Chapter 5

Specifications, Test Methods and Codes for Polyethylene Piping Systems

Introduction

The specification, design and use of polyethylene piping systems are governed by a number of standards, methods and codes such as American Society for Testing and Materials (ASTM), American Water Works Association (AWWA) and Canadian Standards Association (CSA), as well as Technical Reports (TR's) and Technical Notes (TN's) published by the Plastics Pipe Institute. This chapter discusses these guidelines with respect to both the polyethylene materials and the finished piping systems used for pressure pipe applications. There are also many standards and guidelines for non-pressure pipe applications, but they are not covered in this chapter. Emphasis is placed on developing an understanding of:

1. Material specifications relating to properties and classifications of polyethylene for piping
2. Test methods and specifications relating to pipe pressure rating, dimensions, fittings and joints
3. Codes, standards and recommended practices governing the application of polyethylene pipe systems in a variety of end uses

Included at the end of this chapter is a current list of some of the major or most frequently used standards and codes for polyethylene piping.

Properties and Classification of Polyethylene Materials

The properties and performance of polyethylene piping systems, to a great extent, are determined by the polyethylene material itself. As its name suggests, polyethylene is made by the polymerization of ethylene, generally with the addition of another alpha-olefin such as propylene, butene or hexene. For pipe applications, the polyethylene resins are generally made from the combination of thousands of these units. A variety of polymerization catalysts and processes exist commercially which are used to control the number of monomer units in the polymer chain, the type, frequency and distribution of the comonomer unit, the amount and type of branching off of the main polymer chain, and the relative uniformity of the polymer chain lengths in the bulk polyethylene resin.

To a greater or lesser extent, each of the above variables can influence the properties of the polyethylene resin and determine its suitability for piping applications. Three basic parameters of polyethylene can be used to give general indications of the resins' properties and its suitability for the piping applications. These are: density, molecular weight, and molecular weight distribution. The engineering properties of polyethylene chapter of this handbook gives further detail on these properties and their interrelationships.

Table 1 provides a generalized indication of the effects of these three important polyethylene characteristics on resin properties [(1)]. As can be seen from this table, some of the physical properties of polyethylene are primarily determined by only one of the above parameters and are independent of the other two (e.g., hardness or stiffness as functions of density), while some properties are influenced by all three parameters (e.g., low temperature brittleness). Most properties are influenced to a certain degree by a least two of the parameters. Each of these interrelationships of performance properties to molecular characteristics can be complex, subtle or even masked by such overriding influences as thermal history, formulations, sample preparation, etc. As such, it is important when designing or selecting polyethylene materials for piping applications to realize that such relationships can exist.

TABLE 1
Influence of Basic Resin Parameters on Polyethylene Resin Properties*

Property	As Density Increases	As Average Molecular Weight Increases (Melt Index Decreases)	As Molecular Weight Distribution Broadens
Stiffness	Increases	Increases	Decreases
Hardness	Increases	Increases	—
Tensile Strength @ Yield	Increases	Increases	—
Elongation	Decreases	Increases	—
Tensile Strength @ Rupture	Increases	Increases	No Significant Changes
Softening Temperature	Increases	—	Increases
Retention of Strength Under Long-Term Loading	No Significant Change	Increases	No Significant Changes
Resistance to Low Temperature Brittleness	Decreases	Increases	Increases
Permeability	Decreases	—	—
ESCR	—	Increases	Increases
Chemical Resistance	Increases	Increases	—

*Changes in other parameters may alter these effects.

Material Selection and Specification

There are hundreds of types of polyethylene, and it is important to be able to specify the right one for a plastic piping application. In the past, ASTM D 1248 was used to help define the material properties. However, ASTM D 1248 has been modified and now only deals with wire and cable coating grades of polyethylene. Today, the main ASTM standard for aiding in the specification of PE materials for piping applications is D 3350 *"Standard Specification for Polyethylene Plastics Pipe and Fittings Materials."* This ASTM standard defines the most important material properties that need to be considered when choosing a PE material for a pressure pipe application, and defines a classification system to ease the specification process.

ASTM D-3350 *"Standard Specification for Polyethylene Plastics Pipe and Fittings Materials"*

This standard defines basic material requirements, as well as classifies polyethylene piping materials according to a cell classification system consisting of six digits and one letter. Table 2 shows the cell system of ASTM D 3350, with each cell representing a property or characteristic of polyethylene that has been recognized as being significant to processing and/or performance. The properties are divided up into ranges, or cells, so a certain property value can easily be specified.

Another important part of this standard is that not only are the values of the properties specified, but the methodology used to determine the properties is also defined. This way, it is possible to more accurately specify material properties as measured by a certain method, and easier to directly compare different polyethylene materials with a more "apples-to-apples" approach.

Thermal Stability

In addition to the cell classification, in order for a material to meet the requirements of ASTM D 3350, it must also meet the thermal stability requirements. This insures that only those materials that have been adequately stabilized with protective antioxidants and heat stabilizers will be used in long-term piping applications.

TABLE 2
Cell Classification System from ASTM D-3350

PROPERTY	TEST METHOD	0	1	2	3	4	5	6	7	8
Density, g/cm3	D 1505	un-specified	0.925 or lower	>0.925 - 0.940	>0.940 - 0.947	>0.947 - 0.955	>0.955	—	specify value	—
Melt Index	D 1238	un-specified	>1.0	1.0 to 0.4	<0.4 to 0.15	<0.15	A	—	specify value	—
Flexural Modulus, MPa (psi), 2% secant	D 790	un-specified	<138 (<20,000)	138-<276 (20,000 to <40,000)	276-<552 (40,000 to <80,000)	552-<758 (80,000 to <110,000)	758-<1103 (110,000 to <160,000)	>1103 (>160,000)	specify value	—
Tensile strength at yield, MPa (psi)	D638	un-specified	<15 (<2000)	15- < 18 (2200-<2600)	18- <21 (2600-<3000)	21- <24 (3000-<3500)	24- <28 (3500-<4000)	>28 (>4000)	specify value	—
Slow Crack Growth Resistance I. ESCR	D1693	un-specified								
a. Test condition			A	B	C	D	—	—	—	specify value
b. Test duration, hours			48	24	192	600	—	—	—	
c. Failure, max. %			50	50	20	20	—	—	—	
Slow Crack Growth Resistance II. PENT (hours) Molded Plaque, 80°C, 2.4MPa, notch depth Table 1	F 1473	un-specified	—	—	—	10	30	100	500	specify value
Hydrostatic Strength Classification I. Hydrostatic design basis, MPa, (psi), (23°C)	D2837	NPR[B]	5.52 (800)	6.89 (1000)	8.62 (1250)	11.03 (1600)	—	—	—	—
Hydrostatic Strength Classification II. Minimum Required Strength, MPa (psi), (20°C)	ISO 12162	—	—	—	—	—	8 (1160)	10 (1450)	—	—

