is much higher than with fluids. If a gas test is proposed, consult with Fiberspar Technical Management.

4. Test Pressures

The recommended test pressure is **1.2 to 1.5 times the rated operating pressure of the system**, with a **maximum of 1.5 times the rated operating pressure of the Fiberspar LinePipe**.

CAUTION: ***Prior to pressurizing the line it must be at least partially covered and high-pressure fittings should be blocked.***

Increase pressure at a rate not exceeding 20% of the pipe rated pressure per minute to 50% of the desired test pressure, hold and walk the line looking for evidence of leaks. Pay particular attention to all joints. If there is no evidence of pressure loss or leaks, increase at a rate not exceeding 20% of the pipe rated pressure per minute and hold at the desired test pressure. Overpressure up to 200 psi is acceptable until pressure stabilizes. With pressure stabilized, start the clock and monitor the pressure. If there is any unexplained pressure drop, walk the line and look for evidence of leaks.

NOTE:
FS LP expands slightly during initial pressurization. It is therefore recommended that the pipe be allowed to "stabilize" at pressure for a period of time prior to beginning the actual test. This stabilization period is usually about 30 minutes in lines of up to about 5000ft in length, but can be longer in lines of much greater length. It is usually fairly obvious and generally slow pressure leaks will be due to stabilization and not pipe leaks. Having excessive air in the line will also lengthen this stabilization period. Temperature changes cause the test fluid to expand or contract resulting in changes in pressure. Ambient temperature should be tracked to provide compensation on pressure graphs.

Test pressure should be held for a minimum of 2 hours, preferably 4 hours, while the line is checked for leaks. The customer and/or applicable regulations may require longer testing periods. Test periods as long as 24 hours are not uncommon.

5. Pipe Contraction / Expansion

Fiberspar LinePipe behaves differently with respect to most other pipeline products with respect to axial contraction or expansion. Fiberspar LinePipe is designed so that there is virtually no contraction or expansion or the pipe in the axial direction at the rated operating pressure. Below the rated operating pressure there is slight initial axial expansion as the pressure is increased, but this axial expansion diminishes as the pressure nears rated pressure, becoming virtually zero at around rated pressure. However, this expansion tendency is very small, with very small axial forces, and can usually be ignored as the weight of the pipe when filled with water is more than sufficient to prevent any actual any pipe movement.

When the pipe pressure is raised above rated operating pressure (normally only for test purposes) the pipe will try to shrink in length. These forces are relatively small and backfilling the pipe will normally provide enough restraining force to prevent actual movement, but if the pipe has sections not backfilled e.g. close to risers or connections, precautions have to be taken to provide support in these areas to take any contraction loads that may be passed to risers or to isolate other parts of the system.

Particular care must be taken if there are long unrestrained sections, such as in a non backfilled ditch, an above ground installation, or a pull through or river crossing. As well as exerting force on other parts of the system, the Fiberspar LinePipe pipe will tend to tighten around any bends or restraints and can be damaged and provision has to be made for this. Fiberspar engineers can calculate the amount of contraction and the contraction forces and provide advice on how to offset it.

Caution. Connectors should be installed in straight sections of the pipe well away from any bends, and the pipe should be supported, usually by backfilling around the bend area. No levering or forcing of the pipe should be required to line up with the connector

H. Static Discharge

Fiberspar LinePipe is an electrical insulator, and in applications that involve transport of non-polar fluids for example: dry gas, liquid fuels or pure hydrocarbons, especially at high velocities, a static charge may be generated on pipe surfaces. If it is required to repair, purge the line, make a new connection, etc., 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.) procedures for static electricity safety and control, including procedures for discharging static electricity and personnel protection.

In Fiberspar LinePipe applications involving transport of wet gas, or liquid or multiphase flow containing water, no significant static charge is generated on pipe surfaces.

I. Jacketed Pipe

Fiberspar LinePipe is sometimes installed in soil conditions which are not favorable for glass reinforced epoxy pipe. For these applications Fiberspar has developed a jacketed version of the standard LinePipe product. This product is similar to design and performance of the standard LinePipe except that it has an additional extruded jacket on the OD. This jacket provides protection against impact and abrasion damage that can occur in unfavorable soil conditions. This jacketed product also provides added protection to LinePipe, which is used in a pull thru application. The jacket provides a layer of protection between the FRE and the parent pipe.

