



# 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 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.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

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.).

<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.

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## 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 Methods for Determination of Solution Viscosities of Polyamide \(PA\)](#)
- [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 Differential Scanning Calorimetry](#)
- [D4066 Classification System for Nylon Injection and Extrusion Materials \(PA\)](#)
- [F412 Terminology Relating to Plastic Piping Systems](#)

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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](http://www.astm.org).

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

- 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:*

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 100 psi with any decimal figures dropped. Where the hydrostatic design stress code contains less than two figures, a zero

<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

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

**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)

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

**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)

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



**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)
4	9.33	0.375 (9.53)	+0.045 (+1.143)
	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)
6	9.33	0.482 (12.24)	+0.058 (+1.473)
	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)
8	11.0	0.602 (15.29)	+0.072 (+1.829)
	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)
10	11	0.784 (19.91)	+0.094 (+2.388)
	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)
12	11	0.977 (24.82)	+0.117 (+2.972)
	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.

**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).

**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.

**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

**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
Toluene (15%)	+7	–40	±3

**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. 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.

**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 the HDB is 2000 psi (13.8 MPa)

### 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 tolerance applies to measurements made while the pipe is rounded with the manufacturer's recommended equipment. Measure out-of-roundness within one-half pipe diameter or 2 in. (50 mm), whichever is closer, of the rounding equipment. See Test Method **D2122** for definitions of nonroundable and roundable pipe.

(1) The pipe surface shall be free of gross imperfections such as, deep scratches, grooves, or high or low (flat) spots around the pipe circumference.

NOTE 7—Excessive out-of-roundness may be caused by manufacturing irregularities around the circumference of the pipe, such as deep scratches, gouges, flat spots, and high spots. Such defects could detrimentally affect joining. To simulate field joining of roundable pipe, out-of-roundness is checked by fitting a rounding device on the pipe, then measuring diameter.

6.5.1.2 *Wall Thickness*—Make a minimum of six measurements at each cross section in accordance with Test Method **D2122**.

6.5.1.3 *Wall Thickness Eccentricity Range*—Measure in a manner such that the maximum, A, and the minimum, B, wall thickness at single points of each cross section measured are obtained. Calculate the wall thickness eccentricity range, E, in percent for each cross section as follows:

$$E = [(A - B)/A] \times 100 \quad (1)$$

6.5.1.4 *Length*—Measure pipe length and other linear dimensions with a steel tape or other device, accurate to  $\pm 1/32$  in. ( $\pm 1$  mm) in 10 ft (3 m).

6.5.2 *Fittings*—Measure the dimensions of fittings in accordance with Test Method **D2122**.

#### 6.5.3 *Ovality*:

6.5.3.1 *Apparatus*—A micrometer or vernier caliper accurate to within  $\pm 0.001$  in. ( $\pm 0.02$  mm).

6.5.3.2 *Procedure*—Take a series of outside diameter (OD) measurements at closely spaced intervals around the circumference to ensure that the minimum and maximum diameters have been determined.

6.5.3.3 *Calculation*—Calculate the percent ovality as follows:

$$\% \text{ ovality} = \frac{\text{maximum OD} - \text{minimum OD}}{\text{OD minimum} + \text{OD maximum}} \times 200 \quad (2)$$

6.6 *Resistance to Rapid Crack Propagation (RCP)*—Test in accordance with ISO 13478 with the following modification. Temperature of cooling for the crack-initiation groove (10.1 of ISO 13478:1997): 0 °C as prescribed in ISO 22621-1 Annex C.

#### 6.7 *Sustained Pressure Test*:

6.7.1 Select six test specimens of pipe at random, condition at the standard laboratory test temperature and humidity, and pressure test in accordance with Test Method **D1598**.

6.7.1.1 Test specimens shall be prepared so that the minimum length of pipe is equal to 5 times the diameter of the pipe but in no case less than 12 in. (304 mm) for sizes less than 6 in. For sizes 6 in. and larger, the minimum length shall be equal to 3 times the diameter or 30 in. (762 mm), whichever is shorter.

6.7.1.2 Test pressures shall be calculated using the pipe's actual measured minimum wall thickness, outside diameter, and the applicable fiber stress. Piping intended for use at temperatures of 100°F (38°C) and higher shall be tested at both 73°F (23°C) and the maximum design temperature. The test fiber stress shall be the hydrostatic design basis (HDB) or 80 % of the 100 000-h intercept of the material, whichever is greater.

NOTE 8—Air, methane, or nitrogen may be substituted for water as the test medium.

6.7.2 Maintain the specimens at the pressures required, held to  $\pm 10$  psi (0.07 MPa), for a period of 1000 h at the test temperature  $\pm 3.6^\circ\text{F}$  ( $\pm 2^\circ\text{C}$ ).

6.7.3 Failure of two of the six specimens tested shall constitute failure in the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens in retest shall constitute failure in the test. Evidence of failure of the pipe shall be as defined in Test Method **D1598**.

6.8 *Minimum Hydrostatic Burst Pressure (Quick Burst)*—The test equipment, procedures, and failure definitions shall be as specified in Test Method **D1599**. Pressures shall be at a stress greater than 3900 psi (27 MPa) or as calculated (using the pipe's actual measured minimum wall thickness, outside diameter, and the applicable fiber stress), whichever is greater.