Notes to Table 2: A Refer to 10.1.4.1 (ASTM D 3350) B NPR = Not Pressure Rated

As noted earlier, the ASTM D3350 cell classification consists of a string of six digits and one alpha character. The ending code letter designates the color and UV stabilizer as follows:

Code Letter	Color and UV Stabilizer
A	Natural
B	Colored
C	Black with 2% minimum carbon black
D	Natural with UV stabilizer
E	Colored with UV stabilizer

Note: UV = ultraviolet

Polyethylene Grade - D 3350

The grade designation originally established in ASTM D 1248 has been added to D 3350, and further modified to be consistent with newer PE piping materials. The grade consists of the letters “PE”, followed by two numbers. The letters “PE”, of course, are to designate the material as being polyethylene. The first number designates the density cell class of the material. The second number designates the cell class for resistance to slow crack growth of a material when tested in accordance with ASTM D 1693 or ASTM F 1473.

As an example, a high-density polyethylene material- **PE**- with a density of 0.945 g/cc - **cell class 3**, and an ESCR, condition C, of greater than 600 hours - **cell class 4**, would be a grade **PE34**.

An example of the application of this system is given in Table 3 for a polyethylene material with a cell class designation of **345464C**, a standard designation for a modern PE 3408 pipe grade resins.

TABLE 3
Properties of a Class PE345464C Material

Cell Property	Class
Density (0.941 - 0.955 g/cc)	3
Melt Index (<0.15)	4
Flexural Modulus (758- <1103 MPa)(110,000 to <160,000 psi)	5
Tensile Strength at yield (21- < 24 Mpa) (3000 < 3500 psi)	4
Slow Crack Growth Resistance, PENT (100 hours)	6
Hydrostatic Design basis at 23°C at 11.03 MPa (1600 psi)	4
Black with 2% minimum carbon black	C

Such a product would be described as a high-density, high-molecular-weight polyethylene having a hydrostatic design basis at 73°F (23°C) of 1600 psi (11.03 MPa). It would be black and contain 2% (minimum) carbon black. The flexural modulus, tensile strength and Slow Crack Growth Resistance would be as defined by their respective cell values.

A specification writer would want to use the cell classification as a minimum requirement. Additional clarifications and specific project requirements should be included in any material specification for piping applications. PPI has published several Model Specifications that are available to use as a guide.

PPI Designations

The use of the cell classifications per ASTM D3350 provides a detailed description of a polyethylene material for piping. The Plastics Pipe Institute has augmented the grade designation from ASTM D 3350 to include the Hydrostatic Design Stress (HDS) by adding two digits on the material's grade. The Hydrostatic Design Stress is the maximum long-term stress the material can be subjected to after applying a design factor of 0.5 to the material's established Hydrostatic Design Basis (HDB).
By truncating the standard HDS in hundreds, the PPI has adopted the use of **04** for 400 psi (2.26 MPa) HDS, **06** for 630 psi (4.31 MPa) HDS, and **08** for 800 psi (5.4 MPa) HDS. More information on the relationship between the HDB and HDS is in subsequent sections.

Using this format, the PPI designation for a polyethylene material with a grade of **PE34** and a hydrostatic design stress of 800 psi, is a **PE 3408**. This approach is commonly referred to as the thermoplastic material designation code as defined in ASTM F 412.

Test Methods and Standards for Stress Rating, Dimensioning, Fittings and Joining of Polyethylene Pipe Systems

In order to properly specify polyethylene pipe, it is helpful to understand some of the terminology and nomenclature associated with the stress rating of the PE material and the pressure rating of pipe and fittings made from that material.

Pressure Rating of Polyethylene Pipe

Fundamental to the pressure rating of polyethylene piping systems is the concept of the Long-Term Hydrostatic Strength (LTHS) of the material. ASTM D 1598, "Time-to- Failure of Plastic Pipe Under Constant Internal Pressure," is the standard test method by which polyethylene pipe samples are subjected to constant pressure and their time-to-failure is noted as a function of applied stress. Using the relationship known as the "ISO" equation, it is possible to relate the test pressure and pipe dimensions to the resultant hoop or circumferential stress generated in the wall of the pipe by that internal pressure. See the Engineering Properties chapter of this handbook for further information on the derivation of this equation. The ISO equation can be written for either outside diameter (Eq. 1) or inside diameter (Eq. 2) based pipe dimensions:

(1) $$S = \frac{P(OD - t)}{2t}$$

(2) $$S = \frac{P(ID + t)}{2t}$$

WHERE

S = Hoop Stress (psi or MPa)

P = Internal Pressure (psi or MPa)

ID = Average Inside Diameter (in or mm)

OD = Average Outside Diameter (in or mm)

t = Minimum Wall Thickness (in or mm)

After obtaining a number of stress vs. time-to-failure points it is possible to analyze the data to predict the estimated long-term performance of the piping material by calculating a long-term hydrostatic strength (LTHS) of the polyethylene material, and then categorizing the LTHS into a Hydrostatic Design Basis, or HDB, as shown in Table 4. The HDB then becomes the baseline strength for the material when performing any pressure rating calculations. The procedures for the extrapolation of the data are given in ASTM D 2837, "Obtaining Hydrostatic Design Basis for Thermoplastic Materials." This standard method contains not only the least squares calculations for obtaining the linear log-log regression equation of hoop stress vs. hours-to-failure, but also prescribes the minimum number of failure points, their distribution with respect to time, certain statistical tests for the quality of the data, its fit to the least squares line, and the maximum slope of the regression equation. At least one data point must exceed 10,000 hours. PPI's Technical Report 3, "Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strengths (MRS) Ratings for Thermoplastic Piping Materials or Pipe," gives very detailed information on how to properly develop and utilize this design criterion.