J. Corrective Action Request

Fiberspar has a system for the proper reporting of issues and incidents concerning the LinePipe product, service, installations, or other areas concerning the product. Any person involved with Fiberspar LinePipe has the authority to raise a Corrective Action Request (CAR). Fiberspar thoroughly investigates all Corrective Action Requests received and provides a recommendation for improvement going forward.

APPENDIX
FIBERSPAR LINEPIPE SPECIFICATIONS

FIBERSPAR LINEPIPE SPECIFICATIONS

FS LP is available with high-density polyethylene (HDPE) or cross-linked polyethylene (PEX) pressure barriers with temperature ratings to 140°F and 180°F respectively.

Product Identity	ID (in)	OD (in)	Nominal Wt/Ft in Air (lb)	Recommended Maximum Operating Pressure (psi)**	Nominal Ultimate Burst Pressure (psi @140°F)***	Recommended Maximum Tensile Load (lb @ RT)
750 Series						
FS LP 2 1/2" 750*	2.03	2.54	1.02	750	3,500	3,480
FS LP 3" 750*	2.54	3.09	1.33	750	2,850	4,400
FS LP 3 1/2 " 750*	2.97	3.58	1.74	750	2,850	5,960
FS LP 4" 750*	3.48	4.16	2.26	750	2,750	7,960
FS LP 4 1/2 " 750*	3.99	4.73	2.87	750	2,750	10,440
1,000 Series						
FS LP 2 1/2" 1,000*	2.03	2.39	0.80	1,000	3,800	3,880
FS LP 3" 1,000*	2.54	2.98	1.24	1,000	3,800	6,040
FS LP 3 1/2 " 1,000*	3.01	3.54	1.76	1,000	3,850	8,720
FS LP 4" 1,000*	3.52	4.14	2.41	1,000	3,850	11,920
FS LP 4 1/2 " 1,000*	4.03	4.74	3.16	1,000	3,850	15,650
1,500 Series						
FS LP 2 1/2" 1,500*	2.03	2.44	0.92	1,500	4,250	5,480
FS LP 3" 1,500*	2.54	3.04	1.42	1,500	4,200	6,920
FS LP 3 1/2" 1,500*	2.96	3.57	2.02	1,500	4,350	9,960
FS LP 4" 1,500*	3.47	4.18	2.76	1,500	4,400	13,680
FS LP 4 1/2" 1,500*	3.98	4.79	3.61	1,500	4,350	17,840
2,500 Series						
FS LP 1 1/4" 2,500*	1.02	1.33	0.40	2,500	6,800	2,120
FS LP 1 3/4" 2,500*	1.52	1.99	0.89	2,500	6,800	4,720
FS LP 2 1/2" 2,500*	2.03	2.65	1.56	2,500	6,700	8,320
FS LP 3" 2,500*	2.54	3.31	2.44	2,500	6,750	13,040
FS LP 3 1/2" 2,500*	3.05	3.98	3.52	2,500	6,750	18,840

FIBERSPAR LINEPIPE/J SPECIFICATIONS

FS LPJ is available with high-density polyethylene (HDPE) or cross-linked polyethylene (PEX) pressure barriers with temperature ratings to 140°F and 180°F respectively.

Product Identity	ID (in)	OD (in)	Nominal Wt/Ft in Air (lb)	Recommended Maximum Operating Pressure (psi)**	Nominal Ultimate Burst Pressure (psi @140°F)***	Recommended Maximum Tensile Load (lb @ RT)
1,000 Series						
FS LPJ 2 1/2" 1,000*	2.03	2.59	1.13	1,000	3,900	4,000
FS LPJ 3" 1,000*	2.54	3.22	1.71	1,000	3,800	6,000
FS LPJ 3 1/2 " 1,000*	3.01	3.83	2.45	1,000	3,900	8,720
FS LPJ 4" 1,000*	3.52	4.44	3.25	1,000	3,900	11,920
FS LPJ 4 1/2 " 1,000*	4.03	5.04	4.11	1,000	3,900	15,650
1,500 Series						
FS LPJ 2 1/2" 1,500*	2.03	2.68	1.29	1,500	5,100	5,480
FS LPJ 3" 1,500*	2.54	3.29	1.93	1,500	4,30	6,920
FS LPJ 3 1/2" 1,500*	2.96	3.87	2.72	1,500	4,400	9,960
FS LPJ 4" 1,500*	3.47	4.48	3.60	1,500	4,500	13,680
FS LPJ 4 1/2" 1,500*	3.98	5.09	4.57	1,500	4,400	17,840
2,500 Series						
FS LPJ 1 1/4" 2,500*	1.02	1.53	0.58	2,500	6,800	2,120
FS LPJ 1 3/4" 2,500*	1.52	2.19	1.15	2,500	6,900	4,720
FS LPJ 2 1/2" 2,500*	2.03	2.87	1.96	2,500	6,900	8,480
FS LPJ 3" 2,500*	2.54	3.59	3.05	2,500	6,900	13,200
FS LPJ 3 1/2" 2,500*	3.05	4.28	4.30	2,500	6,900	18,88