6.9 *Apparent Tensile Properties*—The procedure and test equipment shall be as specified in Test Method **D2290**, Procedure B. The speed of testing shall be 0.5 in. (12.7 mm)/min. Cut "ring" specimens from pipe. They shall be 1/2 in. (12.7 mm) wide with a 1/4 in. (6.3-mm) wide reduced section. Test a minimum of five specimens. This method is applicable to all pipe of nominal 3/4 in. (19.0-mm) outside diameter and larger.

6.10 *Chemical Resistance*—Determine the resistance to the following chemicals in accordance with Test Method **D543**. Where available, the test specimen shall be a ring 2 in. SDR 11 pipe cut to the ring dimensions specified in 6.10. For materials that are not readily available as 2 in. SDR 11 pipe, the test specimen shall be a plaque of material 1/4 by 2 by 4 in. (6.3 by 50.8 by 101.6 mm) with a 1 in. (25.4 mm) wide reduced section. Test five specimens with each chemical. Weigh the specimens to the nearest 0.005 g and completely immerse them in the chemicals for 72 h. On removal from the chemicals, wipe the specimens with a clean dry cloth. Condition in air for 2 to 2 1/4 h and reweigh. Calculate the increase in weight to the nearest 0.01 % on the basis of initial weight. Test the specimen in tension in accordance with 6.9 within 1/2 h after weighing. Examine the weight and apparent tensile strength of each specimen for conformance to the requirement in 5.9 and **Table 7**. **Warning**—Because of the possible toxicity of these

reagents, refers to the Material Safety Data Sheet on each of these reagents before using or handling them.

## 7. Marking

7.1 *Pipe*—All required marking shall be legible, visible, and permanent. To ensure permanence, marking shall be applied so it can only be removed by physically removing part of the pipe wall. The marking shall (1) not reduce the wall thickness to less than the minimum value for the pipe, (2) not have any effect on the long-term strength of the pipe, and (3) not provide leakage channels when elastomeric gasket compression fittings are used to make the joints. These marking shall consist of the word GAS, the designation ASTM D XXXX, the manufacturer's name or trademark, the nominal pipe size including the sizing system used (IPS, CTS, or OD), DR or minimum wall thickness, material designation, and date of manufacture.

7.1.1 In addition to 7.1, the pipe marking shall include a coding that will enable the manufacturer to determine the location of manufacture, pipe production and resin lots, and any additional information which is agreed upon between the manufacturer and purchaser. The manufacturer shall maintain such records for fifty years or for the design service life of the pipe, whichever is longer.

7.1.2 All the markings in 7.1 and 7.1.1 shall be repeated at intervals not exceeding 2 ft (0.6 m). For indented printing, either the indented print line shall be in a color that contrasts with that of the pipe, or a separate print line shall be in a color that contrasts with the pipe. When color is applied to identify gas service, such as with color stripes, color print line, a color shell or solid color pipe, yellow color shall be used.

NOTE 9—Using color to identify piping service is not mandatory, but if used, yellow color is required.

7.2 PA-11 pipe and fittings intended for natural gas service at elevated temperatures greater than 73°F (23°C) shall be marked with additional code letters from Table 8 (the first code

letter to identify the temperature of pressure rating, the second code letter to identify HDB at highest rated temperature).

NOTE 10—The non-mandatory, preferred order for all the items required in the print line in the marking sections 7.1 and 7.2 are: (1) Pipe size including sizing system (IPS, CTS or OD), (2) SDR (DR) or minimum wall thickness, (3) Manufacturer's name or trademark, (4) GAS, (5) Pipe material designation code, (that is, PA 32312 or 32316) (6) Elevated temperature code from Table 8 as per 7.2 where applicable, (7) ASTM F XXXX, (8) Manufacturer's lot code (includes date of manufacture in some cases), and (9) Additional information, including date of manufacture, coil number, sequential footage, third party certification mark etc.

7.2.1 Where applicable, PA 32312 and PA 32316 pipe shall be marked with the elevated temperature code letters in accordance with Table 8, in addition to the marking requirements of 7.1.

7.3 All PA11 pipe, tubing, and butt fusion fittings meeting the requirements of this specification shall be marked with the 16-character tracking and traceability identifier in accordance with Specification F2897. The 16-character code shall be expressed in alpha-numeric format and Code 128 bar code format with a minimum bar thickness value of 0.005 in. or an alternative 1D or 2D bar code symbology as agreed upon between manufacturer and end user. All fittings shall have the 16-character codes marked or affixed to the product, product packaging, or any manner agreed upon between manufacturer and end user.

7.4 *Butt Fusion Fittings*—In addition to the applicable requirements above, butt fusion fittings shall be marked in accordance with Annex A2.

## 8. Quality Assurance

8.1 When the product is marked with this designation, F2945, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

## SUPPLEMENTARY REQUIREMENTS

These requirements apply only to federal/military procurement, not domestic sales or transfers.