TABLE 4
LTHS and HDB Categories from ASTM D2837

Range of Calculated LTHS Values		Hydrostatic Design Basis	
psi	(MPa)	psi	(MPa)
190 to< 240	1.31 to< 1.65	200	1.38
240 to< 300	1.65 to< 2.07	250	1.72
300 to< 380	2.07 to< 2.62	315	2.17
380 to< 480	2.62 to< 3.31	400	2.76
480 to< 600	3.31 to< 4.14	500	3.45
600 to< 760	4.14 to< 5.24	630	4.34
760 to< 960	5.24 to< 6.62	800	5.52
960 to<1200	6.62 to< 8.27	1000	6.89
1200 to< 1530	8.27 to< 10.55	1250	8.62
1530 to< 1920	10.55 to< 13.24	1600	11.03
1920 to< 2400	13.24 to< 16.55	2000	13.79
2400 to< 3020	16.55 to< 20.82	2500	17.24
3020 to< 3830	20.82 to< 26.41	3150	21.72
3830 to< 4800	26.41 to< 33.09	4000	27.58
4800 to< 6040	33.09 to< 41.62	5000	34.47
6040 to< 6810	41.62 to< 46.92	6300	43.41
6810 to< 7920	46.92 to< 54.62	7100	48.92

The HDB categories are based on an R-10 series, wherein each HDB category is 125% of the preceding category. The range of calculated LTHS values allowed within an HDB category are -4% to +20% of the category value.

Figure 1 shows the log-log relationship of hoop stress vs. time-to-failure for a PE 3408 material tested in water at 73°F (23°C) according to ASTM D 1598. The solid line shown represents the least squares analysis of this data according to the techniques of ASTM D 2837. Note that although the actual test data is only approximately 10,000 hours, the line is extrapolated (dashed portion) to 100,000 hours (11.4 years). It is this projected hoop stress at 100,000 hours that is used to establish the Long-Term Hydrostatic Strength (LTHS). Again, referring to ASTM D 2837 (Table 1, therein), it is possible to place this LTHS within a hydrostatic design basis category (HDB).

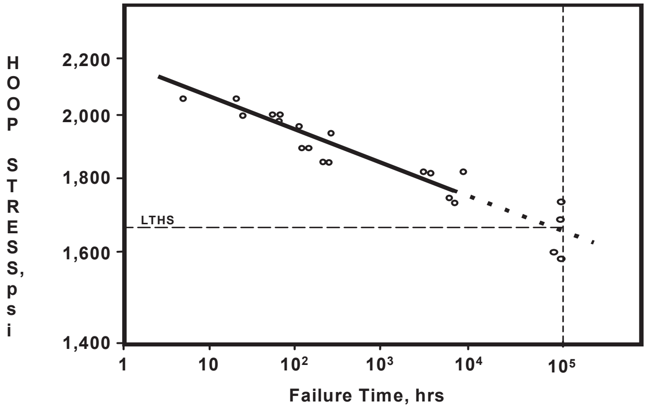

Figure 1 Typical Stress-Rupture Plot for PE 3408 Material

The 100.000-hour stress intercept established in ASTM D 2837 must also be "validated." Certain statistical hydrostatic testing conducted at higher temperatures is performed on specimens from the same lot of pipe material to insure that the curve determined in accordance with the ASTM D 2837 at 73°F remains linear throughout the 100,000 time period. That is to say that the polyethylene material being evaluated remains ductile in character over the course of the 100,000 regression analysis.

Design Factors And Hydrostatic Design Stress

It is necessary in designing plastic piping systems that the HDB be reduced by multiplying it with a design factor (DF) to allow for a greater margin of safety in use and to accommodate potential stresses on the pipe beyond those of internal or line pressure. Other factors to consider are: service and environmental conditions, temperatures higher than 73°F, other fluid mediums, etc. Current industry accepted design factors are 0.5 for water pressure service at 73°F (23°C) and 0.32 for natural gas distribution service. The more demanding and aggressive the application or service conditions, the smaller the design factor may need to be.

The reader should note that the evolution of polyethylene pipe usage has experienced progressive improvements in material science, technical performance and extrusion technology. As a result of this continual advancement in product capability, the design factors are subject to change as material and, hence, pipe performance improvements are recognized. The reader should consult with the pipe manufacturer regarding current recommendations for design factor in light of the anticipated service conditions.

Calculation of the hydrostatic design stress (HDS) is given by equation 3:

(3) $HDS = HDB \times DF$

WHERE
HDS = Hydrostatic Design Stress
HDB = Hydrostatic Design Basis
DF = Design Factor
= 0.50 for water service at 73°F
= 0.32 for natural gas distribution at 73°F

A more thorough discussion on design factors is presented in the design chapter of this Handbook, and additional information on Design Factors is given in PPI TR-9 *"Recommended Design Factors for Pressure Applications of Thermoplastic Pipe Materials."*

Dimensioning Systems

The standard dimensions for piping systems are an important part of the design for several reasons. The diameter of the pipe will dictate its ability to carry a needed volume of fluids. The wall thickness will dictate the strength of the pipe and it's ability to handle internal and external pressures as well as affecting the potential flow capacity. As such, the ratio of the diameter and wall thickness - known as the dimension ratio (DR) - becomes an important design factor for pipe. Standardization of these dimensions means it is possible for accessories such as fittings, valves, and installation equipment to be designed for a limited number of sizes, while at the same time, allowing for enough sizes to give the design engineer flexibility to build the system as needed.

ASTM standards include both imperial and metric dimensions for plastic pipe. For simplicity, metric dimensions are not included in this section.

Diameters

The diameter of the pipe can be either outside diameter or inside diameter. Depending on the calculations needing to be done, both numbers are important. Historically, anything called "pipe" has an inside diameter approximately equal to the nominal diameter of the pipe — 4" pipe has an ID of about 4". This general rule will vary depending on wall thickness. For Outside Diameter controlled pipe, the OD stays constant and the wall thickness changes for different pressure ratings. Tubing sizes are based on the outside diameter — 1" tubing has an OD of about 1". This is generally true as wall thickness affects the ID, not the OD of tubing.

Pipe outside diameters are based on one of several sizing systems. The most common on polyethylene pipe is the old Iron Pipe Size, or IPS, system. Since design familiarity was developed with these standard sizes, polyethylene pipe adopted them for continuity. Other sizing systems in use are Copper Tubing Sizes - CTS, and Ductile Iron Pipe Sizes - DIPS. A product standard will have a complete listing of sizes that are applicable to that standard. For ease of reference a complete set of HDPE pipe sizing tables is presented in the Appendix to Design Chapter 4 of this handbook.

Standard Dimension Ratio

The design of any piping systems is made easier by the use of standard dimension systems, based on either inside or outside pipe diameter. As mentioned earlier, the diameter divided by the wall thickness becomes an important design parameter. This result is called the Dimension Ratio - DR. The dimension ratio is very important for pipe design because the diameter to wall thickness relationship dictates the stress carrying capabilities of the pipe.

