



# Standard Specification for Polyamide 11 Gas Pressure Pipe, Tubing, and Fittings<sup>1</sup>

This standard is issued under the fixed designation F2945; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers requirements and test methods for the characterization of polyamide 11 pipe, tubing, and fittings for use in fuel gas pipelines. The pipe and fittings covered by this specification are intended for use in the distribution and transmission of fuel gases.

1.1.1 This specification does not cover threaded pipe. Generic fusion guidelines are given in [Appendix X1](#). Design considerations are discussed in [Appendix X2](#). In-plant quality control programs are specified in [Annex A1](#).

1.2 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

NOTE 1—Heat fusion joining of PA11 pipe and fittings meeting the requirements of this standard is limited to PA11 pipe and fittings meeting the requirements of this standard. Heat Fusion joining of PA11 pipe and fittings meeting the requirements of this standard is not allowed to pipes and fittings made from any other thermoplastic materials (for example, PA12, PEs, PVCs, etc.).

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following is an index of the annexes and appendixes in this specification:

Annexes	Subject
<a href="#">Annex A1</a>	In-Plant Quality Control for sizes up to 12 in.
<a href="#">Annex A2</a>	PA-11 Butt Fusion Fittings
Appendixes	Subject
<a href="#">Appendix X1</a>	Butt Fusion Guidelines for PA-11 Piping
<a href="#">Appendix X2</a>	Design Consideration

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standard-*

*ization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- [D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents](#)
- [D618 Practice for Conditioning Plastics for Testing](#)
- [D638 Test Method for Tensile Properties of Plastics](#)
- [D648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position](#)
- [D789 Test Method for Determination of Relative Viscosity of Concentrated Polyamide \(PA\) Solutions](#)
- [D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials](#)
- [D792 Test Methods for Density and Specific Gravity \(Relative Density\) of Plastics by Displacement](#)
- [D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure](#)
- [D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings](#)
- [D1600 Terminology for Abbreviated Terms Relating to Plastics](#)
- [D1898 Practice for Sampling of Plastics \(Withdrawn 1998\)<sup>3</sup>](#)
- [D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings](#)
- [D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe](#)
- [D2774 Practice for Underground Installation of Thermoplastic Pressure Piping](#)
- [D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products](#)
- [D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by](#)

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.60 on Gas.

Current edition approved Sept. 1, 2018. Published November 2018. Originally approved in 2012. Last previous edition approved in 2015 as F2945–15. DOI: 10.1520/D2945–18.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on www.astm.org.

\*A Summary of Changes section appears at the end of this standard

- Differential Scanning Calorimetry
- D4066 Classification System for Nylon Injection and Extrusion Materials (PA)
- F412 Terminology Relating to Plastic Piping Systems
- F1025 Guide for Selection and Use of Full-Encirclement-Type Band Clamps for Reinforcement or Repair of Punctures or Holes in Polyethylene Gas Pressure Pipe
- F1563 Specification for Tools to Squeeze-off Polyethylene (PE) Gas Pipe or Tubing
- F1733 Specification for Butt Heat Fusion Polyamide(PA) Plastic Fitting for Polyamide(PA) Plastic Pipe and Tubing
- F1973 Specification for Factory Assembled Anodeless Risers and Transition Fittings in Polyethylene (PE) and Polyamide 11 (PA11) and Polyamide 12 (PA12) Fuel Gas Distribution Systems
- F2138 Specification for Excess Flow Valves for Natural Gas Service
- F2145 Specification for Polyamide 11 (PA 11) and Polyamide 12 (PA12) Mechanical Fittings for Use on Outside Diameter Controlled Polyamide 11 and Polyamide 12 Pipe and Tubing
- F2600 Specification for Electrofusion Type Polyamide-11 Fittings for Outside Diameter Controlled Polyamide-11 Pipe and Tubing
- F2897 Specification for Tracking and Traceability Encoding System of Natural Gas Distribution Components (Pipe, Tubing, Fittings, Valves, and Appurtenances)
- 2.2 *ANSI Standards:*<sup>4</sup>
- B 16.40 Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems
- B 31.8 Gas Transmission and Distribution Piping Systems
- 2.3 *Federal Specifications:*<sup>5</sup>
- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
- OPS Part 192 Title 49, Title 49 Code of Federal Regulations
- 2.4 *Military Standards:*<sup>6</sup>
- MIL-STD-129 Marking for Shipment and Storage
- MIL-STD-1235 (ORD) Single- and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes
- 2.5 *ISO Standards:*<sup>7</sup>
- ISO 75–1 Plastics - Determination of temperature of deflection under load - Part 1: General test method
- ISO 75–2 Determination of temperature of deflection under load - Part 2: Plastics and ebonite
- ISO 179/1eA Determination of Charpy impact properties. Non-instrumented impact test
- ISO 527–1 Determination of tensile properties - Part 1: General principles
- ISO 527–2 Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics

- ISO 1183 Methods for determining the density of non-cellular plastics - Part 1: Immersion method, liquid pycnometer method and titration method
- ISO 22621 Part 1 Plastics piping systems for the supply of gaseous fuels for maximum operating pressure up to and including 2 MPa (20 bar)–Polyamide (PA): General
- ISO 13478 Thermoplastics pipes for the conveyance of fluids- Determination of resistance to rapid crack propagation (RCP) - Full-scale test (FST)
- 2.6 *Plastic Pipe Institute:*<sup>8</sup>
- PPI TR3 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 TR4 Hydrostatic Design Bases and Maximum Recommended Hydrostatic Design Stresses for Thermoplastic Piping Materials
- PPI TN7 Nature of Hydrostatic Stress Rupture Curves
- PPI TR9 Recommended Design Factors for Pressure Applications of Thermoplastic Pipe Materials
- PPI TR-45 Butt Fusion Joining Procedures for Field Joining of Polyamide-11

**3. Terminology**

- 3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified.
- 3.2 The gas industry terminology used in this specification is in accordance with ANSI B31.8 or CFR OPS Part 192 Title 49, unless otherwise indicated.
- 3.3 The term *pipe* used herein refers to both pipe and tubing unless specifically stated otherwise.
- 3.4 *Definitions of Terms Specific to This Standard:*<sup>18</sup>
- 3.4.1 *re-rounding equipment, n*—equipment used to reform the pipe and permanently reduce ovality to 5 % or less.
- 3.4.2 *rounding equipment, n*—equipment, devices, clamps, and so forth, used to temporarily hold the pipe round while out-of-roundness measurements are made, or a joining procedure (heat fusion, electrofusion, or mechanical) is performed.
- 3.4.3 *standard thermoplastic material designated code, n*—the pipe material designation code shall consist of the abbreviation for the polyamide (PA) followed by Arabic numerals which describe the short term properties in accordance with Classifications from Table 2 followed by the hydrostatic design stress for water at 73.4 °F (23 °C) in units of

<sup>8</sup> Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

**TABLE 1 Sustained Pressure**

Test Temperature	Min Hr.	PA 32312 Hoop Stress	PA 32316 Hoop Stress
73 ± 3.6 F (23 ± 2 C)	1000 hr	2800 psi (19 MPa)	3200 psi (22 MPa)
176 ± 3.6F (80 ± 2 C)	100 hr	1850 psi (12.7 MPa)	1850 psi (12.7 MPa)

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

<sup>5</sup> DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 <http://quicksearch.dla.mil/>

<sup>6</sup> Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

<sup>7</sup> Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, <http://www.plasticpipe.org>.

**TABLE 2 D4066–94b Classifications (dry as molded)**

Classification	ASTM Test Method	ISO Test Method	Designation
PA			Polyamide PA11
3 (group)			Heat stabilized
2 (class)			
3 (grade)			
Relative Viscosity, min.	D789		1.83
Melting Point, °C	D3418, DTA or DSC		185 -195
Specific Gravity	D792	ISO 1183	1/03-1.06
Tensile strength, min. (MPa)	D638	ISO 527-1 and ISO 527-2	48
Elongation (ultimate), %, min.	D638		200
Flexural Modulus, Mpa	D790	ISO 527-1 and ISO 527-2	900
Izod Impact Resistance, J/m2, min		ISO 179/ 1eA	55
Deflection temperature, min at 1.8 Mpa, min °C	D648	ISO 75-1 and 75-2	40
Moisture, as received, max.	D789		0.08

100 psi with any decimal figures dropped. Where the hydrostatic design stress code contains less than two figures, a zero is used before the number. Thus, a complete material designation code shall consist of two letters and five figures for polyamide 11 materials. For example, PA 32316 is a polyamide 11 with a 1600 psi design stress for water at 73.4 °F (23 °C). The hydrostatic design stresses for gas are not used in this designation code.