*Represents thermoplastic barrier material.
**Pressure ratings are based on minimum 20-year service life using ASTM D2992 long-term test procedures. Recommended maximum operating pressure is Fiberspar recommendation for general oilfield water, low-vapor pressure hydrocarbon and multiphase service conditions at the maximum rated temperature. Consult Fiberspar for a recommended maximum pressure rating for other service conditions.
***Value varies slightly depending on pressure barrier used (HDPE or PEX). For an exact value for a specific product, please refer to the detailed specification sheet.

Appendix 2 Material datasheets for Fiberspar spoolable pipe

ms31004.doc

FRN: GENERAL

Fiberspar Corporation

GLASS FIBER TOW
MATERIAL SPECIFICATION
(G56 thru 675)

REV.	DESCRIPTION	APPROVED
0	Initial Release	10/23/98

TITLE **GLASS FIBER TOW MATERIAL SPECIFICATION (G-56 thru 675)**

JB 10/8/98	SAB 10/13/98	JJ 10/12/98
SCN 10/13/98	WDS 10/7/98	LH 10/19/98

PEC 10/20/98

Fiberspar Corporation
28 Patterson Brook Road
West Wareham, MA 02576

DOCUMENT MS31.004

Page 1 of 4 Pages REV. 0

ms31004.doc

1.0 PURPOSE

To document the requirements for purchase of glass fiber tows.

2.0 SCOPE

This specification is applicable to untwisted glass fiber tow material. This material contains filaments of continuous electrical grade glass fibers (E-glass) in a single tow.

3.0 SPECIFICATION

3.1 Material

The material furnished in accord with this specification shall be filament continuous tow glass fibers with a 0.45% sizing by weight. FIBERSPAR purchase orders shall specify the appropriate yield, (i.e. 56, 62, 100, 113, 225, 450, or 675). Material Properties shall be within the following ranges:

PARAMETER	UNITS	MINIMUM VALUE	MAXIMUM VALUE
Glass Type		E-Glass	N/A
Degree of Twist		No Twist	N/A
Sizing (by weight loss on ignition)	Percentage by weight	0.3	0.6
Moisture Content	Percentage by weight	N/A	0.05
Yield (by any of three methods)			
56	tex*	8184	9416
	LYPP**	53	61
	denier***	73656	37664
62	tex*	7408	8532
	LYPP**	58	67
	denier***	67741	78016
100	tex*	4604	5297
	LYPP**	94	108
	denier***	41436	47674
113	tex*	4065	4681
	LYPP**	106	122
	denier***	37168	42805
225	tex*	2046	2354
	LYPP**	211	243
	denier***	18414	21186
450	tex*	1023	1177
	LYPP**	422	485
	denier***	9207	10593
675	tex*	680	784
	LYPP**	633	729
	denier***	6222	7166

*tex – grams per thousand meters
**LYPP – linear yards per pound
***denier - grams per 9000 meters.

3.2 Purchasing

3.2.1 Purchases shall be made from a supplier of glass fibers listed on the Approved Supplier List (ASL) or be approved in advance by the Quality Assurance Manager.

3.2.2 Fiberspar purchase order shall specify the following:

- Yield (56, 62, 100, 113, 225, 450, 675)
- Pounds per spool required
- Total pounds required
- Specification No. MS31.004 and revision level

3.3 Packaging & Marking

3.3.1 The fiber shall be spooled on standard 3 inch diameter by 11 inch long paper cores.

3.3.2 Material shall be spooled to leave a nominal ½ inch of each end of the spool exposed.

3.3.3 Nominal spool weight, in pounds, shall be as specified on the Purchase Order.

3.3.4 The manufacturer identity, batch number, nominal spool weight, number of splices, and date of manufacture shall appear on each spool, box, and other packages containing spools of product, and shall be marked in accord with the manufacturer's standard labeling.