The dimension ratio, DR may be based on inside diameter (ID) controlled pipe or outside diameter (OD) controlled pipe.

Standard Inside Dimension Ratio (SIDR) is the ratio of the average specified inside diameter to the minimum specified wall thickness (D_i/t) for inside diameter controlled plastic pipe. In this system the inside diameter of the pipe remains constant and the OD changes with wall thickness. The standard intervals for this system are derived by subtracting one from the pertinent number selected from the ANSI Preferred Number Series 10. Some of the more common values are shown in Table 5.

TABLE 5
Standard Dimension Ratios Based on Controlled Inside or Outside Diameter Pipe

ANSI Preferred Number Series 10	SDR = Series 10 + 1	SIDR = Series 10 - 1
5.0	6.0	4.0
6.3	7.3	5.3
8.0	9.0	7.0
10.0	11.0	9.0
12.5	13.5	11.5
16.0	17.0	15.0
20.0	21.0	19.0
25.0	26.0	24.0
31.5	32.5	30.5
40.0	41.0	39.0
50.0	51.0	49.0
63.0	64.0	62.0

The Standard Dimension Ratio (SDR) is the ratio of the average specified outside diameter to the minimum specified wall thickness (D_o/t) for outside diameter-controlled plastic pipe. In this system the outside diameter of the pipe remains constant and the ID changes with wall thickness. The standard intervals for this system are derived by adding one to the pertinent number selected from the ANSI Preferred Number Series 10. Some of the more common SDR values are shown in Table 5.

Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, they are acceptable in engineered products when mutually agreed upon by the customer and manufacturer if (1) the pipe is manufactured from plastic compounds meeting the material requirements of the end use specification, and (2) the strength and design requirements are calculated on the same bases as those used in the end use specification.

The SDR system is of further use in that a table of pressure ratings can be constructed based on SDR regardless of the pipe's diameter. Utilizing SDR = OD / t (equation 3) for HDS and the accepted design factor (DF), the ISO equation (1) can be rewritten to calculate the maximum internal pressure a pipe can sustain over time.

(4)
$$P = \frac{2 \text{ x HDS x (DF)}}{(SDR - 1)}$$

WHERE

P = Internal pressure (psi or MPa)

HDS = Hydrostatic Design Stress (psi or MPa)

SDR = Standard Dimension Ratio

DF = Design Factor

= 0.50 for water at 73°F

Table 6 shows the pressure ratings for water applications of some of the more common SDR's and HDB's encountered in polyethylene piping system design, assuming a standard operating temperature of 73°F.

TABLE 6

Maximum Pressure Ratings of SDR Pipe at 73°F Using A Design Factor of 0.5

HDB, psi SDR	1600*	1250*	1000*
32.5	50	40	32
26	65	50	40
21	80	62	50
17	100	80	62
13.5	130	100	80
11	160	125	100

* Value shown are psig

Standard Specifications for Fittings and Joinings

One of the best attributes of PE pipe is its ability to be joined by heat fusion (butt, socket and saddle). Butt fusion is performed by heating the ends of the pipe and/or fitting with an electrically heated plate at about 400°F until the ends are molten. The ends are then forced together at a controlled rate and pressure, and held until cooled. Performed properly, this results in a joint that is integral with the pipe itself, is totally leak-proof, and is typically stronger than the pipe itself. Heat fusion joining can be also be used for saddle fusion of service lines from a main line — even while the main line is in service. Another type of heat fusion is electrofusion. The main difference between conventional heat fusion and electrofusion is the method by which heat is supplied.

While heat fusion is a good method for joining PE pipe and fittings, mechanical fittings are another option. Mechanical fittings consist of compression fittings, flanges, or other types of manufactured transition fittings. There are many types and styles of fittings available from which the user may choose. Each offers its particular advantages and limitations for each joining situation the user may encounter.

The chapter on joining polyethylene pipe within this Handbook provides more detailed information on these procedures. It should be noted that, at this time, there are no known adhesives or solvent cements that are suitable for joining polyethylene pipes.

Joining of polyethylene pipe can be done by either mechanical fittings or by heat fusion. All joints and fittings must be designed at the same high level of performance and integrity as the rest of the piping system. For gas distribution systems, the installation of a plastic pipe system must provide that joining techniques comply with Department of Transportation 49 CFR 192 subpart F-Joining of Materials Other Than by Welding. The general requirements for this subpart are:

General

a. The pipeline must be designed and installed so that each joint will sustain the longitudinal pullout or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading.

b. Each joint must be made in accordance with written procedures that have been proven by test or experience to produce strong, gas-tight joints.

c. Each joint must be inspected to ensure compliance with this subpart. Within 49 CFR 192 subpart F, 192.281 specifies selected requirements for plastic joints; 192.282 specifies requirements for qualifying joining procedures; 192.285 specifies qualifying persons to make joints; and 192.287 specifies inspection of joints.

Since fittings need to be able to handle the same stresses as the pipe, fusion fittings for polyethylene pipe are produced from the same stress rated materials as are used to make the pipe itself. However, since the geometry of the fittings is different from the pipe, the stress induced by internal pressure is different. Therefore, fittings are designed to handle a specific maximum working pressure and the pressure-to-stress equations based on OD and wall thickness may not apply. Typically, the fitting will be rated to handle the same stress as the pipe to which it is designed to be joined. If there is a question about the pressure rating of the fitting, contact the fitting manufacturer.

Specifications for socket, butt fusion, and electrofusion fittings have been developed by ASTM:

- D 2683 "Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Fittings."
- D 3261 "Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene Plastic Pipe and Tubing."
- F 1055 "Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing."
- D 2657 "Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings."

A generic joining procedure for polyethylene gas pipe has also been published by the PPI: TR-33 "Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe." In addition to these standards and procedures, each manufacturer will have published joining procedures for their pipe and/or fittings. Some of the relevant standards that pertain to fitting performance or joining practices are listed in the Appendix.

Codes, Standards and Recommended Practices for Polyethylene Piping Systems

There are a large number of codes, standards and practices that govern, or greatly influence the polyethylene piping industry. These standards cover a broad range of applications for polyethylene pipe and fittings. Some standards pertain to the product performance requirements for a specific application, while other standards are guidelines and practices detailing how a certain type of activity is to be performed. Some are test methods that define exactly how a particular test is to be run so that a direct comparison can be made between results. There are several standards writing organizations that deal directly with the manufacture, testing, performance, and use of polyethylene pipe and fittings. Some of the major codes and standards organizations are discussed below. A more inclusive listing can be found in the Appendix of this chapter.