3.4.4 *thermoplastic pipe dimension ratio (DR), n*—the ratio of pipe diameter to wall thickness. It is calculated by dividing the specified outside diameter of the pipe, in inches, by the minimum specified wall thickness, in inches. The standard dimension ratio (SDR) is a common numbering system which is derived from the ANSI preferred number series R 10.

3.4.5 *toe-in, n*—a small reduction of the outside diameter at the cut end of a length of thermoplastic pipe.

#### 4. Requirements for Materials

4.1 *General*—The polyamide 11 material used to make pipe and fittings shall be virgin or reworked material (see 4.5) and shall have a Plastics Pipe Institute (PPI) long-term hydrostatic design stress and hydrostatic design basis rating as determined per PPI TR3 and PPI TR4.

4.2 *Classification*—Polyamide materials suitable for use in the manufacturing of pipe and fittings under this specification shall be classified in accordance with Classification D4066-94b, as shown in Table 2.

4.3 *Short- and Long-Term Properties*—Polyamide 11 pipe and fittings shall be made from a Polyamide 11 material which also satisfies the combinations of short- and long-term property requirements shown in Table 3.

4.4 *Resistance to Rapid Crack Propagation (RCP) for Materials*—The material classification (formulation) used in the manufacture of pipe and fittings under this specification

shall be tested for resistance to failure by RCP in accordance with 6.6. The data obtained shall be made available upon request without limitations on disclosure, and shall not subsequently be subject to disclosure limitations when used by others. The values obtained are applicable to all pipes with the wall thickness of the pipe tested and all thinner wall pipes.

4.5 *Rework Material*—Clean PA11 rework material of the same commercial designation, generated from the manufacturer’s own pipe and fitting production shall not be used unless the pipe and fitting produced meet all the requirements of this specification. The use of these PA11 rework materials shall be governed by the requirements of 4.6 and the principals of PPI TN-30/2006. In pipe, rework materials shall be limited to a maximum of 30 % by weight.

4.6 *Documentation*—A documentation system to allow for traceability of raw materials including percentage and material classification (or designation, if applicable) of rework materials used in the manufacture of the pipe product meeting the requirements of this specification shall exist and be supplied to the purchaser, if requested.

#### 5. Requirements for Pipe and Fittings

5.1 *General*—Pipe shall be supplied in either coils or straight lengths. Any pipe supplied in coils must meet the same requirements before and after coiling.

5.2 *Workmanship*—The pipe and fittings shall be homogeneous throughout and free of visible cracks, holes, foreign inclusion, blisters, and dents, or other injurious defects. The pipe and fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

##### 5.3 Pipe and Tubing Dimensions and Tolerances:

5.3.1 *Dimension*—The dimensions shall be specified by wall thickness and outside diameter.

5.3.1.1 *Diameters*—The outside diameter shall meet the requirements given in Table 4 or Table 5 when measured in accordance with 6.5.

5.3.1.2 *Toe-In*—When measured in accordance with 6.5.1.1, the outside diameter at the cut end of the pipe shall not be more than 1.5 % smaller than the undistorted outside diameter. Measurement of the undistorted outside diameter shall be made no closer than 1.5 pipe diameters or 11.8 in. (300 mm),

**TABLE 3 Short and Long Term Property Requirements**

PA Material Designation Code	Short-Term in Accordance with Table 2	Long-Term in Accordance with D2837
PA32312	PA323	HDB of 2500 psi for 73 °F (23 °C)
PA32316	PA323	HDB of 3150 psi for 73 °F (23 °C)