3.4 Certificate of Compliance

3.4.1 The manufacturer shall provide a Certificate of Compliance (COC) listing each batch of product, and the results of testing to establish the parameters above as a minimum.

3.4.2 The COC shall certify the grade of the glass (E-glass) and the degree of twist (no twist).

3.4.3 A representative of the manufacturer shall sign the COC.

3.4.4 The COC shall be delivered with or prior to receipt of the material.

3.4.5 Properties shall be measured in each lot at least once for every 1000 lbs of material delivered.

3.5 Acceptance Criteria

Product shall be received and accepted if:

- Product is in agreement with this specification as described by the Purchase Order.
- Test results reported on the COC agree with the tabulated ranges above.
- Product and packaging comply with any additional requirements included on the Purchase Order.

3.6 Disposition

3.6.1 Product conforming to this specification shall be issued to stores in accord with the applicable Quality Procedures.

3.6.2 Product not in conformance shall be placed on quality hold per Quality Procedure QP13.001, and a non-conformance report issued.

4.0 DOCUMENTATION

Purchase records, COC's, test data shall be maintained in accordance with procedure QP10.002 (Receiving Inspection).

Ms31.040.doc

Fiberspar Corporation

HIGH DENSITY POLYETHYLENE (HDPE)
L-HDPE
MATERIAL SPECIFICATION

REV.	DESCRIPTION	APPROVED
0	Initial Release	
1	CN# 03-001	

TITLE
HIGH DENSITY POLYETHYLENE (HDPE)
L-HDPE
MATERIAL SPECIFICATION

Fiberspar Corporation
28 Patterson Brook Road
West Wareham, MA 02576

DOCUMENT
MS31.040

Ms31.040.doc

1.0 PURPOSE

To document the requirements for purchase of High Density Polyethylene (L-HDPE) thermoplastic material at Fiberspar Corporation (FIBERSPAR).

2.0 SCOPE

This specification is applicable to the (L-HDPE) liner material.

3.0 REFERENCES

3.1 Inspection and Test Procedure (QP10.001).

3.2 Receiving Inspection Procedure (QP10.002).

3.3 Handling of Non-Conforming Material (QP13.001).

4.0 DEFINITIONS

4.2 High Density

High density, as it applies to polyethylene pipe, is a material having a density of 0.941-0.959 g/cm^3, as defined by the Plastic Pipe Institute (PPI).

5.0 PROCEDURE

5.1 Material Grade

The material furnished shall be in accord with this specification and from an approved Fiberspar supplier. The material must be a PPI approved PE 3408 pipe grade polyethylene. The only grades qualified for use at Fiberspar are Nova's Novapol HD-2007-H and Solvay's Fortiflex HDPE K44-15-122. Material shall be in the form of pellets.

5.2 Purchase Order Information

Fiberspar purchase orders shall specify the following:

- Appropriate material specification.
- Fiberspar and Supplier product part numbers.
- Quantity required.
- Certificate of Analysis (COA) is required with each order.
- Packaging requirements.

5.3 Packaging & Marking

The resin shall be packaged in plastic-lined cardboard "gaylords". Nominal package weight, in pounds, shall be as specified on the Purchase Order. The packages shall be identified with part number, batch number, package weight, and date of manufacture.

5.4 Acceptance Criteria

The following test, examinations, and acceptance/rejection criteria shall be applied upon receipt of product from the supplier.

5.4.1 Certificate of Analysis (COA)
A COA referencing the Purchase Order and providing the material supplier batch number, date of manufacture and results of acceptance testing performed by the manufacturer.

5.4.2 Visual Examination
Plastic packaging shall be visually examined without aid of magnification devices. It shall be examined for container damage, leaks, contamination, and proper labeling.

5.5 Disposition
Disposition shall be in accord with (QP10.001) and (QP10.002).

5.5.1 Product not in conformance shall be placed on Quality Hold until returned to supplier by Materials Control per (QP13.001).

6.0 DOCUMENTATION

Materials Control shall maintain records of all purchases. Quality Assurance shall maintain records on all COA's and test data provided by suppliers.

Bibliographic Information

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