Plastics Pipe Institute (PPI)

The Plastics Pipe Institute is a trade association dedicated to promoting the effective use of plastics piping systems. Prior sections of this chapter reviewed the subjects of PPI designations, pressure ratings and hydrostatic design basis (HDB). The assignment of a recommended hydrostatic design basis for a thermoplastic material falls under the jurisdiction of the Hydrostatic Stress Board - HSB - of the Plastics Pipe Institute. The Hydrostatic Stress Board has the responsibility of developing policies and procedures for the recommendation of the estimated long-term strength for commercial thermoplastic piping materials. The document most widely used for this is Technical Report-3, TR-3 "Policies and Procedures for Developing Hydrostatic Design Bases (HDB), Pressure Design Bases (PDB), Strength Design Bases (SDB), and Minimum Required Strengths (MRS) for Thermoplastic Piping Materials or Pipe." The material stress ratings themselves are published in TR-4, "PPI Listing of Hydrostatic Design Bases (HDB), Strength Design Bases (SDB), Pressure Design Bases (PDB) and Minimum Required Strengths (MRS) Ratings for Thermoplastic Piping Materials or Pipe." There are many other publications pertaining to various aspects of polyethylene pipe available from PPI such as: TN's - Technical Notes, TR's - Technical Reports, Model Specifications, and White Papers on specific positions addressed by the industry. Check the website www.plasticpipe.org for up-to-date publications.

Technical Report 3

TR-3 is a publication that is under the jurisdiction of the Hydrostatic Stress Board and is a compilation of the policies and procedures for recommending the stress or pressure rating of thermoplastic materials such as those used in pressure pipe and fitting or multi-layer pipes intended for use in pressure applications. This recommendation can be in the form of an HDB established according to ASTM D 2837, a PDB for a multi-layer pipe also established according to D 2837, a MRS established according to ISO TR9080, or an SDB established according to ASTM F 2018. In order to better understand the purpose and limitations of this document, it is strongly suggested that the Foreword and Notes to the Reader of TR-3 be read. Further questions should be directed to the Chairman of the HSB - who is the Technical Director of the Plastics Pipe Institute.

Technical Report 4

The recommendations of the Hydrostatic Stress Board are published in TR-4, "PPI Listing of Hydrostatic Design Bases (HDB), Strength Design Bases (SDB), Pressure Design Bases (PDB) and Minimum Required Strengths (MRS) Ratings for Thermoplastic Piping Materials or Pipe." TR-4 lists these thermoplastic piping materials according to the material type - PVC, CPVC, PE, PEX, POM, PVDF, and PA - and the HDB/HDS category for selected temperatures. It also lists the actual pressure ratings recommended for pipes of multi-layer construction which behave like thermoplastic piping materials during testing and can be evaluated by the same methodology. Again, the Foreword and Notes to the Reader should be studied to better understand how to apply these ratings.

Current printings of both TR-3 and TR-4 can be found at the PPI website at www.plasticpipe.org. It should also be noted that the PPI produces a number of related documents and publications to assist the designer or installer in the use HDPE pipe. These guides, reports, and technical notes are all available for download from the same website.

ASTM

The American Society for Testing and Materials (ASTM) is a consensus standards writing organization, and has published standards for a multitude of industries and applications. Those pertaining to polyethylene pipe are found in Volume 8.04 "Plastic Pipe and Building Products." ASTM employees do not write these standards; rather they are written by interested parties and experts within the industry who are members of ASTM. Most anyone can be a member of ASTM and participate in the standard writing process. Other standards, pertaining to plastics in general are found in other books within Volume 8 - 8.01, 8.02, or 8.03.

ASTM Standards pertaining to PE pipe can be a Standard Specification that defines the product requirements and performance for a specific application. It can also be a Standard Practice, which defines how a particular activity is to be performed, or a Standard Test Method, which defines how a particular test on PE pipe, fittings, or materials is to be done. While ASTM standards are mainly used in North America, many are also ANSI approved for international recognition, or are equivalent to an ISO standard. When a manufacturer prints the ASTM Standard on a product, the manufacturer is certifying that the product meets all of the requirements of that standard.

The typical sections covered in an ASTM Product Standard are:

Scope - what products and applications are covered under this standard.

Referenced Documents - what other standards or specifications are referenced in this standard.

Terminology - lists definitions that are specific to this standard.

Materials - defines material requirements for products that conform to this standard.

Requirements - details the performance requirements that the product must meet. This section will also contain dimensions.

Test Methods - details how the testing is to be performed to determine conformance to the performance requirements.

Marking - details the print that must be on the product. Includes the standard number, manufacturer's name, size, date of manufacture, and possibly the application such as "water." There may be other wording added to the print as the purchaser requires.

This is only a typical example of sections that may be included. While ASTM has defined protocol for product standards, each one may contain sections unique to that standard. Each standard should be reviewed individually for its requirements. A listing of major ASTM standards pertaining to PE pipe and fittings is in the Appendix. Current publications of these standards can be found at the website www.astm.org.

ISO

The International Organization for Standardization (ISO) is a network of national standards institutes from 140 countries working in partnership with international organizations, governments, industry, business and consumer representatives. It serves as a bridge between public and private sectors.

The ISO committee responsible for development of plastics pipe standards is Technical Committee 138. The committee's stated scope is: Standardization of pipes, fittings, valves and auxiliary equipment intended for the transport of fluids and made from all types of plastic materials, including all types of reinforced plastics. Metal fittings used with plastics pipes are also included. The main committee has seven subcommittees devoted to specific issues.

TC 138 has 35 participating countries, including the United States and Canada, and 27 observer countries. For ISO matters the United States is represented by the American National Standards Institute (ANSI). Canadian representation is through the Standards Council of Canada (SCC). The United States representation has been passed through ANSI to the Plastics Pipe Institute.

NSF International

NSF International plays a vital role in the use of polyethylene pipe and fittings for potable water applications. NSF is an independent, not-for-profit organization of scientists, engineers, educators and analysts. It is a trusted neutral agency, serving government, industry and consumers in achieving solutions to problems relating to public health and the environment. NSF standards are developed with the active participation of public health and other regulatory officials, users and industry. The standards specify the requirements for the products, and may include requirements relating to materials, design, construction, and performance. NSF has policies that establish additional requirements that a company must comply with to be able to obtain and maintain certification of products and authorization to use the NSF Mark for potable water applications.