**TABLE 4 Outside Diameters and Tolerances for PA11 Pipe, in. (mm)**

Nominal Pipe Size	Outside Diameter	Tolerance	Maximum out-of-roundness (SDR 13.5 SDR 11)
1/2	0.840 (21.3)	±0.004 (±0.102)	0.016 (0.406)
3/4	1.050 (26.7)	±0.004 (±0.102)	0.02 (0.508)
1	1.315 (33.4)	±0.005 (±0.127)	0.02 (0.508)
1 1/4	1.660 (42.1)	±0.005 (±0.127)	0.024 (0.61)
2	2.375 (60.3)	±0.006 (±0.152)	0.024 (0.61)
3	3.500 (88.9)	±0.008 (±0.203)	0.03 (0.762)
4	4.500 (114.3)	±0.009 (±0.229)	0.03 (0.762)
5	5.563 (141.3)	±0.010 (±0.254)	0.06 (1.524)
6	6.625 (168.3)	±0.011 (±0.279)	0.07 (1.778)
8	8.625 (219.1)	±0.013 (±0.330)	0.08 (2.04)
10	10.750 (273.0)	±0.015 (±0.381)	0.1 (2.5)
12	12.750 (323.8)	±0.017 (±0.432)	0.1 (2.5)

**TABLE 5 Tubing Diameters, Wall Thicknesses, and Tolerances, in. (mm)**

Nominal Tubing Size (CTS)	Outside Diameter	Tolerance	Maximum Wall Thickness	Wall Thickness Tolerance
1/2	0.625 (15.9)	±0.004 (±0.10)	0.090 (2.27)	+0.009 (+0.23)
1/2	0.625 (15.9)	±0.004 (±0.10)	0.104 (2.64)	+0.010 (+0.25)
3/4	0.875 (22.2)	±0.004 (±0.10)	0.090 (2.27)	+0.009 (+0.23)
1	1.125 (28.6)	±0.005 (±0.13)	0.090 (2.27)	+0.012 (+0.31)
1	1.125 (28.6)	±0.005 (±0.13)	0.099 (2.51)	+0.011 (+0.28)
1	1.125 (28.6)	±0.005 (±0.13)	0.101 (2.56)	+0.012 (+0.31)
1	1.125 (28.6)	±0.005 (±0.13)	0.121 (3.07)	+0.015 (+0.38)
1 1/4	1.375 (34.9)	±0.005 (±0.13)	0.090 (2.27)	+0.011 (+0.28)
1 1/4	1.375 (34.9)	±0.005 (±0.13)	0.121 (3.07)	+0.015 (+0.38)

whichever distance is less, from the cut end of the pipe. Undistorted outside diameter shall meet the requirements of [Table 4](#) or [Table 5](#).

**5.3.1.3 Wall Thickness**—The wall thickness shall be as specified in [Table 5](#) or [Table 6](#) when measured in accordance with [6.5.1.2](#). The minimum wall thickness at any point of measurement shall be not less than the minimum wall thickness specified in [Table 5](#) or [Table 6](#).

**5.3.1.4 Wall Thickness Eccentricity Range**—The wall thickness eccentricity range shall be within 12 % when measured in accordance with [6.5.1.3](#).

**5.3.1.5 Ovality**—The ovality (cross section) of 3 in. IPS (88.9 mm) and smaller pipe shall not exceed 5 % when measured in accordance with [6.5.3](#). Measurements of coiled pipe shall be made on a sample cut from the coil, and in case of disagreement, conditioned per [6.3](#).

NOTE 2—Other factors, that is, installation compaction, static soil loading, and dynamic vehicular loads may increase the ovality; therefore, 5 % was chosen as the limit for the amount contributed by manufacturing, packing, in-plant storage, and shipping.

(1) Before or during installation, coiled pipe larger than 3 in. IPS (88.9 mm) shall be processed by the installer through re-rounding equipment that corrects ovality to 5 % or less.

NOTE 3—Ovality is a packaging condition that occurs when roundable pipe is wound into a coil—the pipe flattens out as it is coiled. Ovality is corrected when joining equipment is applied to roundable pipe, or by field processing roundable pipe through re-rounding and straightening equipment during installation.