### S1. Responsibility for Inspection

S1.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for performance of all inspection and test requirements specified herein. The producer shall use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1—In U.S. federal contracts, the contractor is responsible for inspection.

### S2. Packaging and Marking for U.S. Government Procurement

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practices in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD 129 for military agencies.

NOTE S2—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.



ANNEXES

(Mandatory Information)

**A1. IN-PLANT QUALITY CONTROL PROGRAM FOR PLASTIC PIPE AND FITTINGS UP TO AND INCLUDING 12 IN. NOMINAL DIAMETER**

**A1.1 Quality Control**

A1.1.1 The following in-plant quality control program shall be used to assure compliance with this specification. The pipe and fittings producers shall maintain records on all aspects of this program and supply these to the purchaser, if requested.

A1.1.2 *In-Plant Quality Control Test Methods*—Test methods other than those specified in Section 6 are used as long as they provide equivalent results. In case of disagreement, those test methods in the applicable ASTM standard shall be used.

**A1.2 Pipe Tests**

A1.2.1 *Material and Extrusion Process Qualification*—Sustained pressure tests shall be made on one pipe size in the range of 2 in., or less, and on one pipe size in the range of 2½ in., or greater. This test shall also be made on pipe from each particular commercial plastic resin initially and at least twice a year thereafter for material and extrusion process qualification and not as a quality control on the product. This test shall be made in accordance with 6.7.

A1.2.2 *Product Quality Control*—The tests in Table A1.1 shall be made per size per extrusion die at the denoted frequencies and the test results recorded and filed for inspection on request.

NOTE A1.1—When the pipe fails to meet this specification in any test, additional tests shall be made on the pipe produced back to the previous acceptable result to select the pipe produced in the interim that does pass the requirement. Pipe that does not meet the requirement shall be rejected.

NOTE A1.2—For pipe sizes above 4-in. nominal diameter, the quick burst test (Test Method D1599) may be replaced by the Apparent Ring Tensile Strength Test (Test Method D2290) if agreed to between the purchaser and the manufacturer.

A1.2.3 *Burst Pressure Multilevel Plan* (see Fig. A1.1)—This multilevel plan is based on MIL-STD-1235 (ORD), and is used only when the same product is extruded continuously under the same operating conditions and production is at a steady rate.

**TABLE A1.1 Product Quality Control Tests**

Property	Frequency
Diameter	Once every hour or every coil, whichever is less frequent
Wall thickness	Once every hour or every coil, whichever is less frequent
Ring tensile or burst pressure	Once every 8 h or once every coil, whichever is less frequent, or multilevel plan described in A3.2.3

Before this reduced sampling plan is considered, steady production conditions must be carefully chosen to ensure a continuous and consistent high quality output. Any interruption (shutdown) or change in resin lot number, percentage rework, or production conditions outside normal operating variations shall cause sampling to revert to Level 1. A sampling level change is considered only when approved by a production supervisor or authorized quality control personnel. Level 1 Test one specimen every 8 h. If 16 consecutive specimens have met requirements, proceed to Level 2. Level 2 Collect one specimen every 8 h. After 72 h (3 days) or portion thereof, test two randomly selected specimens. If both pass, discard the remaining 7 specimens. If any specimen fails to meet requirements, revert to Level 1 (see also Note A1.1). Product for which a specimen has been collected shall not be shipped until after the 72-h time period and randomly selected samples have been tested. Continue to test 2 out of 9 specimens for 16 three-day periods (48 days of production), then proceed to Level 3. Level 3 Collect one specimen every 8 h. After 21 days or portion thereof, test three randomly selected specimens. If all three pass, discard the remaining specimens. If any specimen fails to meet requirements, revert to Level 1 (see also Note A1.3). Product for which a specimen has been collected shall not be shipped until after the 21-day time period. Continue testing at Level 3 until production conditions necessitate reverting to Level 1.

**A1.3 Fitting Tests**

A1.3.1 The fittings tests listed in the following subparagraphs shall be conducted at the frequencies indicated.

NOTE A1.3—When any fitting fails to meet the requirements of this specification, or the applicable referenced fitting specification, additional tests should be made on fittings produced back to previous acceptable result to select the fittings produced in the interim that do meet the requirements. Fitting that do not meet the requirements shall be rejected.

A1.3.2 *Dimensions:*

A1.3.2.1 *Butt Fusion Fittings:*

(1) *Outside Diameter and Wall Thickness*—Once an hour or one out of ten fittings, whichever is less frequent?

