

Spoolable Reinforced Plastic Line Pipe

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Spoolable Reinforced Plastic Line Pipe

1 Scope

This specification provides requirements for the manufacture and qualification of spoolable reinforced plastic line pipe in oilfield and energy applications, including transport of multiphase fluids, hydrocarbon gases, hydrocarbon liquids, oilfield production chemicals, and nonpotable water. Also included are performance requirements for materials, pipe, and fittings.

These products consist of a liner, a reinforcement layer consisting of helically wrapped steel or nonmetallic reinforcing elements, and an outer cover. The spoolable reinforced line pipe under this specification is capable of being spooled for storage, transport, and installation. For offshore use, additional requirements may apply and are not within the scope of this document.

This specification is limited to pipe and end fittings and couplings and does not relate to other system components and appurtenances. Where other system components (e.g., elbows, tees, valves) are of conventional construction, they will be governed by other applicable codes and practices.

Products manufactured and qualified to this specification are eligible for participation in the API Monogram Program.

2 Normative References

The following referenced documents are indispensable for the application of this document. All of these documents do not necessarily apply to all products conforming to this specification. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

API Recommended Practice 15SIH, *Installation and Handling of Spoolable Reinforced Line Pipe*

API Recommended Practice 17B, *Recommended Practice for Flexible Pipe*

API 1104, *Standard for Welding Pipelines and Related Facilities*

ASME¹ B31.3, *Process Piping*

ASME BPVC. Section IX, *Welding and Brazing Qualifications*

ASTM² A370, *Standard Test Method and Definitions for Mechanical Testing of Steel Products*

ASTM A751, *Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products*

ASTM D746, *Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact*

ASTM D885, *Standard Test Methods for Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Manufactured Organic Base Fibers*

ASTM D1598, *Test Method for Time-To-Failure of Plastic Pipe under Constant Internal Pressure*

¹ American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990, www.asme.org

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, www.astm.org.

ASTM D1599, *Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings*

ASTM D2256, *Standard Test Method for Tensile Properties of Yarns by the Single Strand Method*

ASTM D2412, *Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading*

ASTM D2444, *Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)*

ASTM D2565, *Standard Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications*

ASTM D2992-18, *Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings*

ASTM D3222, *Standard Specification for Unmodified Poly (Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials*

ASTM D3350, *Standard Specification for Polyethylene Pipe and Fittings Materials*

ASTM D4000, *Standard Classification System for Specifying Plastic Materials*

ASTM D4067, *Standard Classification System for and Basis for Specification for Reinforced and Filled Poly (Phenylene Sulfide) (PPS) Injection Molding and Extrusion Materials Using ASTM Methods*

ASTM D4101, *Standard Specification for Polypropylene Injection and Extrusion Materials*

ASTM D5575, *Standard Classification System for Copolymers of Vinylidene Fluoride (VDF) with Other Fluorinated Monomers*

ASTM D5857, *Standard Specification for Polypropylene Injection and Extrusion Materials Using ISO Protocol and Methodology*

ASTM D6358, *Standard Classification System and Basis for Specification for Poly (Phenylene Sulfide) (PPS) Injection Molding and Extrusion Materials Using ISO Methods*

ASTM D6779, *Standard Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials (PA)*

ASTM D7269, *Standard Test Methods for Tensile Testing of Aramid Yarns*

ASTM E739, *Standard Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N) and Strain-Life (ϵ -N) Fatigue Data*

ISO 1167-1, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 1: General Method*

ISO³ 4437-1:2014, *Plastics piping systems for the supply of gaseous fuels*

ISO 9001, *Quality management systems — Requirements*

ISO 15156, *Petroleum and natural gas industries-Materials for use in H₂S-containing environments in oil and gas production*

³ International Organization for Standardization, ISO publications are available from the American National Standards Institute (ANSI), 25 West 43rd Street, 4th Floor, New York, NY 10036, www.iso.org, www.ansi.org

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

ISO/IEC 17020, *Conformity assessment — Requirements for the operation of various types of bodies performing inspection*

ISO/IEC 17065, *Conformity assessment — Requirements for bodies certifying products, processes and services*

ISO 23936-1, *Petroleum, petrochemical and natural gas industries -- Non-metallic materials in contact with media related to oil and gas production — Part 1: Thermoplastics*