There are two NSF Standards that are of particular importance to the polyethylene pipe and fittings industry: Standard 14, "Plastic Piping components and Related Materials" and Standard 61, "Drinking Water System Components-Health Effects." Standard 14 includes both performance requirements from product standards and provisions for health effects covered in Standard 61. NSF Standard 14 does not contain performance requirements itself, but rather NSF will certify that a product conforms to a certain ASTM, AWWA, etc... product performance standard. In order to be certified for potable water applications under Standard 14, the product must also satisfy the toxicological requirements of Standard 61.

It is also an option to be certified under Standard 61 only, without certifying the performance aspects of the product. In the early 1990's NSF separated the toxicological sections of Standard 14 into a new Standard 61. This was done for several reasons, but mainly to make it easier to bring new, innovative products to market without undue expense and time, while continuing to keep the public safe. This was a great benefit to the industry. Now manufacturers have a choice of staying with Standard 14 or switching to Standard 61. Many manufacturers who have in-house quality programs and the ability to perform the necessary tests switched to this new potable water certification option.

AWWA

The American Water Works Association (AWWA) is a leader in the development of water resource technology. While AWWA prepares and issues standards, they are not specifications. These standards describe minimum requirements and do not contain all of the engineering and administrative information normally contained in specifications. The AWWA standards usually contain options that must be evaluated by the user of the standard. Until each optional feature is specified by the user, the product or service is not fully defined. The use of AWWA standards is entirely voluntary. They are intended to represent a consensus of the water supply industry that the product described will provide satisfactory service.

There are currently two AWWA standards that pertain to polyethylene pipe: AWWA C901, "Polyethylene (PE) Pressure Pipe and Tubing, 1/2 inch through 3 inch, for Water Service" and AWWA C906, "Polyethylene (PE) Pressure Pipe and Fittings, 4 inch through 63 inches, for Water Distribution." Standard C901 addresses polyethylene pressure pipe and tubing for use primarily as potable water service lines in the construction of underground distribution systems. It includes dimensions for pipe and tubing made from PE materials with standard PE designations PE 2406 and PE 3408, in pressure classes of 80 psi, 100 psi, 125 psi, 160 psi and 200 psi. Pipe, ranging in nominal size from 1/2 inch through 3 inch conforms to outside-diameter dimensions of iron pipe sizes (OD based, IPS pipe) or to the inside-diameter dimensions of iron pipe sizes (ID based, IPS pipe). Tubing, ranging in size from 1/2 inch through 2 inch, conforms to the outside-diameter dimensions of copper tubing sizes (CTS). There are also sections on materials, testing and marking requirements; inspection and testing by manufacturer; and in-plant inspection by purchaser.

AWWA Standard C906 addresses larger diameter polyethylene pressure pipe made from materials conforming to standard PE designations PE 2406 and PE 3408. The pipe is primarily intended for use in transporting potable water in either buried or above-ground installations. The standard covers 10 dimension ratios (DR's) for nominal pipe sizes ranging from 4 inch through 63 inch. The available pipe sizes are limited by a maximum wall thickness of 3 inch. Pipe outside diameters (OD's) conform to the outside diameter dimensions of iron pipe sizes (IPS), ductile iron pipe size (DIPS), or those established by the International Organization for Standardization (ISO). Pressure class ratings range from 40 psi to 198 psi for PE 2406 materials, and from 51 psi to 254 psi for PE 3408 materials.

At the time of this writing, another important resource is being developed with the AWWA forum, Manual 55. This soon to be published AWWA manual is a design and installation guide for the use of polyethylene pipe in potable water applications. The manual is intended to supplement C901 and C906 and provide specific design recommendations as it relates to the use of polyethylene pipe in potable water systems. The publication of this important document is anticipated in 2006.

Plumbing Codes

Piping systems used in buildings must meet standards established in the plumbing code adopted by the jurisdiction in which the building is to be constructed. Within the United States there are several "model" codes, any one of which can be used as the basis for a local jurisdiction's code. Most widely used model codes include the International Plumbing Code (IPC), produced by the International Code Council (ICC) and the Uniform Plumbing Code (UPC), produced by the International Association of Plumbing and Mechanical Officials (IAPMO). One of the model codes may be adopted in its entirety or modified by the jurisdiction. Some states adopt a statewide code which municipalities may or may not be allowed to amend based on state law. Both designers and contractors need to be familiar with the code that applies to a particular project with a specific jurisdiction.

Other Codes and Standards

There are several other codes and standards writing organizations which pertain to polyethylene pipe. These groups usually have a type of certification program for products to be used in a certain industry or application, and may or may not write their own performance standards. If they do not write their own standards, they will certify products to an existing standard such as ASTM, AWWA, etc. The certification process will normally consist of an initial application stating what specific products are requesting certification, an on-site inspection of the production facilities, and testing of the product to assure performance to the relevant product specification. This is followed up by annual random inspections and product testing.

The Canadian Standards Association (CSA) provides a good example of the type of compliance certification program that relates to the use of polyethylene pipe in both water (CSA B137.1) and gas distribution (C137.4) applications. CSA's certification of compliance to the standards to which a particular polyethylene pipe is made allows the producer of that product to place the CSA mark on the product. The presence of the mark assures the purchaser that the product has met the requirements of the CSA certification program and insures that the product meets the appropriate product specifications as determined by the audits and inspections conducted by the Canadian Standards Association.

Factory Mutual

Factory Mutual Research (FM), an affiliate of FM Global, is a non-profit organization that specializes in property loss prevention knowledge. The area that pertains to HDPE pipe is the FM Standard "Plastic Pipe and Fittings for Underground Fire Protection Service." Certification to this standard may be required by an insurance company for any PE pipe and fittings being used in a fire water system. FM Global requires an initial inspection and audit of production facilities to be assured that the facility has the proper quality systems in place similar to ISO 9000 requirements. Then testing of the pipe must be witnessed by an FM representative. This testing must pass the requirements set forth in the FM Standard for PE pipe. After initial certification, unannounced audits are performed on at least an annual basis. More information can be found at their website www.fmglobal.com, or by calling at (401) 275-3000.

Conclusion

Polyethylene resins are produced to cover a very broad range of applications. The physical performance properties of these various formulations of polyethylene vary significantly making each grade suitable for a specific range of applications. To that end, the polyethylene pipe industry has worked diligently to establish effective standards and codes which will assist the designer in the selection and specification of piping systems produced from polyethylene materials which lend themselves to the type of service life sought. As such, the discussion which has been presented here should assist the designer and/or installer in his understanding of these standards and their significance relative to the use of these unique plastic piping materials.