A1.3.3 *Other Tests:*

A1.3.3.1 At the start of each production run, whenever production conditions have changed or when the resin lot is changed, but not less frequently than once per 500 fittings thereafter, the following tests shall be made:

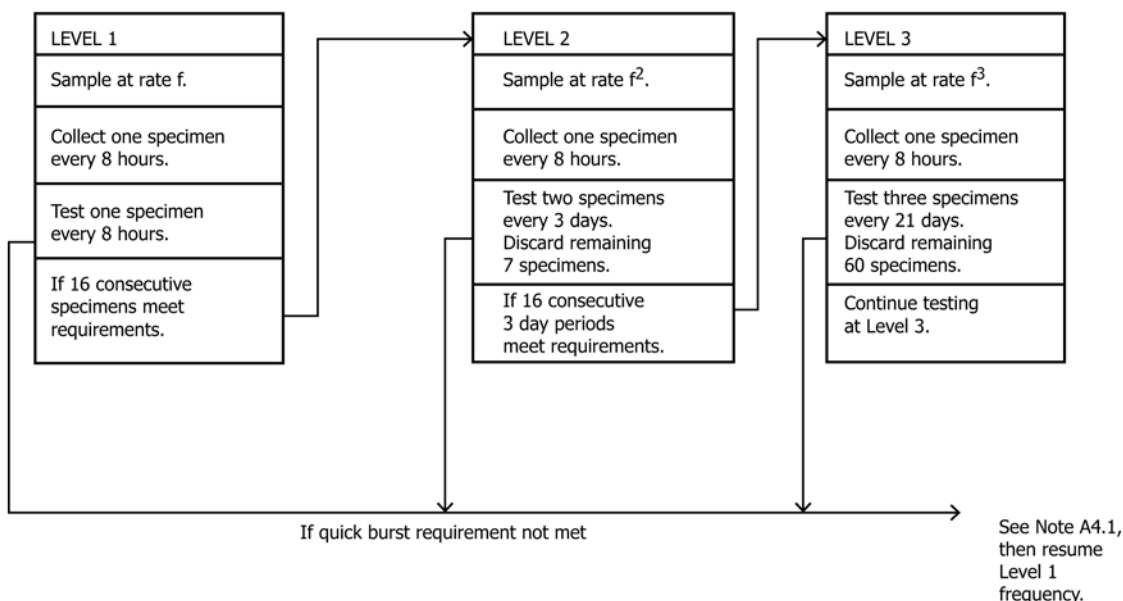


FIG. A1.1 Quick Burst Multilevel Sampling Plan

(1) The knit line strength for at least one fitting from each cavity shall be demonstrated by one of the following tests:

(1a) Crushing a fitting, or a portion of a fitting, in a manner that applies load in the direction normal to the knit line. See Note A1.4.

(1b) Apparent tensile strength tests of a ring cut from a fitting, with the load oriented normal to the knit line. See Note A1.5.

(1c) Burst testing of the fitting. See Note A1.5.

(2) The integrity of at least one part from each mold cavity shall be verified, using a method selected by the manufacturer as appropriate for this specific product and process.

NOTE A1.4—Separation in the knit constitutes a failure.

NOTE A1.5—In tests 2 and 3 the strength requirements shown in this standard must be met.

## A2. REQUIREMENTS FOR PA-11 BUTT FUSION FITTINGS

### A2.1 Scope

A2.1.1 This specification covers polyamide-11 (PA-11) butt fusion fittings for use with pipe (IPS) and tubing (CTS). Included are requirements for materials, workmanship, dimensions, marking, sustained pressure, and burst pressure.

A2.1.2 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.

### A2.2 Classification

A2.2.1 *General*—This Annex covers butt fusion fittings intended for use with polyamide 11 (PA-11) gas piping and tubing.

A2.2.1.1 Fittings covered by this Annex are normally molded. Fittings may be machined from extruded or molded stock.

A2.2.1.2 Fittings fabricated by thermal welding are not included in this Annex.

### A2.3 Requirements for Fittings

A2.3.1 In addition to the fitting requirements of the body of this standard, PA-11 butt fusion fittings shall meet the following requirements:

#### A2.3.2 Dimensions and Tolerances:

A2.3.2.1 *Outside Diameter*—Nominal outside diameters of butt fusion fittings shall conform to the nominal iron pipe size (IPS) or copper tubing size (CTS) dimensions at area of fusion. These dimensions and tolerances shall be as shown in Table A2.1, Table A2.2, and Table A2.3 of this Annex.

A2.3.2.2 *Inside Diameter (CTS Fittings Only)*—Inside diameters of butt fusion fittings for tubing at area of fusion shall conform to the dimensions of the tubing being joined. The dimensions and tolerances for the fittings are shown in Table A2.3.

**TABLE A2.1 IPS Sizing System Outside Diameters and Tolerances for Fittings for Use with Polyamide-11 (PA-11) Pipe, in.**

Nominal Pipe Size	Average Outside Diameter at Area of Fusion <sup>A</sup>	Tolerance
1/2	0.840	±0.008
3/4	1.050	±0.008
1	1.315	±0.010
1 1/4	1.660	±0.010
1 1/2	1.900	±0.010
2	2.375	±0.010
3	3.500	±0.012
4	4.500	±0.015
.6	6.625	±0.018
8	8.625	±0.025
10	10.750	±0.027
12	12.750	±0.036

<sup>A</sup> Defined as measured 1/4 in. (6.4 mm) from fitting outlet extremity.

**A2.3.2.3 Wall Thickness**—The wall thicknesses of butt fusion fittings shall not be less than the minimum specified for the pipe or tubing. The wall thicknesses and tolerances at the area of fusion shall be as shown in [Table A2.3](#), [Table A2.4](#), of this Annex.