ISO/TS 29001, *Petroleum, Petrochemical, and Natural Gas Industries—Sector-Specific Quality Management Systems — Requirements for Product and Service Supply Organizations*

NACE⁴ MR0175, *Petroleum and natural gas industries-Materials for use in H₂S-containing environments in oil and gas production*

NACE TM0177, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H₂S Environments*

NORSOK M-710, *Qualification of Non-metallic Sealing Materials and Manufacturers*

PPI⁵ TR-3, *Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe*

PPI TR-19, *Chemical Resistance of Thermoplastics Piping Materials*

3 Terms, Definitions, and Abbreviations

For the purposes of this document, the following terms, definitions, and abbreviations apply.

3.1 Terms and Definitions

3.1.1

batch

Pipe produced sequentially with no interruptions or shutdowns that are not a part of the normal production process.

NOTE In this document, “batch” refers to manufactured product; “lot” refers to raw material components.

3.1.2

blistering

Damage in the form of gas-filled pockets caused by the release of absorbed gas on depressurization within a solid polymer layer (e.g., polymeric liner).

3.1.3

brittle failure

A failure mode that exhibits no visible (to the naked eye) permanent material deformation (stretching, elongation, or necking down) in the area of the break.

⁴ National Association of Corrosion Engineers International, 1440 South Creek Drive, P.O. Box 218340, Houston, TX 77218-8340, www.nace.org

⁵ Plastics Pipe Institute, 105 Decker Court, Suite 825, Irving, TX 75062, www.plasticpipe.org



3.1.4**connector**

A device used to provide a leak-tight (except to intentionally vent gas) structural connection between the end fitting and adjacent piping (e.g., bolted flanges, clamped hubs, and proprietary connectors).

3.1.5**coupling**

A fitting developed for joining one section of pipe to another. (e.g., in-line connector)

3.1.6**coupon**

A test piece cut from a representative specimen.

3.1.7**cover**

The protective outer sheath of the pipe.

3.1.8**cyclic loading**

More than 7000 cycles and $\Delta P/NPR > 6\%$, where ΔP is maximum to minimum amplitude.

3.1.9**deplasticization**

The extraction or loss of any of a group of additive substances in a polymer formulation that are used to impart flexibility or other properties to the finished product.

3.1.10**design life**

A period of time used in design calculations, selected for the purpose of verifying that a replaceable or permanent component is suitable for the anticipated period of service.

3.1.11**disbondment**

Separation of the previously bonded layers.

3.1.12**end fitting**

A mechanical device that forms the transition from the pipe to the connector.

3.1.13**factor, design**

F_d

A number less than or equal to one that takes into consideration manufacturing and testing variables, including normal variations in material, manufacture, dimensions, handling, and installation techniques, and the precision and bias of the test methods.

3.1.14**factors, service**

F_{Sn}

A group of operating factors each less than or equal to one that considers the application or use and that may include environment (fluids), cycling loading, and temperature as described in this document.

3.1.15**field fitting**

An end fitting or coupling designed for permanent installation.

3.1.16**function**

An action(s) that an item is designed to perform.

3.1.17**laboratory test fitting**

A fitting used for testing to determine the properties of the pipe body.

3.1.18**liner**

A continuous polymeric layer that is in contact with the conveyed fluid.

3.1.19**liner collapse**

Movement of the liner away from the structural layer on reduction of internal pressure.

3.1.20**lower confidence limit****LCL**

Hydrostatic pressure calculated for a specific time-to-failure using Formula A1.25 in ASTM D2992-18, replacing σ_y by σ_n in accordance with A1.4.6.4 in ASTM D2992-18.

NOTE For 95 % confidence limits, there is a 2.5 % probability that the pipe's actual mean pressure versus time-to-failure regression line may fall below this calculated LCL.

3.1.21**lower prediction limit****LPL**

Hydrostatic pressure calculated for a specific time-to-failure using Formula A1.25 in ASTM D2992-18.

NOTE For 95 % prediction limits, there is a 2.5 % probability that an individual data point may fall below this calculated LPL.

3.1.22**lowest allowable installation temperature**

The lowest allowable pipe temperature for deployment (e.g., unspooling).