**5.3.1.6 Length**—The pipe shall be supplied in straight lengths or coils as agreed upon between the manufacturer and the purchaser. The length shall not be less than the minimum length agreed upon when corrected to 73 °F (23 °C).

**5.3.1.7** When sizes other than those listed in [Table 4](#), [Table 5](#) or [Table 6](#) are used, tolerances shall be: for outside diameter,

use same tolerance of next smaller size; for wall thickness, use same tolerance percentage as shown in the tables.

**5.4 Conditioning**—For those tests where conditioning is required, or unless otherwise specified, condition the specimens prior to testing for a minimum of 1 h in water or 4 h in air at 73.4 ± 3.6 °F (23 ± 2 °C) or in accordance with [6.3](#). The conditioning requirements of [6.3](#) shall be used in all cases of disagreement.

**5.5 Resistance to Rapid Crack Propagation (RCP)**—Additional testing for resistance to RCP is required when the wall thickness of the pipe being produced in accordance with this standard exceeds that of the pipe used to establish the resistance to RCP. In these circumstances, additional testing for resistance to failure by RCP in accordance with [6.6](#) shall be conducted. The data obtained shall be made available upon request without limitations on disclosure, and shall not subsequently be subject to disclosure limitations when used by others.

NOTE 4—The requirements and testing for resistance to RCP do not provide information for all possible conditions of use. The user should consult with the manufacturer and other appropriate sources such as resin suppliers, research, academia, etc., to determine that the RCP resistance provided by the pipe producer is sufficient for the intended use.

**5.6 Minimum Hydrostatic Burst Pressure/Apparent Tensile Strength (Quick Burst)**—The pipe or system shall fail in a ductile manner when tested in accordance with Test Method [D1599](#) at a hoop stress greater than 3900 psi (27 MPa). For pipe sizes above 4-in. nominal diameter, the testing laboratory shall be allowed to replace the quick burst test (Test Method [D1599](#)) by the apparent ring tensile strength test (Test Method [D2290](#)). The minimum apparent tensile strength at yield when determined in accordance with [6.9](#) shall be 3900 psi (27 MPa).

TABLE 6 Wall Thickness and Tolerances for PA11 Pipe, in. (mm)<sup>A,B</sup>

Nominal Pipe Size (IPS)	DR <sup>C</sup>	Minimum	Tolerance
1/2	9.33	0.090 (2.29)	+0.011 (+0.279)
	D	0.090 (2.29)	+0.011 (+0.279)
3/4	11.0	0.095 (2.41)	+0.011 (+0.279)
	Sch 40	0.113 (2.87)	+0.014 (+0.356)
1	D	0.090 (2.29)	+0.011 (+0.279)
	17	0.112 (2.85)	+0.013 (+0.330)
	13.5	0.141 (3.58)	+0.017 (+0.432)
	Sch 40	0.145 (3.68)	+0.017 (+0.432)
	11	0.173 (4.39)	+0.021 (+0.533)
2	11	0.216 (5.49)	+0.026 (+0.660)
	9.33	0.255 (6.48)	+0.031 (+0.787)
3	13.5	0.259 (6.58)	+0.031 (+0.787)
	11.5	0.304 (7.72)	+0.036 (+0.914)
	11	0.318 (8.08)	+0.038 (+0.965)
	9.33	0.375 (9.53)	+0.045 (+1.143)
4	17	0.265 (6.73)	+0.032 (+0.813)
	13.5	0.333 (8.46)	+0.040 (+1.016)
	11.5	0.391 (9.93)	+0.047 (+1.194)
	11.0	0.409 (10.39)	+0.049 (+1.246)
	9.33	0.482 (12.24)	+0.058 (+1.473)
6	17	0.390 (9.91)	+0.047 (+1.194)
	13.5	0.491 (12.47)	+0.059 (+1.499)
	11.5	0.576 (14.63)	+0.069 (+1.753)
	11.0	0.602 (15.29)	+0.072 (+1.829)
8	21	0.411 (10.44)	+0.049 (+1.245)
	17	0.507 (12.90)	+0.061 (+1.549)
	13.5	0.639 (16.23)	+0.077 (+1.956)
	11.5	0.750 (19.05)	+0.090 (+2.286)
	11	0.784 (19.91)	+0.094 (+2.388)
10	21	0.512 (13.00)	+0.061 (+1.549)
	17	0.632 (16.05)	+0.076 (+1.930)
	13.5	0.796 (20.22)	+0.096 (+2.438)
	11.5	0.935 (23.75)	+0.112 (+2.845)
	11	0.977 (24.82)	+0.117 (+2.972)
12	21	0.607 (15.42)	+0.073 (+1.854)
	17	0.750 (19.05)	+0.090 (+2.286)
	13.5	0.944 (23.98)	+0.113 (+2.870)
	11.5	1.109 (28.17)	+0.133 (+3.378)
	11	1.159 (29.44)	+0.139 (+3.531)