**A2.3.2.4 Measurements**—These shall be made in accordance with Test Method [D2122](#) for roundable pipe.

#### **A2.3.3 Pressure Test Requirements:**

**A2.3.3.1 Short-Term Rupture Strength for Fittings 1/2 to 12 in. and 90 to 315 mm, Nominal Diameter**—The minimum short-term rupture strength of the fitting and fused pipe or tubing shall not be less than the minimum short-term rupture strength of the pipe or tubing in the system when tested in accordance with 10.5.3. These minimum pressures shall be as shown in [Table A2.4](#) of this Annex. Test specimens shall be prepared for testing in the manner described in [6.8](#) of this specification. The test equipment, procedures, and failure definitions shall be as specified in Test Method [D1599](#).

**A2.3.3.2 Sustained Pressure**—The fitting and fused pipe or tubing shall not fail, as defined in Test Method [D1598](#), when tested at the time, pressures, and test temperatures selected from test options offered in [Table A2.5](#). The test specimens shall be prepared for testing in the manner prescribed in [6.7](#).

## **A2.4 Workmanship, Finish, and Appearance**

**A2.4.1** The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this Annex. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

## **A2.5 Test Methods**

### **A2.5.1 Dimensions and Tolerances:**

**A2.5.1.1 Outside Diameter**—Measure the outside diameter of the fittings at the area of fusion in accordance with the Wall Thickness section of Test Method [D2122](#) by use of a circumferential tape readable to the nearest 0.001 in. (0.02 mm).

**A2.5.1.2 Inside Diameter (CTS Fittings Only)**—Inside diameters of butt fusion fittings for tubing at area of fusion shall conform to the dimensions of the tubing being joined. The dimensions and tolerances for the fittings are shown in [Table A2.3](#).

**A2.5.1.3 Wall Thickness**—Make a series of measurements using a cylindrical anvil tubular micrometer or other accurate device at closely spaced intervals to ensure that minimum and maximum wall thicknesses to the nearest 0.001 in. (0.02 mm) have been determined. Make a minimum of six measurements at each cross section.

### **A2.5.2 Pressure Testing:**

**A2.5.2.1 Preparation of Specimens for Pressure Testing**—Prepare test specimens in such a manner that each, whether individual fittings or groups of fittings, is a system incorporating at least one length of pipe or tubing. Fuse all fitting outlets with the appropriate size pipe or tubing. At least one piece of pipe or tubing in the system shall have a minimum length equal to five pipe diameters.

#### **A2.5.2.2 Sustained Pressure Test:**

(1) Select the test temperature and pressures from one of the options offered in [Table A2.5](#).

(2) Select the test specimens at random and condition at the selected option test temperature. Test the fitting specimens with water, in accordance with Test Method [D1598](#) at the selected option, stress, and hours of testing.

Note—Other test mediums and test conditions than offered in [Table A2.5](#) may be used as agreed upon between the manufacturer and the purchaser.

(3) Test six specimens at the selected option conditions and time.

(4) Failure of two of the six specimens tested shall constitute failure of the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens in retest shall constitute failure of the test.

**A2.5.3 Minimum Hydrostatic Burst Pressure for Fittings 1/2 to 12 in. Nominal Diameter**—The test equipment, procedures, and failure definitions shall be as specified in Test Method [D1599](#). The hydrostatic pressure shall be increased at a uniform rate such that the specimen fails between 60 and 70 s from start of the test. Minimum failure pressures are shown in [Table A2.4](#).

## **A2.6 Product Marking**

**A2.6.1** Fittings shall be marked with the following:

**A2.6.1.1** This designation: “ASTM F2945,”

**A2.6.1.2** Manufacturer’s name or trademark,

**A2.6.1.3** GAS,

**A2.6.1.4** Material designations (PA32312 or PA32316), and

**A2.6.1.5** Date of manufacture or manufacturing code.

**A2.6.2** Where the physical size of the fitting does not allow complete marking, marking may be omitted in the following sequence: size, date of manufacture, material designation, manufacturer’s name or trademark.

**A2.6.3** Where recessed marking is used, take care not to reduce the wall thickness below the minimum specified.

**TABLE A2.2 Diameter, Wall Thickness, and Tolerances for Fittings for Use with Polyamide-11 (PA-11) Tubing**

Tubing Type, in. (mm)	Nominal Tubing Size, in.	Diameter at Area of Fusion <sup>A</sup>				Minimum Wall Thickness, in. (mm)
		Outside, in. (mm)		Inside, in. (mm)		
		Average	Tolerance	Average	Tolerance	
0.062 (1.57)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.495 (12.58)	±0.004 (±0.10)	0.062 (1.58)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.745 (18.92)	±0.004 (±0.10)	
0.090 (2.29)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.437 (11.10)	±0.004 (±0.10)	0.090 (2.28)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.687 (17.44)	±0.004 (±0.10)	0.090 (2.28)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.937 (23.80)	±0.005 (±0.12)	0.090 (2.28)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.187 (30.14)	±0.005 (±0.12)	0.090 (2.28)
DR 11	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.715 (18.16)	±0.004 (±0.10)	0.077 (1.96)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.915 (23.24)	±0.005 (±0.12)	0.101 (2.56)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.125 (28.58)	±0.005 (±0.12)	0.121 (3.08)
DR 9.3	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.483 (12.26)	±0.004 (±0.10)	0.067 (1.70)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.679 (17.24)	±0.004 (±0.10)	0.094 (2.38)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.873 (22.18)	±0.005 (±0.12)	0.121 (3.08)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.069 (27.16)	±0.005 (±0.12)	0.148 (3.76)

<sup>A</sup> Defined as measured ¼ in. (6.4 mm) from fitting outlet extremity.

**TABLE A2.3 IPS Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyamide-11 (PA-11) Pipe, in.<sup>A,B,C</sup>**

Nominal Pipe Size	Minimum Wall Thickness									
	SCH 40	SCH 80	SDR 21	SDR 17	SDR 13.5	DR 10	DR 11.5	SDR 11	DR 9.3	SDR 9
½	0.109	0.147	...	...	...	...	...	0.076	0.090	...
¾	0.113	0.154	...	...	...	...	...	0.095	0.113	0.117
1	0.133	0.179	...	...	...	...	...	0.119	0.142	0.146
1¼	0.140	0.191	...	...	...	0.166	...	0.151	0.179	0.184
1½	0.145	0.200	...	...	...	...	...	0.173	0.204	0.211
2	0.154	0.218	...	...	...	...	...	0.216	0.256	0.264
3	0.216	0.300	...	...	0.259	...	0.305	0.318	0.377	0.389
4	0.237	0.337	...	0.264	0.333	...	0.392	0.409	0.484	0.500
6	0.280	0.432	0.316	0.390	0.491	...	0.576	0.603	0.713	0.736
8	0.322	...	0.410	0.508	0.639	...	0.750	0.785	0.928	0.958
10	0.365	...	0.511	0.633	0.797	...	0.935	0.978	1.156	1.194
12	0.406	...	0.608	0.750	0.945	...	1.109	1.160	1.371	1.417

<sup>A</sup> Tolerance +20 %, 0 %.

<sup>B</sup> For those SDR groups having overlapping thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.

<sup>C</sup> For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001 in.

**TABLE A2.4 Minimum Burst Pressure Requirements at 73.4°F for Common PA-11 Fitting Sizes<sup>A</sup>**

Wall Thickness, DR, or Schedule	Nominal Diameter	Minimum Pressure, psi
DR 7	ALL <sup>B</sup>	1300
SDR 9	ALL <sup>B</sup>	975
DR 9.3	ALL <sup>B</sup>	945
SDR 11	ALL <sup>B</sup>	775
DR 11.5	ALL <sup>B</sup>	745
DR 15.5	ALL <sup>B</sup>	540
SDR 17	ALL <sup>B</sup>	495
SDR 21	ALL <sup>B</sup>	385
DR 32.5	ALL <sup>B</sup>	250
0.062 in. (1.575 mm)	½ CTS	860
0.062 in. (1.575 mm)	¾ CTS	590
0.062 in. (1.575 mm)	1 CTS	450
0.090 in. (2.286 mm)	½ CTS	1315
0.090 in. (2.286 mm)	¾ CTS	700
0.090 in. (2.286 mm)	1 CTS	650
0.090 in. (2.286 mm)	1¼ CTS	540

<sup>A</sup> Fiber stress of 3900 psi (27 MPa) for PA32312 and PA32316.

<sup>B</sup> Refers to IPS diameters shown in [Table A2.1](#) and [Table A2.2](#).

## A2.7 Quality Assurance

A2.7.1 When the product is marked with this ASTM designation, F2945, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this Annex and has been found to meet the requirements of this Annex.



**TABLE A2.5 Sustained Pressure Test Options, psig (MPa)**

SDR/DR	Option 1 <sup>A,B</sup>	Option 2 <sup>B,C</sup>
	73°F (23°C)/1000 h	176°F (80°C)/170 h
DR 7	935 (6.5)	485 (3.3)
SDR 9	700 (4.8)	360 (2.5)
SDR 11	560 (3.9)	290 (2.0)
DR 15.5	385 (2.7)	200 (1.4)
SDR 17	350 (2.4)	180 (1.2)
SDR 21	280 (1.9)	145 (1.0)
DR 32.5	180 (1.2)	90 (0.6)

<sup>A</sup> Sustained pressure is based on stress of 2800 psi (19 MPa).

<sup>B</sup> All psig values were rounded to nearest 5 psig.

<sup>C</sup> Sustained pressure is based on stress of 1450 psi (10 MPa).

## APPENDIXES

### (Nonmandatory Information)

#### X1. BUTT FUSION GUIDELINES FOR POLYAMIDE 11

##### X1.1 General

X1.1.1 The PPI TR-45 referenced butt fusion procedures are intended to be used for jointing polyamide 11 (PA-11) piping. Critical parameters in the butt fusion process are heater iron surface temperature, heat soak time, and interfacial pressure during the initial contact of the molten pipe ends and during cooling and cooling time. The heat soak time and cooling time parameters vary as a function of pipe size and wall thickness. As a general guideline, the heat soak time for should be

sufficiently long to produce a melt bead of approximately  $\frac{1}{16}$ – $\frac{1}{8}$  in. The pipe should be held under pressure until cooled to the touch.

##### X1.2 Butt Fusion Procedure

X1.2.1 PPI TR-45 Butt Fusion Joining Procedures for Field Joining of Polyamide-11 (2008) is the recommended procedure for butt fusion joining of PA-11 piping.

#### X2. DESIGN CONSIDERATIONS

##### X2.1 General

X2.1.1 The design of a plastic piping system for natural gas service must include consideration of the combined effects of time, internal and external stress, and environment as an overall basis for selecting a specific kind and size of plastic pipe. The design stress for plastic pipe used for transport of fuel gases is regulated by the U.S. Department of Transportation as published in OPS Part 192 Title 49 of the Code of Federal Regulations. The American Gas Association Plastic Materials Committee, the Fuel Gas Division of PPI, and members of ASTM Committee F17 are cooperating with the ASME Gas Piping Technology Committee to provide assistance in selecting safe design stress levels for the various kinds of plastic pipe.

##### X2.2 Design Equations

X2.2.1 *Relationship Between Pipe Stress and Pressure*—The following expression is used to relate stress, pressure, pipe size, and wall thickness:

$$P = 2S/(DR - 1) \text{ or } 2S[(D_o / t) - 1] \quad (\text{X2.1})$$

where:

$S$  = stress in the circumferential or hoop direction, psi (MPa),

$P$  = internal pressure, psig (MPa),

$DR$  = dimension ratio,

$D_o$  = average outside diameter, in. (mm), and

$t$  = minimum wall thickness, in. (mm).

X2.2.2 The following expression can be used to determine the burst pressure or sustained pressures needed in testing:

$$P_b = 2S_y/(DR - 1) \quad (\text{X2.2})$$

where:

$P_b$  = burst pressure, psig (MPa),

$S_y$  = yield stress, psi (MPa), and

$DR$  = dimension ratio.

$$P_s = 2S_f/(DR - 1) \quad (\text{X2.3})$$

where:

$P_s$  = sustained pressure, psig (MPa),

$S_f$  = fiber stress psi (MPa), and

$DR$  = dimension ratio.

X2.2.3 *Relation between Hydrostatic Design Basis (HDB) and Hydrostatic Design Stress (HDS)*—The HDS is determined by multiplying the HDB by a design factor,  $f$ . The design factor,  $f$ , has a value less than 1.0.

$$HDS = (HDB)(f) \quad (\text{X2.4})$$

NOTE X2.1—The actual choice of design factor for a given installation must be reviewed by the design engineer taking into account federal, state,

and local code requirements. For example, the design factor for gas pipelines under the jurisdiction of the Department of Transportation is 0.32.

### X2.3 Design Stress and Internal Pressure for Natural Gas

X2.3.1 The design stresses for natural gas pipe are based on the hydrostatic design basis at 73°F (23°C) obtained in accordance with Test Method **D2837**. The hydrostatic design basis of the polyamide 11 is 2500 psi at 73°F for PA32312 and 3150 psi for PA32316.

X2.3.2 The design stresses for natural gas at service temperatures above 73°F (23°C) should be based on hydrostatic design basis of the pipe that are applicable for the particular use temperature.

X2.3.3 The design stresses for natural gas are obtained by multiplying the hydrostatic design basis by design factors or service factors according to the class of location as described in Chapter IV of the American National Standard Code for Pressure Piping ANSI B31.8, or, for gas operators in the United States, Subpart C of the Minimum Federal Safety Standards for Transportation of Natural and Other Gas by Pipeline, Title 49, Code of Federal Regulations.

### X2.4 Thermal Stress

X2.4.1 Calculate the longitudinal stress (theoretical) induced in a pipe member between fixed points as follows:

$$S = E \times C \times \Delta t \quad (\text{X2.5})$$

where:

- $S$  = stress, psi (MPa),
- $E$  = modulus of elasticity, psi (MPa), instantaneous, at 73°F (23°C),
- $C$  = coefficient of expansion, in./in./°F, (mm/mm/°C), and
- $\Delta t$  = maximum temperature minus minimum temperature, °F (°C).

X2.4.1.1 The measured stress has been determined to be less than that calculated. This difference is caused by the stress relaxation in viscoelastic materials.

X2.4.2 Calculate the theoretical force sustained at the fixed points (typically joints) in a pipe member as follows:

$$F = S \times A \quad (\text{X2.6})$$

where:

- $F$  = force, lbf (N),
- $S$  = stress, psi (MPa), and
- $A$  = cross-sectional pipe wall area, in.<sup>2</sup> (mm<sup>2</sup>).

X2.4.3 Calculate pipe contraction in unrestrained pipe caused by a reduction in temperature as follows:

$$\Delta L = k \times L \times C \times \Delta t \quad (\text{X2.7})$$

where:

- $\Delta L$  = change in length,
- $K$  = 1000 for  $\Delta L$  (mm), L (m), C (°C<sup>-1</sup>),  $\Delta t$  (°C), or
- $K$  = 12 for  $\Delta L$  (in.), L (ft), C (°F<sup>-1</sup>),  $\Delta t$  (°F),
- $L$  = original length,
- $C$  = coefficient of linear expansion, and
- $\Delta t$  = temperature change.

### X2.4.4 Design Pressure:

X2.4.4.1 The design pressure of plastic pipe is selected by the pipeline operator on the basis of the gas supply system operating requirements, the polyamide 11 materials used and the authority having jurisdiction. In accordance with **Eq X2.8** the design pressure of PA11 piping depends upon; the PA-11HDB, the pipe's DR; and is reduced by a service design factor,  $f$ . US CFR Title 49, Part 192.121 prescribes the use of the following equation in calculating the design pressures in the design of plastic pipe.

$$\text{Design Pressure, } DP = \frac{2Sf}{(SDR - 1)} \text{ or } DP = \frac{2Stf}{(D - t)} \quad (\text{X2.8})$$

where:

- $S$  = HDB,
- $f$  = design pressure,
- $SDR$  = standard dimension ratio,
- $D$  = specified outside diameter, and
- $t$  = specified wall thickness.

X2.4.4.2 The design factor,  $f$ , is a number less than 1.00 that takes into consideration the variables and degree of safety involved in a properly installed thermoplastic pressure piping application. The design factor for plastic pipe used for the transport of USA jurisdictional natural and other gas is prescribed by the U.S. Department of Transportation as published in the US Code of Federal Regulations, Title 49, Part 192. The federal code currently permits the use of a design factor of 0.40 for polyamide 11 gas piping. For applications not falling under the jurisdiction of Part 192 other design factors may be used. The Plastics Pipe Institute's TR-9 report provides a more thorough discussion of design factors. **Table X2.1** lists typical PA-11 design pressure calculations at 73°F (23°C) made in accordance with **Eq X2.8**.

### X2.5 Installation Procedure

X2.5.1 It is recognized that certain minimum requirements exist for the support of earth loads from backfill and other external forces. Proper installation techniques can be used with flexible conduit to support relatively large earth loads without excessive deflection by mobilizing lateral passive soil forces. Proper installation technique ensures that the necessary passive soil pressure at the side of the pipe will be developed and maintained. It is also recognized that internal pressures may be valuable in minimizing the deflection caused by earth loads. Installation procedures described in Recommended Practice

**TABLE X2.1 Typical PA-11 Design Pressures (DP) as Calculated Using Eq X2.8**

PA-11 Material	PA 32316	PA 32312
HDB (psi)	3150	2500
Design Factor	0.4	0.4
SDR	DP, psig	DP, psig
17	158	125
13.5	202	160
11	252	200
9.5	296	235
7	420	333

**D2774**, ANSI B31.8, and the AGA Plastic Pipe Manual for Gas Service are recommended.

X2.5.2 Unrestrained plastic pipe expands and contracts from thermal change significantly more than metallic pipe. This ratio may be of the magnitude of ten to one. The typical coefficient of thermal expansion for unrestrained polyamide 11 pipe is  $11.0 \times 10^{-5}$  (in/in)/°F. Mains and service lines installed by insertion are considered to approximate unrestrained conditions inside the casing pipe except at end connections. Direct-burial pipe is considered to be partially restrained by passive soil pressures except in the vicinity of joints.

X2.5.3 Internal pressure, earth settlement, ground movement, and thermal contraction impose stresses on the pipe that can be transmitted to joints. These stresses are additive. Installation practices should reflect the need for continuous support and containment of the pipe through suitable bedding and backfilling procedures. Attention should be given to all joints, particularly to transition joints between polyamide 11 and metal pipe.

X2.5.4 It is desirable to have pipe joints that are as strong as the pipe itself in the longitudinal (axial) direction. The joint strength is a function of the assembly procedure, the design of the fitting, and the pipe material and dimensions.

X2.5.5 For those mechanical devices that are not designed to restrain the pipe against pullout forces, provisions must be

made in the field to prevent pullout, keeping in mind that mechanical joints are vulnerable to the effects of internal pressure, temperature changes, earth settlement, and ground movement. A somewhat limited alternative is to use long sleeve-type fittings that permit limited movement without loss of pressure seal. Otherwise, provisions must be made in the field to prevent pullout through suitable anchoring at the joint.

X2.5.6 Kinks found in the pipe shall be cut out. Pipe with kinks shall not be placed in service.

## X2.6 Repair Considerations

X2.6.1 Repairs may be made to plastic pipe under appropriate circumstances. Selection and installation considerations for the use of full encirclement band clamps are available in Guide **F1025**. Additional information on repair of plastic pipe may be found in manufacturers' literature, the AGA Plastic Pipe Manual for Gas Service,<sup>9</sup> ANSI B31.8 Gas Transmission and Distribution Piping Systems, and in the ASME Guide for Gas Transmission and Distribution Piping Systems.<sup>10</sup>

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<sup>9</sup> Available from American Gas Association 400 N. Capitol St. (4th Floor) Washington, DC 20001.

<sup>10</sup> Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

## SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (F2945–12a) that may impact the use of this standard.

(1) Revisions were made to **1.1** and **7.3** to include gas transmission pipeline applications.

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