3.1.23**manufacturer**

An entity that fabricates products according to this specification.

3.1.24**maximum pressure rating****MPR**

The maximum internal hydrostatic pressure that can be applied continuously to a pipe with a high degree of certainty that failure of the component will not occur.

3.1.25**maximum operating pressure****MOP**

The maximum pressure permitted for normal pipeline operation. It is obtained by multiplying the NPR by application-related service factors.

3.1.26**operating MBR**

The minimum allowable bend radius for the installed and pressurized pipe.

3.1.27**respooling MBR**

The minimum allowable bend radius when repooling the pipe in the factory or the field.

3.1.28**handling MBR**

The minimum allowable bend radius the unpressurized pipe is subjected to during storage and handling.

3.1.29**nominal pressure rating****NPR**

The pressure rating of the pipe as defined by the manufacturer and that does not exceed the MPR.

3.1.30**preconditioning**

The process of subjecting the pipe to a prescribed bend radius prior to testing.

NOTE Preconditioning can include a certain minimum number of bending cycles to the prescribed bend radius.

3.1.31**product family**

A group of pipe products in a range of sizes and pressure ratings manufactured with the same material types, production process and process controls, and pipe construction.

3.1.32**product family representative****PFR**

A product variant chosen for full qualification.

3.1.33**product variant****PV**

A member of a product family with a specific pressure rating and diameter.

3.1.34**purchaser**

An organization, facility, or individual that buys equipment manufactured according to this specification.

3.1.35**qualified operator**

An individual who has been evaluated and can perform assigned covered tasks and recognize and react to abnormal operating conditions.

3.1.36**qualification test temperature**

The temperature at which pressure tests are performed to establish the MPR for nonmetallic reinforced products.

3.1.37**qualification testing**

Activities performed prior to production with the intention of establishing the suitability of a product, design, procedure, or material.

NOTE Qualification testing may be repeated periodically as a quality control measure.

3.1.38**regression analysis**

A statistical procedure to establish a long-term strength from stress rupture testing results performed over a long period of time, typically greater than 10,000 hours.

3.1.39**regression curve reference time****RCRT**

The time of 175,000 hours that is used in this specification to define MPR.

NOTE A pipe's design life can be less than, equal to, or greater than the RCRT.

3.1.40**reinforcing elements**

The primary contributor to the hydrostatic strength of the pipe.

3.1.41**rupture**

A tear, break, or fracture.

3.1.42**service life**

The period of time during which the pipe fulfills all performance requirements.

3.1.43**short-term burst pressure**

Burst pressure measured in a short-term test, where pressure is increased at a prescribed rate within a prescribed temperature range.

3.1.44**spoolable pipe**

Pipe that can be provided as a coil or on a structural reel for transportation.

NOTE For the purposes of this specification, the terms "coils," "reels," and "spools" are used interchangeably.

3.1.45**spoolable composite pipe**

A family of composite reinforced pipes in which the flexible structural layer enables spooling and unspooling.

NOTE This includes, but is not limited to, S-GRE and RTP pipe.

3.1.46**spoolable glass reinforced epoxy pipe (S-GRE)**

A type of spoolable composite pipe in which the structural layer consists of an even number of balanced helical windings of continuous glass fibers in an epoxy thermoset resin matrix.

3.1.47**spoolable reinforced thermoplastic pipe (RTP)**

A type of spoolable composite pipe that consists of a thermoplastic liner on which the structural layer is wound, consisting of an even number of balanced helical windings of reinforcement elements.

3.1.48**tape**

A reinforcement type in which the strength elements are consolidated in a matrix material and provided as a flat, flexible, ribbon.

3.1.49**traceability**

The ability to identify the origin of materials and parts used to manufacture a product and/or the product processing or manufacturing history.