Extensive reference has been made throughout the preceding discussion to standards writing or certifying organizations such as ASTM, AWWA, NSF, etc. The standards setting process is dynamic, as is the research and development that continues within the polyethylene pipe industry. As such, new standards and revisions of existing standards are developed on an ongoing basis. For this reason, the reader is encouraged to obtain copies of the most recent standards available from these various standards organizations.

References

1. ASTM Annual Book of Standards, Volume 8.03 Plastics, (III): D 3100 - Latest, American Society for Testing and Materials, West Conshohocken, PA.
2. ASTM Annual Book of Standards, Volume 8.04 Plastic Pipe and Building Products, American Society for Testing and Materials, West Conshohocken, PA.
3. Plastics Pipe Institute, Various Technical Reports, Technical Notes, Model Specifications, Washington, DC.
4. NSF Standard 14, Plastic Piping Components and Related Materials , NSF International, Ann Arbor, MI.
5. NSF Standard 61, Drinking Water System Components - Health Effects, NSF International, Ann Arbor, MI.

Appendix 1- Major Standards, Codes and Practices

General

ASTM

D 3350	Polyethylene Plastics Pipe and Fittings Materials
D 1598	Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
D 1599	Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing and Fittings
D 2122	Determining Dimensions of Thermoplastic Pipe and Fittings
D 2837	Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials
D 2488	Description and Identification of Soils (Visual-Manual Procedure)
D 2657	Heat-Joining Polyolefin Pipe and Fittings
D 2683	Socket Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing
F 412	Terminology Relating to Plastic Piping Systems
F 480	Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDRs), SCH 40, and SCH 80
F 948	Time-to-Failure of Plastic Piping Systems and Components Under Constant Internal Pressure With Flow
F 1055	Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing
F 1248	Test Method for Determination of Environmental Stress Crack Resistance (ESCR) of Polyethylene Pipe
F1290	Electrofusion Joining Polyolefin Pipe and Fittings
F 1473	Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins
F 1533	Deformed Polyethylene (PE) Liner
F 1901	Polyethylene (PE) Pipe and Fittings for Roof Drain Systems
F 1962	Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossing
F 2164	Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure
F 2231	Standard Test Method for Charpy Impact Test on Thin Specimens of Polyethylene Used in Pressurized Pipes
F 2263	Standard Test Method for Evaluating the Oxidative Resistance of Polyethylene (PE) Pipe to Chlorinated Water

PPI TECHNICAL REPORTS

TR-3	Policies and Procedures for Developing Hydrostatic Design Bases (HDB), Pressure Design Bases (PDB), Strength Design Bases (SDB), and Minimum Required Strengths (MRS) Ratings for Thermoplastic Piping Materials for Pipe
TR-4	PPI Listing of Hydrostatic Design Bases (HDB), Strength Design Bases (SDB), Pressure Design Bases (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe
TR-7	Recommended Methods for Calculation of Nominal Weight of Solid Wall Plastic Pipe
TR-9	Recommended Design Factors for Pressure Applications of Thermoplastic Pipe Materials
TR-11	Resistance of Thermoplastic Piping Materials to Micro- and Macro-Biological Attack
TR-14	Water Flow Characteristics of Thermoplastic Pipe
TR-18	Weatherability of Thermoplastic Piping Systems
TR-19	Thermoplastic Piping for the Transport of Chemicals
TR-21	Thermal Expansion and Contraction in Plastics Piping Systems
TR-30	Investigation of Maximum Temperatures Attained by Plastic Fuel Gas Pipe Inside Service Risers
TR-33	Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe
TR-34	Disinfection of Newly Constructed Polyethylene Water Mains
TR-35	Chemical & Abrasion Resistance of Corrugated Polyethylene Pipe
TR-36	Hydraulic Considerations for Corrugated Polyethylene Pipe
TR-37	CPPA Standard Specification (100-99) for Corrugated Polyethylene (PE) Pipe for Storm Sewer Applications
TR-38	Structural Design Method for Corrugated Polyethylene Pipe
TR-39	Structural Integrity of Non-Pressure Corrugated Polyethylene Pipe
TR-40	Evaluation of Fire Risk Related to Corrugated Polyethylene Pipe

PPI TECHNICAL NOTES

TN-4	Odorants in Plastic Fuel Gas Distribution Systems
TN-5	Equipment used in the Testing of Plastic Piping Components and Materials
TN-6	Polyethylene (PE) Coil Dimensions
TN-7	Nature of Hydrostatic Stress Rupture Curves
TN-11	Suggested Temperature Limits for the Operation and Installation of Thermoplastic Piping in Non-Pressure Applications
TN-13	General Guidelines for Butt, Saddle and Socket Fusion of Unlike Polyethylene Pipes and Fittings
TN-14	Plastic Pipe in Solar Heating Systems
TN-15	Resistance of Solid Wall Polyethylene Pipe to a Sanitary Sewage Environment
TN-16	Rate Process Method for Projecting Performance of Polyethylene Piping Components
TN-17	Cross-linked Polyethylene (PEX) Tubing
TN-18	Long-Term Strength (LTHS) by Temperature Interpolation.
TN-19	Pipe Stiffness for Buried Gravity Flow Pipes
TN-20	Special Precautions for Fusing Saddle Fittings to Live PE Fuel Gas Mains Pressurized on the Basis of a 0.40 Design Factor
TN-21	PPI PENT test investigation
TN-23	Guidelines for Establishing the Pressure Rating for Multilayer and Coextruded Plastic Pipes

Gas Pipe, Tubing and Fittings

ASTM

D 2513	Thermoplastic Gas Pressure Pipe, Tubing and Fittings
F 689	Determination of the Temperature of Above-Ground Plastic Gas Pressure Pipe Within Metallic Castings
F 1025	Selection and Use of Full-Encirclement-Type Band Clamps for Reinforcement or Repair of Punctures or Holes in Polyethylene Gas Pressure Pipe
F 1041	Squeeze-Off of Polyolefin Gas Pressure Pipe and Tubing
F 1563	Tools to Squeeze Off Polyethylene (PE) Gas Pipe or Tubing
F 1734	Practice for Qualification of a Combination of Squeeze Tool, Pipe, and Squeeze-Off Procedure to Avoid Long-Term Damage in Polyethylene (PE) Gas Pipe
F 1924	Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing
F 1948	Metallic Mechanical Fittings for Use on Outside Diameter Controlled Thermoplastic Gas Distribution Pipe and Tubing
F 1973	Factory Assembled Anodeless Risers and Transition Fittings in Polyethylene (PE) Fuel Gas Distribution Systems
F 2138	Standard Specification for Excess Flow Valves for Natural Gas Service