<sup>A</sup> The sizes listed in Table 6 are those commercially available sizes used by the gas industry.

<sup>B</sup> The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

<sup>C</sup> The DR shown are designations commonly accepted by the gas industry and do not calculate exactly.

5.7 Sustained Pressure—Using one of the two test conditions in Table 1, the pipe or system shall not fail in less than the prescribed hours when tested in accordance with Test Method D1598.

5.8 Outdoor Storage Stability—Black polyamide 11 materials shall contain 2 to 3 percent well dispersed carbon black, and due to the absorptive properties of the carbon black, is considered to be stabilized against deterioration from unprotected exposure to UV for not less than 10 years. Yellow polyamide 11 material shall be stabilized and protected against deterioration from unprotected UV exposure for not less than 3 years.

NOTE 5—The determination for outdoor storage resistance is often based on measuring the ductility properties of the pipe material exposed to artificial weathering. These requirements and test methods are based on expected UV exposure levels in North America. Alternate requirements and alternate determination methods may be appropriate in other regions of the world. As an example ISO 4437 standard requires a minimum resistance to an accumulation of 3.6GJ for non-black polyethylene materials.

5.9 Chemical Resistance—The weight, yield strength, and relative viscosity requirements for PA11 pipe when measured in accordance with 6.10 are in Table 7.

TABLE 7 Chemical Resistances

Chemical	Weight Change, max%	Yield Strength Change, max%	Relative Viscosity, %
Mineral Oil	+0.5	-12	±3
Tertiary-butyl mercaptan (5%)	+0.5	-12	±3
Methanol	+5	-35	±3
Ethylene glycol	+0.5	-12	±3
Toulene (15%)	+7	-40	±3

5.10 Elevated Temperature Service—Polyamide 11 piping materials intended for use at temperatures above 100 °F (38 °C) shall have the PPI hydrostatic design basis (HDB) determined at the specific temperature in accordance with Test Method D2837. The 100 000-h intercept (long-term strength) shall be categorized in accordance with Table 8 and be listed as the “hydrostatic design basis of XXX psi at XXX °F (°C) for (compound name).”

5.11 Squeeze Off—This requirement is limited to pipe sizes, wall thicknesses, squeeze procedures, and conditions deemed suitable for squeeze-off in service by the pipe manufacturer.

**TABLE 8 Pipe Categories**

Property	Test Method	Category							
		A	B	C	D	E	F	G	H
Temperature, °F (°C)	...	100 (38)	120 (49)	140 (60)	160 (71)	180 (82)	...	...	...
Hydrostatic Design Basis, psi (MPa)	<b>D2837</b>	400 (2.8)	500 (3.4)	630 (4.3)	800 (5.5)	1000 (6.9)	1250 (8.6)	1600 (11.0)	2000 (13.8)

Examples: CH – At 140 °F (60 °C) the HDB is 2000 psi (13.8 MPa)

There shall be no leakage or visual evidence of splitting, cracking, breaking, or reduction in Sustained Pressure requirements when pipe is tested as follows:

5.11.1 Prepare six randomly selected pipe specimens in accordance with Test Method **D1598**, except they shall be unfilled.

5.11.2 The squeeze-off shall be affected at the midpoint of the test specimen, 90° to the point of the measured minimum wall thickness. Close the squeeze bars to the gap stop in Specification **F1563** and hold in constraint for 4 h. Remove squeeze bars and reround pipe by closing squeeze bars at a point 90° for the squeeze area.

5.11.3 Immediately upon removal of the squeeze-off tool, fill the specimens with ambient temperature water that is 67 ± 10 °F (19.4 ± 5.0 °C), condition, and test in accordance with **5.7**.

NOTE 6—Many design factors for elevated temperature service cannot be covered in this specification. Users should consult applicable codes for limitations on pertinent maximum temperatures.

## 5.12 Joints:

### 5.12.1 Butt Fusion:

5.12.1.1 Butt fusion joints of polyamide 11 pipe and fittings should be made in accordance with the manufacturer's recommendations and the user's written procedure.

5.12.1.2 PA 11 butt fusion joining shall be between components (pipes, fittings, or valves) having the same SDR or DR. Butt fusion between unlike SDR or DR components shall be allowed only if it has been demonstrated that long term performance is not adversely affected. The minimum requirement to demonstrate long term performance shall be the requirements of **5.6** of this specification. The Hydrostatic Design Basis (HDB) of the PA11 material shall be confirmed using specimens containing butt fusion joints resulting from different SDRs or DRs. Pipe/pipe joints of the material that pass shall validate pipe/pipe, pipe/fitting, or fitting/fitting joints of the same SDR ratio for the material.

5.13 *Fittings*—Fittings shall meet the requirements of the applicable ASTM standards.

5.13.1 *Butt Heat Fusion Fittings*—Butt heat fusion fittings intended for use with PA11 piping systems shall conform to the requirements of **Annex A2** of this standard.

5.13.2 *Electrofusion Fittings*—Electrofusion fittings intended for use with PA11 piping systems shall conform to the requirements contained within Specification **F2600**. Electrofusion joints shall be made in accordance to user's written procedures and the fitting manufacturer's installation instructions.

5.13.3 *Mechanical Fittings*—Mechanical fittings intended for use with PA11 piping systems shall conform to the

requirements contained within Specification **F2145**. Mechanical fittings shall be installed in accordance with the user's written procedures and the fitting manufacturer's installation instructions.

5.13.4 *Transition Fittings and Anodeless Risers*—Transition fittings and anodeless risers intended for use with PA11 piping systems shall conform to the requirements contained within Specification **F1973**.

5.14 *Valves*—PA-11 thermoplastic gas valves shall meet the requirements of ANSI Standard B 16.40.

5.15 *Excess Flow Valves*—Excess flow valves shall meet the requirements of Specification **F2138**.

## 6. Test Methods

6.1 *General*—The test methods in this specification cover plastic pipe and fittings to be used for the transport of fuel gas. Test methods that are applicable from other specifications will be referenced in the paragraph pertaining to that particular test.

6.2 *Sampling*—Take a representative sample of the pipe and fittings sufficient to determine conformance with this specification. About 40 ft (12 m) of pipe is required to perform all the tests prescribed. The number of fittings required varies, depending upon the size and type of fitting. A sampling plan shall be agreed upon by the purchaser and the manufacturer (see Practice **D1898**).

6.2.1 *Pipe Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

6.3 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 73.4 ± 3.6 °F (23 ± 2 °C) and 50 ± 5 % relative humidity for not less than 40 h, in accordance with Procedure A of Practice **D618** for those tests where conditioning is required and in all cases of disagreement.

6.4 *Test Conditions*—Conduct the test in the standard laboratory atmosphere of 73.4 ± 3.6 °F (23 ± 2 °C) and 50 ± 5 % relative humidity, unless otherwise specified.

### 6.5 Dimensions and Tolerances:

6.5.1 *Pipe*—Any length of pipe is used to determine the dimensions. Coiled pipe shall be measured in the natural springback condition, unless specified otherwise.

6.5.1.1 *Diameter*—Measure the diameter of the pipe in accordance with Test Method **D2122**. The average outside diameter for nonroundable pipe is the arithmetic average of the maximum and minimum diameters at any cross section on the length of the pipe. For roundable pipe, out-of-roundness