3.2 Abbreviations

CLR	crack length ratio
CSR	crack sensitivity ratio
CTR	crack thickness ratio
DMA	dynamic mechanical analysis
DSC	differential scanning calorimetry
F_d	design factor
F_{Sn}	service factor
HIC	hydrogen induced cracking
LAOT	lowest allowable operating temperature
LCL	lower confidence limit
LCL_{RCRT}	LCL at time RCRT
LPL	lower prediction limit
MBR	minimum bend radius
MAOT	maximum allowable operating temperature
MOP	maximum operating pressure
MPR	maximum pressure rating
NPR	nominal pressure rating
NPR_PV	nominal pressure rating of the product variant
NPR_PFR	nominal pressure rating of the product family representative
P_{PV1000}	1000-hour test pressure of the product variant
$P_{PFR1000}$	1000-hour LPL intercept pressure of the product family representative
PE	polyethylene
PE-RT	polyethylene of raised temperature resistance
PEX	cross-linked polyethylene
PFR	product family representative
PPS	polyphenylene sulfide
PV	product variant
PVDF	polyvinylidene fluoride
QA	quality assurance
QC	quality control
RCRT	regression curve reference time
RTP	reinforced thermoplastic pipe
SCE	saturated calomel electrode

SMYS	specified minimum yield strength
SSC	sulfide stress cracking
UV	ultraviolet

4 Materials

4.1 Materials Selection

The manufacturer shall be responsible for the selection and supply of all materials so that the materials meet the specified service and installation requirements.

4.2 Material Requirements

4.2.1 Liner

4.2.1.1 General

Polymeric compounds shall be specified using the standard classification systems described in [Table 1](#).

Fitness for purpose shall be established in [Section 5](#) and as specified in [Table 2](#).

Masterbatch addition to the base resin is acceptable. If a masterbatch is used, only resin manufacturer approved masterbatches shall be used. The compound consisting of the base resin and approved masterbatch shall be considered as one material for the purposes of the substitution requirements of [5.4](#). As an alternative, if the masterbatch is not a resin manufacturer approved masterbatch, the pipe manufacturer shall demonstrate that the compound meets the same cell classification per [Table 1](#) as the manufacturer's masterbatch/base resin compound, except for Property 6 (Hydrostatic Strength Classification).

Fusion joints in the liner are permitted provided that they are performed by a qualified operator using a procedure qualified according to a recognized standard.

The liner shall be confirmed through testing to retain its integrity for the specified fluids under the given service conditions based on the property requirements in [Table 2](#).

The final material properties after processing shall be within the acceptable range of properties for the given service conditions, and verified based on the material qualification program in this section and the product qualification program in [Section 5](#).

Reprocessed material shall not be used.

Processing parameters as documented in [6.2](#) shall be specific and controlled to prevent unwanted changes in microstructure and the consequent unwanted changes in material properties.

Changes to the liner may require requalification—see 5.4 for additional information.

4.2.1.2 Chemical Resistance and Aging

The manufacturer shall document the effects of the chemical components of the service environment at the manufacturer's specified operating temperature range on the liner materials. An engineering assessment shall be conducted to verify that the liner will retain integrity and fitness for purpose at the design conditions. The assessment shall be based on testing and experience and shall predict the aging or deterioration of the polymer under the influence of environment. At a minimum, polymer aging estimates shall consider temperature, water cut, and pH. Special attention should be given to deplasticization, loss, and/or degradation of additive formulation components, fluid absorption, and changes of dimensions.

Materials used by products covered by this standard shall be demonstrated to remain stable for the design life of the product, retaining the necessary performance characteristics required to meet the original design specification. An internationally accepted chemical resistance test method, such as ISO 23936-1 or NORSOK M-710, should be used to establish compatibility with representative service fluids.

PPI TR-19 may be used as a screening tool for evaluating fluid compatibility.

4.2.1.3 Blister Resistance

For single layer liners, it shall be shown that the material will not blister or sustain other damage visible with the unaided eye during rapid depressurization from the NPR and service conditions according to the following method for material coupon testing. If the manufacturer applies an F_{Sn} for gas service, the test shall be at least $NPR \times F_{Sn}$.

The following conditions shall apply at a minimum.

- a) Samples: Samples shall be taken from an extruded polymer liner.
- b) Fluid mixtures: Use gas fluid components of specified environment as documented in the test procedure.
- c) Soak time: Use sufficient time to ensure > 95 % saturation, as calculated from diffusion coefficients of fluids in the polymer.
- d) Test cycles: Use expected number of decompressions in service, or 20 cycles as a minimum.
- e) Decompression rate: Use expected decompression rate in service or a minimum 70 bar/min (1015 psi/min). A lower depressurization rate is acceptable for pressure values below 10 % of the starting pressure.
- f) Thickness: Nominal manufactured or as a minimum 6-mm liner wall thickness.
- g) Temperature: Use the maximum operating temperature at a minimum.
- h) Procedure: After the last depressurization cycle (at a minimum), samples shall be examined at a magnification of 20x for signs of blistering and slitting.

The acceptance criterion shall be that no blistering or slitting is observed.

For multilayer coextruded liners, it shall be shown that the liner structure will not blister or sustain other damage visible with the unaided eye and the adhesion between layers shall not be compromised during the pipe blowdown test (see [Annex B](#)). The use of a shorter test specimen than specified in [Annex B](#) is acceptable. Use the expected number of decompressions in service, or 20 cycles at a minimum. A single-sided exposure coupon test is also acceptable. If the manufacturer applies an F_{Sn} for gas service, the test shall be at $NPR \times F_{Sn}$.

4.2.1.4 Fluid Permeability

For fluid permeability tests, the following conditions shall apply at a minimum.

- a) Sample: Sample shall be taken from an extruded material.
- b) Thickness: Minimum is 1 mm (0.04 in.) (see NOTE).
- c) Diameter: Minimum is 40 mm (1.57 in.) effective diameter (see NOTE).
- d) Temperature: Data required over the design range of the polymer, with sufficient tests to allow interpolation.
- e) Pressure: Permeability can be assumed to be independent of pressure.

- f) Repeatability: A sufficient number of tests shall be performed to ensure repeatability. ISO 2556 requires a minimum of three samples for each measurement.

NOTE The test may be performed using a disc sample with other dimensions, provided the ratio diameter over thickness is greater than 20. Alternatively, an extruded tube may be used.

The procedure for the fluid permeability test should typically pressurize one side of the specimen and measure fluid flow at the other side when steady state flow conditions are reached. Tests should characterize the transport of individual permeating species. Diffusion, solubility, and permeation coefficients should be derived.

Table 1—Polymer Material Cell Classification Standards

Polymer	Standard	Title
Polyethylene (PE)	ASTM D3350	<i>Standard Specification for Polyethylene Plastics Pipe and Fittings Materials</i>
All polyamides (nylons)	ASTM D6779	<i>Standard Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials (PA)</i>
PPS	ASTM D6358	— <i>Standard Classification System and Basis for Specification for Poly (Phenylene Sulfide) (PPS) Injection Molding and Extrusion Materials Using ISO Methods</i>
	ASTM D4067	— <i>Standard Classification System for and Basis for Specification for Reinforced and Filled Poly (Phenylene Sulfide) (PPS) Injection Molding and Extrusion Materials Using ASTM Methods</i>
Polypropylene	ASTM D4101	— <i>Standard Specification for Polypropylene Injection and Extrusion Materials</i>
	ASTM D5857	— <i>Standard Specification for Polypropylene Injection and Extrusion Materials Using ISO Protocol and Methodology</i>
PVDF	ASTM D3222	— <i>Standard Specification for Unmodified Poly (Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials</i>
	ASTM D5575	— <i>Standard Classification System for Copolymers of Vinylidene Fluoride (VDF) with Other Fluorinated Monomers</i>
PEX	ASTM F876	<i>Standard Specification for Crosslinked Polyethylene (PEX) Tubing</i> NOTE Dimensional requirements do not apply to API 15S applications.
Other polymers	ASTM D4000	— <i>Standard Classification System for Specifying Plastic Materials</i>

Table 2—Property Requirements for Materials of Construction

Characteristic	Tests	Standard	Liner	Reinforcement Layer	Cover
Permeation characteristics	Fluid permeability	See 4.2.1.4	X		X
	Blistering resistance	See 4.2.1.3	X		
Compatibility and aging	Fluid compatibility	See 4.2.1.2 and 4.2.2.1	X	X	X
	Aging tests	See 4.2.1.2 and 4.2.2.1	X	X	X
	Weathering resistance	ASTM D2565			X

4.2.2 Reinforcement Layer

4.2.2.1 General

The helical reinforcing elements shall be a single material. Reinforcement tapes, with either metal wires or nonmetallic reinforcement fibers, and a matrix material, are considered as single material. Additional nonhelical