PPI

TR-22	Polyethylene Plastic Piping Distribution Systems for Components of Liquid Petroleum Gase
MS-2	Model Specification for Polyethylene Plastic Pipe, Tubing and Fittings for Natural Gas Distribution

OTHER STANDARDS FOR GAS PIPING APPLICATIONS

Title 49, CFR part 192	Transportation of Natural Gas and Other Gas by Pipe Line
AGA	AGA Plastic Pipe Manual for Gas Service (American Gas Association)
API	API Spec 15LE Specification for Polyethylene Line Pipe (American Petroleum Institute)

Water Pipe, Tubing and Fittings

ASTM

D 2104	Polyethylene (PE) Plastic Pipe, Schedule 40
D 2239	Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
D 2447	Polyethylene (PE) Plastic Pipe, Schedules 40 to 80, Based on Outside Diameter
D 2609	Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe
D 2683	Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
D 2737	Polyethylene (PE) Plastic Tubing
D 3035	Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter
D 3261	Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
F 405	Corrugated Polyethylene (PE) Tubing and Fittings
F 667	Large Diameter Corrugated Polyethylene (PE) Tubing and Fittings
F 714	Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Outside Diameter
F 771	Polyethylene (PE) Thermoplastic High-Pressure Irrigation Pipeline Systems
F 810	Smooth Wall Polyethylene (PE Pipe for Use in Drainage and Waste Disposal Absorption Fields
F 982	Polyethylene (PE) Corrugated Pipe with a Smooth Interior and Fittings
F 894	Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe
F 905	Qualification of Polyethylene Saddle Fusion Joints
F 1055	Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing
F 1056	Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings
F 1759	Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications
F 2206	Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock

PEX

F 876	Cross-linked Polyethylene (PEX) Tubing
F 877	Cross-linked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems
F 1281	Standard Specification for Cross-linked Polyethylene/Aluminum/ Cross-linked Polyethylene (PEX - AL -PEX) Pressure Pipe
F 1282	Standard Specification Polyethylene/Aluminum/ Polyethylene (PE -Al - PE) Composite Pressure Pipe
F 1807	Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR 9 Cross-linked Polyethylene (PEX) Tubing
F 1865	Mechanical Cold Expansion Insert Fitting With Compression Sleeve for Cross-linked Polyethylene (PEX) Tubing
F 1960	Mechanical Cold Expansion Insert Fittings with PEX Reinforcing Rings for Use with Cross-linked (PEX) Tubing
F 1961	Metal Mechanical Cold Flare Compression Fittings with Disc Spring for Cross-linked Polyethylene (PEX) Tubing
F 1974	Standard Specification for Metal Insert Fittings for Polyethylene/Aluminum/ Polyethylene and Cross-linked Polyethylene/Aluminum/ Crosslinked Polyethylene Composite Pressure Pipe
F 2023	Standard Test Method for Evaluating the Oxidative Resistance of Cross-linked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water
F 2080	Cold Expansion Fittings with Metal Compression Sleeves for Cross-linked Polyethylene (PEX) Pipe
F 2098	Stainless Steel Clamps for Securing SDR 9 Cross-linked Polyethylene (PEX) Tubing to Metal Insert Fittings
F 2159	Standard Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing
F 2262	Standard Specification for Cross-linked Polyethylene/Aluminum/ Crosslinked Polyethylene Tubing OD Controlled SDR9

PPI

MS-3	Model Specification for Polyethylene Plastic Pipe, Tubing and Fittings for Water Mains and Distribution

AWWA

C 901	Polyethylene (PE) Pressure Pipe, Tubing, and Fittings, 1/2 inch through 3 inch for Water Service
C 906	Polyethylene (PE) Pressure Pipe and Fittings, 4 inch through 63 inch for Water Distribution
M 55	AWWA Manual 55: PE Pipe - Design and Installation

CSA

B 137.1	Polyethylene Pipe, Tubing and Fittings for Cold Water Pressure Services
B137.4	Polyethylene Piping Systems for Gas Services (Canadian Standards Association)

Installation

ASTM

D 2321	Underground Installation of Flexible Thermoplastic Sewer Pipe
D 2774	Underground Installation of Thermoplastic Pressure Piping
F 449	Subsurface Installation of Corrugated Thermoplastic Tubing for Agricultural Drainage or Water Table Control
F 481	Installation of Thermoplastic Pipe and Corrugated Tubing in Septic Tank Leach Fields
F 585	Insertion of Flexible Polyethylene Pipe into Existing Sewers
F 645	Selection, Design and Installation of Thermoplastic Water Pressure Pipe System
F 690	Underground Installation of Thermoplastic Pressure Piping Irrigation Systems
F 1176	Design and Installation of Thermoplastic Irrigation Systems with Maximum Working Pressure of 63 psi
F 1417	Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air
F 1606	Standard Practice for Rehabilitation of Existing Sewers and Conduits with Deformed Polyethylene (PE) Liner
F 1668	Guide for Construction Procedures for Buried Plastic Pipe
F 1759	Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications
F 1743	Qualification of a Combination of Squeeze Tool, Pipe, and Squeeze-Off Procedures to Avoid Long-Term Damage in Polyethylene (PE) Gas Pipe
F 1804	Determine Allowable Tensile Load For Polyethylene (PE) Gas Pipe During Pull-in Installation
F 1962	Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe of Conduit Under Obstacles, Including River Crossings
F 2164	Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure

CONDUIT

F 2160	Standard Specification for Solid Wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)
F 2176	Standard Specification for Mechanical Couplings Used on Polyethylene Conduit, Duct, and Innerduct

ISO STANDARDS

9080	Thermoplastics pipes and fittings for the transport of fluid - Methods of extrapolation of hydrostatic stress rupture data to determine the long-term hydrostatic strength of thermoplastics pipe materials
4427	Polyethylene (PE) pipes for water supply
4437	Buried polyethylene (PE) pipes for the supply of gaseous fuels - Metric series - Specifications
12162	Thermoplastics materials for pipes and fittings for pressure applications - Classification and designation - Overall service (design) coefficient

AASHTO STANDARDS

M 252	Plastic and Corrugated Drainage Tubing
M 294	Corrugated Polyethylene Pipe, 12 to 24 inch Diameter
F 2136	Standard Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack Growth Resistance of HDPE Resins or HDPE Corrugated Pipe

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

S376.1	Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipelines