Chapter 5

Standard Specifications, Standard Test Methods and Codes for PE (Polyethylene) Piping Systems

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Introduction

The specification, design and use of PE piping systems is addressed by a number of standard specifications, standard test methods and codes including those issued by ASTM International (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 (PPI). A listing of the more frequently referenced standards, reports and recommendations is presented in the Appendix to this Chapter.

This Chapter covers topics relating to PE pipe of solid wall or of profile wall construction. These topics include:

1. Material specifications relating to properties and classifications of PE materials for piping applications.

2. Standard requirements relating to pipe pressure rating, dimensions, fittings and joints.

3. Codes, standards and recommended practices governing the application of PE pipe systems in a variety of end uses.

Readers seeking information on PE pipes of corrugated wall construction are invited to visit PPI's web site at http://plasticpipe.org/drainage/index.html

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Standard Requirements for PE Piping Materials

As discussed in Chapter 3, polyethylene (PE) is a complex polymer with properties that can be optimized based on the desired end use. Such modifications are effected by choice of catalyst system, polymerization conditions and, the use of a small quantity of co-monomer (a monomer or monomers other than ethylene). All these changes allow PE to be tailor made to a wide range of processing and performance requirements.

For classifying this wide array of property variations that find use in piping applications, ASTM issued standard D 3350, "Standard Specification for Polyethylene Plastic Pipe and Fittings Materials". This standard recognizes six properties that are considered important in the manufacture of PE piping, in the heat fusion joining of this material and, in defining its long-term performance capabilities. Each property is assigned into a "Cell" and, each cell consists of a number of "Classes". A cell number covers a narrow range of the larger overall range that is covered by a property "cell". These D 3350 property cells and classes are identified in Table 1.

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TABLE 1

Cell Classification System from ASTM D 3350-06 [1,2]

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 b. Test duration, hours c. Failure, max. %			A 48 50	B 24 50	C 192 20	C 600 20	— — —	— — —	— — —	specify value
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 1-A: Refer to 10.1.4.1 (ASTM D 3350) B: NPR = Not Pressure Rated, 1.) D 3350 is subject to periodic revisions, contact ASTM to obtain the latest version, 2.) The property and density are measured on the PE base resin; all the other property values are measured on the final compound.

In addition, by means of a Code letter, ASTM D3350 designates whether the material includes a colorant and also, the nature of the stabilizer that is included for protecting the material against the potential damaging effects of the ultraviolet (UV) rays in sunlight. Table 2 lists the Code letters that are used in D 3350 and what they reprsent.

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TABLE 2

Code Letter Representation

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

For designating a PE material in accordance with ASTM D 3350 the cell number for each cell property is identified, and this is done in the same order as shown in Table 1. This is then followed by an appropriate Code letter to indicate color and stabilization as shown in Table 2. An example of this material designation system is presented in Table 3 for the case of a PE material having designation code PE445574C.

TABLE 3

Properties of a Cell number PE445574 Material

Digit Designating the Applicable Property Cell(1)	Class Number or Code Letter	Corresponding Value of Property (from Table1)
1st Digit – Density of PE base resin, gm/cm^3	4	>0.947 – 0.955
2nd Digit – Melt Index of compound, gm/10 minutes	4	<0.15
3rd Digit – Flexural Modulus of compound, psi (MPa)	5	110,000 - < 160,000 (758 - <1103)
4th Digit – Tensile Strength at Yield of compound, psi (MPa)	5	3,500 - <4,000 (24 - <28)
5th Digit – Resistance to Slow Crack Growth of compound (SCG), hrs.	7	500 minimum based on PENT test
6th Digit – Hydrostatic Design Basis for water at 73°F(23°C), psi of compound (MPa)	4	1600 (11.03)
Code Letter	C	Black with 2% minimum carbon black

(1) The density is that of the PE resin. All the other properties are determined on the final compounded material.

A PE material that complies with the Table 3 cell designation i.e. PE445574C would be a higher density (higher crystallinity), lower melt index (higher molecular weight) material that exhibits exceptionally high resistance to slow crack growth. In addition, it offers a hydrostatic design basis (HDB) for water at 73°F (23°C) of 1600 psi (11.03 MPa). Finally, it would be black and contain a minimum of 2% carbon black.

The cell classification system provides the design engineer with a very useful tool in specifying the requirements of PE materials for piping projects.

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Standard PE Piping Material Designation Code

While all PE piping standards specify minimum material requirements based the on the cell requirements of ASTM D3350, a simpler, short-hand, ASTM recognized material designation code is commonly used for quickly identifying the most significant engineering properties of a PE pipe material. An important feature of this designation code is that it identifies the maximum recommended hydrostatic design stress (HDS) for water, at 73°F(23°C). Originally, this designation code was devised to only apply to materials intended for pressure piping. However, there is a recognition that even in non-pressure applications stresses are generated which makes it prudent to use a stress rated material. This has led to the common practice of using this material designation code for quickly identifying all PE piping materials intended for pipes of solid wall or, of profile wall construction.

This code is defined in ASTM F412, "Standard Terminology Relating to Plastic Piping Systems", under the definition for the term code, thermoplastic pipe materials designation. It consists of the ASTM approved abbreviation for the pipe material followed by four digits (e.g., PE4710). The information delivered by this code is as follows:

- The ASTM recognized abbreviation for the piping material. PE, in the case of polyethylene materials.
- The first digit identifies the density range of the base PE resin, in accordance with ASTM D3350, that is used in the material. As discussed in Chapter 3, the density of a PE polymer reflects the polymer's crystallinity which, in turn, is the principal determinant of the final material's strength and stiffness properties.
- The second digit identifies the compound's resistance to slow crack growth (SCG), also in accordance with ASTM D3350. A material's resistance to SCG relates very strongly to its long-term ductility, a property that defines the material's capacity for safely resisting the effects of localized stress intensifications.
- The last two numbers identify the compound's maximum recommended hydrostatic design stress (HDS) category (1) for water, at 73°F(23°C). This recommendation is established in consideration of various factors but, primarily the following: The capacity for safely resisting the relatively well distributed stresses that are generated only by internal pressure, and, the capacity for safely resisting add-on effects caused by localized stress intensifications.(1)

(1) More discussion on these topics later in this Chapter.

The Standard Designation Codes for materials which are recognized as of this writing by current ASTM, AWWA, CSA and other standards are listed in Table 4. This table gives a brief explanation of the significance of the code digits. It should be recognized that a new material may be commercialized which qualifies for a code designation that has not been recognized as of this writing. For a listing of the most current recognized code designations the reader is invited to consult the periodically updated PPI publication TR-4. Contact PPI via their website, www.plasticpipe.org

TABLE 4
Standard Designation Codes for Current Commercially Available PE Piping Compositions

Standard Designation Code	What the Digits in the Code Denote		
	The 1st Digit	The 2nd Digit	The last two Digits[1]
	Cell Number Based on the Density Cell In accordance with ASTM D3350 (See Table 1)	Cell Number Based on the Resistance to SCG Cell In accordance with ASTM D3350 [2] (See Table 1)	Recommended Standard Hydrostatic Design Stress (HDS) Category, for water, at 73°F (23°C) (psi)
PE2406	Cell number 2	Cell number 4	630
PE2708		Cell number 7	800
PE3408	Cell number 3	Cell number 4	800
PE3608		Cell number 6	
PE3708		Cell number 7	800
PE3710			1,000
PE4708	Cell number 4	Cell number 7	800
PE4710			1,000

(1) The last two digits code the Standard HDS Category in units of 100psi. For example, 06 is the code for 630psi and 10 is the code for 1,000psi.

(2) It should be noted that the lowest Cell number for SCG resistance for pipe is 4. Based on research and experience a rating of at least 4 has been determined as sufficient for the safe absorption of localized stresses for properly installed PE pipe.

Standard Equation for Determining the Major Stress Induced in a Pressurized Pipe

There are two major stresses which are induced in the wall of a closed cylindrical vessel, such as a pipe, when it is subjected to internal fluid pressure. One runs along the axis of the vessel, often called the axial (longitudinal) stress, and the other, which is often called the hoop stress, runs along its circumference. Since the magnitude of the hoop stress is about twice that of the axial stress the hoop stress is considered as the significant stress for purposes of pressure pipe design.

The hoop stress is not constant across a pipe's wall thickness. It tends to be larger on the inside than on the outside of a pipe. And, this tendency is heightened in the case of materials having high stiffness and in thicker walled pipes. However, in the case of pipes made from thermoplastics – materials which are characterized by significantly lower stiffness than metals – it has long been accepted that the hoop stress is constant through the pipe's wall thickness. For such case the so called thin-walled hoop stress equation is accepted as satisfactory and it has been adopted by standards which

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cover thermoplastics pipe. This equation, which more commonly is identified as the ISO (International Organization for Standardization) equation because it has been also adopted for thermoplastic pipes by that organization, is as follows:

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

WHERE

S **= Hoop stress (psi or, MPa)**

P **= Internal pressure (psi or, MPa)**

D_m **= Mean diameter (in or, mm)**

t **= minimum wall thickness, (in or, mm)**

Because PE pipe is made either to controlled outside diameters or in some cases, to controlled inside diameters the above equation appears in PE pipe standards in one of the following forms:

When the pipe is made to a controlled outside diameter:

(2) $$S = \frac{P}{2}\left[\frac{D_o}{t} - 1\right]$$

Where Do is the average outside diameter

When the pipe is made to a controlled inside diameter:

(3) $$S = \frac{P}{2}\left[\frac{D_o}{t} + 1\right]$$

Where Di is the average inside diameter

For purposes of pressure pipe design, the pipe's pressure rating (PR) is determined by the hydrostatic design stress (HDS) that is assigned to the material from which the pipe is made. Therefore, Equation (2) can be re-arranged and written in terms of HDS and as follows:

(4) $$PR = \frac{2\,(HDS)}{\left[\frac{D_o}{t} - 1\right]}$$

Where PR is the pressure rating (psi or, MPa) and HDS is the hydrostatic design stress (psi or, MPa)

And, Equation (3) becomes:

(5) $$PR = \frac{2\,(HDS)}{\left[\frac{D_t}{t} + 1\right]}$$

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The term D_o/t is referred to as the *outside diameter dimension ratio* and the term D_i/t as the *inside diameter dimension ratio*. However, the convention in PE pipe standards is to limit these ratios to a standard few. The ASTM terms and abbreviations for these preferences are:

- *Standard Dimension Ratio (SDR)*, for a standard D_o/t dimension ratio
- *Standard Inside Diameter Ratio (SIDR)*, for a standard D_i/t dimension ratio

Standard Diameters

Standard specifications for PE pipe allow the pipe to be made to either controlled inside diameters or, to controlled outside diameters. The inside diameter system, applicable to small diameter sizes only, is intended for use with insert type fittings for which the pipe must have a predicable inside diameter, independent of pipe wall thickness. And the outside diameter systems are intended for use with fittings that require a predictable outside diameter, also independent of wall thickness.

There is but one standard inside diameter sizing convention, SIDR , and this system is based on the inside diameters of the Schedule 40 series of iron pipe sizes (IPS). But there are four standard outside diameter sizing conventions and these are as follows:

- The outside diameters specified for iron pipe sized (IPS) pipe
- The outside diameters specified for ductile iron pipe sizes (DIPS)
- The outside diameters specified for copper tubing sizes (CTS)
- The outside diameters specified by the International Standards Organization (ISO 161/1)

The scope of a consensus standard usually identifies the sizing convention system that is covered by that standard.

PE Pipe Standards are Simplified by the Use of Preferred Values

The most widely accepted standards for PE pipes are those that define pipes which when made to the same Dimension Ratio and from the same kind of material are able to offer the same pressure rating independent of pipe size (See Equations 4 and 5). These standards are commonly referred to as Dimension Ratio/Pressure Rated (DR-PR) so as to distinguish them from other standards, such as those based on Schedule 40 and 80 dimensioning, in which the Dimension Ratio varies from one size to the next.

For the purpose of limiting standard pressure ratings (PR) in DR-PR standards to just those few which adequately satisfy common application requirements these standards require that the Dimension Ratios be one of certain series of established preferred numbers. They also require that the pipe's pressure rating be determined based on a recognized HDS category that is also expressed in terms of a preferred

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number (See previous discussion on PE pipe material designation code). The preferred numbers for both are derived from the ANSI Preferred Numbers, Series 10. The Series 10 numbers get that name because ten specified steps are required to affect a rise from one power of ten to the next one. Each ascending step represents an increase of about 25% over the previous value. For example, the following are the ANSI specified steps between 10 and 100: are 10; 12.5; 16.0; 20.0; 25.0; 31.5; 40.0; 50.0; 63.0; 80.0; 100.

A beneficial feature of the use of preferred numbers is that when a preferred number is multiplied or, is divided by another preferred number the result is always a preferred number.

The table that follows lists the Standard Dimension Ratios, all based on preferred numbers, which appear in the various ASTM, AWWA and CSA DR-PR based standards for PE pipe.

TABLE 5
Standard Dimension Ratios (SDRs)

Based on Mean Diameter (D_m/t) (Same numerical value as ANSI Preferred Number, Series 10)	Based on Outside Diameter SDR = (D_o/t (Series 10 Number + 1)	Based on Inside Diameter SIDR = (D_i/t) (Series 10 Number – 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 recognized standard HDS categories for water, at 73°F (23°C), are: 630 psi (4.34 MPa); 800 psi (5.52 MPa); and 1,000psi (6.90 MPa) (See discussion under the heading, Standard PE Piping Material Designation Code).

And, the standard pressure ratings for water, at 73°F (23°C), which are commonly recognized by DR-PR standard specifications for PE pipe are as follows: 250; 200; 160; 125; 100; 80; 63; 50; and 40 psig. However, individual standards generally only cover a selected portion of this broad range.

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The result of the use of these standard preferred number values is that a pipe's standard pressure rating (PR) is a consistent result, independent of pipe size, which simply depends on its standard dimension ratio and the standard HDS of the material from which the pipe was made. This relationship is shown in Table 6, as follows.

TABLE 6
Standard Pressure Ratings for Water, at 73°F (23°C), for SDR-PR Pipes, psig (1)

Standard Dimension Ratio		Standard Pressure Rating (psig) as a function of a Material's HDS for Water, at 73°F (23°C), psi		
SDR (In the Case of Pipes Made to Standard OD's)	SIDR (In the Case of Pipes Made to Standard ID's)	HDS = 630psi (4.34 MPa)	HDS = 800psi (5.52 MPa)	HDS = 1000psi (6.90 MPa)
32.5	30.5	40	50	63
26.0	24.0	50	63	80
21.0	19.0	63	80	100
17.0	15.0	80	100	125
13.5	11.5	100	125	160
11.0	9.0	125	160	200
9.0	7.0	160	200	250

(1) Note: The Standard Pressure Ratings are the calculated values using equations (4) and (5) but with a slight rounding-off so that they conform to a preferred number.

Although the adoption of preferred numbers by the ASTM, CSA and AWWA DR-PR based standards is very widespread, there are a few exceptions. In some DR-PR standards a non-preferred Diameter Ratio has been included so as to define pipes which offer a pressure rating that more closely meets a particular application requirement. In addition, where existing system conditions or special requirements may be better served by other than standard diameters or Standard Dimension Ratios many standards allow for the manufacture of custom sized pipe provided all the performance and quality control requirements of the standard are satisfied and also, provided the proposed changes are restricted to pipe dimensions and that these changes are mutually agreed upon by the manufacturer and the purchaser.

Determining a PE's Appropriate Hydrostatic Design Stress (HDS) Category

As stated earlier, the last two digits of the PE pipe material designation code indicate the material's maximum allowable HDS for water, at 73°F (23°C). This value of HDS is then used for the determining of a pipe's pressure rating. This practice of using an allowable stress, instead of basing design on a particular measure of strength that is reduced by a specified "factor of safety", is recognized by many standards and codes that cover other kinds of pipes and materials. One reason for avoiding the specifying of a factor of safety is that it is misleading because it implies a greater degree of safety

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than actually exists. This is because a particular laboratory measure of strength only defines a material's reaction to a certain kind of a major test stress whereas, in an actual installation a material can also be subjected to other add-on stresses which can have a significant effect on ultimate performance. To provide a satisfactory cushion against the effect of these add-on stresses the chosen measure of strength is reduced by an appropriate strength reduction factor. But, as can be appreciated, the magnitude of this factor needs to be greater than the resultant true factor of safety.

As discussed in Chapter 3, it is recognized that a very significant strength of PE pressure pipe is its long-term hoop strength based on which it resists the effects of sustained internal hydrostatic pressure. The manner by which this long-term hydrostatic strength (LTHS) is forecast and, the reduction of the resultant LTHS into one of a limited hydrostatic design basis (HDB) strength categories is also described in Chapter 3. As implied by its name, the HDB is a design basis the limitations of which need to be recognized when using it for the establishment of a hydrostatic design stress (HDS). This is done by the choice of an appropriate strength reduction factor. This factor has many functions, but one of the more important ones is the providing of a suitable cushion for the safe absorption of all stresses the pipe may see in actual service, not just the stresses upon which the material's HDB has been determined.

So as not to mistake this strength reduction factor for a true factor of safety it has been designated as a design factor (DF). Furthermore, this factor is a multiplier, having a value of less than 1.0, as compared to a factor of safety which normally is a divisor having a value greater than 1.0. For consistency in design, the DF's are also expressed in terms of a preferred number. Therefore, when an HDB – which is expressed in terms of a preferred number – is reduced by a DF – also, a preferred number – it yields an HDS that is always a preferred number. The resultant value of this HDS becomes part of the standard PE material code designation.

Determining the Appropriate Value of HDS

As explained in Chapter 3, HDB of a PE pipe material is determined on the basis of PE pipe samples that are only subjected to the relatively well distributed stresses that are generated by internal pressure. This test model does not expose the test pipe to other stresses, in particular to the very localized stresses that are intensified by external causes such as by stone impingement or, by scratches and gouges or, by geometric effects inherent in fittings and joints. Extensive field experience and studies indicate that in the case of certain older generation PE materials which have been shown to exhibit low resistance to slow crack growth (SCG) localized stress intensifications can initiate and then, propagate the growth of slowly growing cracks. After some time, when these cracks grow to a size where they span through a pipe's entire wall thickness the end result is a localized fracture. As is the case for traditional

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piping materials, and as it has been demonstrated to be also the case for plastics, the potential damaging effect of a localized stress intensification depends strongly on the material's ability to safely deform locally and thereby, blunt a nascent crack, a reaction that reduces the magnitude of the localized stress. A feature of modern high performance PE materials is that they offer this ability to a significantly high degree.

To avoid the chance of a failure by the slow crack mechanism a three-fold approach has proven to be very successful:

1. PE pipe, and for that matter, pipe made from any material needs to be handled, joined and installed so as to minimize the development of excessive localized stress intensifications. Requirements for proper handling, joining and installing of PE piping – which are not at all onerous – are covered by standards, guides and manuals issued by ASTM, AWWA and other organizations. They are also described in this Handbook.

2. PE piping materials need to offer adequate resistance to slow crack growth (SCG). All Current commercially available materials meet not less than Cell number 4 of the requirement for resistance to SCG Cell that is specified by ASTM D3350. However, the newer generation of high performance materials have far superior resistance to slow crack growth and therefore, qualify for the Cell number 7 requirement for this property(See Table 1).

3. The design factor (DF) based on which an HDB (hydrostatic design basis) is reduced to and HDS (hydrostatic design stress) needs to leave sufficient cushion for the safe absorption of stresses that are in addition to those upon which the HDB has been established. While the DF has many roles, this is one of the more important ones.

Over 40 years of actual experience and many studies regarding the fracture mechanics behavior of PE pipe materials have shown that when the first two approaches are in play – a principal objective of standards for PE piping – the establishment of an HDS by the reduction of an HDB by means of a DF = 0.50 results in a very reliable and very durable field performance. However, more recent developments in the manufacture of PE resin have resulted in the availability of higher performance PE's that offer exceptional resistance to SCG. These materials, which exceed the requirements for Cell number 7 of the SCG cell in ASTM 3350, have demonstrated that they have a significantly greater capacity for safely shedding-off localized stress intensifications. Consequently, the HDS for these materials does not need to provide the same cushion against localized stress intensifications as established for the traditional materials. It has been determined that for such high performance materials a DF of 0.63 is proven to be reliable.

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For a PE pipe material to qualify as a high performance material it must be experimentally demonstrated that it meets the following three requirements:

1. By means of supplementary elevated temperature stress-rupture testing followed by a Rate Process Analysis of the test results it must be demonstrated that at 73°F (23°C) the slope of the stress regression line shall remain linear out to at least 50 years. This means that the failure mode of test samples remains in the ductile region for at least this same time period. This test protocol is referred to as the Substantiation requirement (See Chapter 3 for a discussion of Rate Process and Substantiation methodologies). Such performance at the higher test stresses is an indicator of a PE's very high resistance to SCG at the lower operating stresses.

2. The resistance to SCG of the composition must qualify it for Cell number 7 of the Slow Crack Growth Resistance Cell of ASTM D3350. To qualify, the failure time must exceed 500 hrs when the material is evaluated in accordance with method ASTM F1473. This is a fracture mechanics based method (Described in Chapter 3) which yields an index – one that has been calibrated against actual quality of longer-term field experience – of a PE's capacity for resisting localized stress intensifications that are caused by external (i.e., non-pressure) causes.

3. The LCL (lower confidence limit) ratio of the stress rupture data for these high performance materials has been raised to a minimum of 90 percent. This ratio represents the amount of scatter in the data; it means that the minimum predicted value of the LTS (long term strength) based on statistical analysis of the data shall not be less than 90 percent of it's average predicted value.

A PE material which qualifies for the second of these three requirements is identified by the number 7 as the second numeral in the PE pipe material designation code (For example, PE4710 and PE2708).

It should be evident from the above discussion that the HDS of a PE pipe material is not solely determined by its HDB, a measure of the material's capacity for resisting stresses induced by internal hydrostatic pressure. The HDS that is established needs also to reflect the material's capacity for safely shedding off add-on stresses. Thus, even if two PE pipe materials have the same HDB their allowable HDS's can be different. For this reason PE pipe standards designate a PE by its pipe material designation code, a code which both identifies the material's resistance to SCG and its recommended HDS (See Table 4). The pipe's pressure rating for the standard condition of water and 73°F (23°C) is derived from this HDS. Table A.2 in Chapter 3 (Appendix) lists factors for the determining of a pipe's pressure rating for other temperatures.

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As pointed out in Item 3 under this Section's introductory paragraph, the DF has other important roles than just that of allowing for the safe absorption of other than the stresses that are induced by hydrostatic pressure. Included among these roles are the following:

- The hydrostatic design basis (HDB), upon which a DF is applied, is but a design basis that has been established based on a forecast of the average value of the material's hydrostatic strength at a loading that is continually sustained for 100,000hrs (11.4yrs). The DF must give recognition to the fact that a PE's minimum strength is actually somewhat below its predicted average and that the resultant HDS is intended for a loading duration that shall be substantially longer than 11.4 years.
- The forecasted value of a material's long-term hydrostatic strength (LTHS) is established using "perfect" test pipes that have not been subjected to the normal effects of handling and installation and that include no typical components of a piping system.
- The minimum value of material's long-term strength may somewhat vary due to normal variabilities in the processes that are used both in the manufacture of the pipe material and the pipe.
- The forecasted value of a material's LTHS has been established under conditions of constant pressure and temperature whereas in actual service these can vary.

A Widely Recognized Source of HDS Recommendations

Most PE pipe standards that are issued by ASTM establish PE pipe pressure ratings based on the HDS's that are recommended by the Hydrostatic Stress Board (HSB) of the Plastics Pipe Institute. This group has been issuing HDS recommendations for commercial grade materials since the early 1960's. The membership of the HSB is constituted of persons who are recognized experts in the technology of thermoplastic pressure pipe. These experts include representatives from material and pipe producers, testing laboratories, trade associations, a regulatory agency and private consultants. And, all major thermoplastic pipe materials are represented, including polyvinyl chloride (PVC), chlorinated PVC (CPVC), polyethylene (PE), and cross-linked PE (PEX).

The HDS recommendations that are issued by the HSB are based upon a close review of detailed longer-term stress rupture data and they take into account the various factors, as above discussed, that need to be considered when establishing an HDS. The HSB's policies regarding data requirements are presented in PPI publication TR-3, "Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis, and Minimum Required Strength (MRS) Ratings for Thermoplastic Pipe

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Materials or Pipe". A listing of HDS recommendations is offered in the periodically updated publication TR-4, "PPI Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials".

A current edition of both TR-2 and TR-4 can be found at the PPI website www.plasticpipe.org. Also available at this website are other reports, recommendations, notes and model specifications intended to assist users and designers in the optimum use of PE pipe. Each of these publications may be downloaded from this website.

Standard Specifications for Fittings and Joints

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 also be used for connecting service lines to mains using saddle fittings — 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. More complete details of the fusion joining procedure and other methods of joining PE pipe can be found in Chapter 9, "PE Pipe Joining Procedures".

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:

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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 PE fittings are also subjected to stresses they must also be produced from stress rated PE materials. However, since the geometry of the fittings is different from the pipe, the stress fields induced by internal pressure and by external causes are more complex. Because of this, there are no simple equations that can be used for the design of pressure rated fittings. The practice is to establish fitting pressure ratings by means of testing. Typically, the fitting will be rated to handle the same pressure as the pipe to which it is designed to be joined. If there is a question about the pressure rating of the fitting, the reader is advised to contact the manufacturer.

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

- 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."

Generic fusion procedures for PE pipe products have also been published by the Plastic Pipe Institute (PPI). They include, TR 33 " Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe" and TR 41 "Generic Saddle 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.

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Codes, Standards and Recommended Practices for PE Piping Systems

There are a large number of codes, standards and practices that apply to the use of PE piping. These consensus documents cover a broad range of applications for PE 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 organizations that issue standards, codes of practice, manuals, guides, and recommendations that deal with the manufacture, testing, performance, and use of PE pipe and fittings. Some of the major ones 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 proper and effective use of plastics piping systems. 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.

It should be noted that while the Hydrostatic Stress Board (HSB) is a division of the Plastics Pipe Institute, involved in the development and issuance of policies, procedures, and listings of stress and pressure ratings for all thermoplastic pipe materials, PPI itself is an industry association focused on the promotion and effective and proper use of pipe primarily made from polyethylene (PE), cross linked polyethylene (PEX), and polyamide (POM) materials.

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ASTM

ASTM International is a consensus standards writing organization, and has published standards for a multitude of materials, products, practices 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 approved by the American National Standards Institute (ANSI) for international recognition, or are equivalent to an International Standards Organization (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 included 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.

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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.

The ISO committee having jurisdiction 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 who had delegated it down to ASTM and, who in turn, had delegated it to the Plastics Pipe Institute.

NSF International

NSF International plays a vital role in the use of pipe and fittings for potable water and plumbing 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 has three essential missions, as follows:

1. To issue standards that establish the necessary public health and safety requirements for thermoplastic piping materials and for piping products intended for use in the transport of potable water and for drainage and venting systems in plumbing applications.
2. To establish the appropriate test methods by which these requirements are evaluated.
3. To offer a certification program which affirms that a particular product which carries an NSF seal is in compliance with the applicable NSF requirements

NSF standards are developed with the active participation of public health and other regulatory officials, users and industry. The standards specify the requirements

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for the products, and may include requirements relating to materials, design, construction, and performance.

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.

For products intended for potable water applications, 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. These AWWA standards describe minimum requirements and do not contain all of the engineering and administrative information normally contained in a specification that is written for a particular project. 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 PE 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 to pressure classes of 80 psi, 100 psi, 125 psi, 160 psi and 250 psi.

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This standard covers PE pipe in nominal sizes from ½ inch through 3 inch that are made to controlled outside-diameters based on iron pipe sizes i.e. (OD based IPS size) and also to controlled inside-diameter based on iron pipe sizes i.e. (ID based IPS size). It also covers tubing, ranging in size from ½ inch through 2 inch that 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 PE pressure pipe. The pipe is primarily intended for use in transporting potable water in either buried or above-ground installations. The standard covers 10 standard dimension ratios (SDR'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 Standards Organization (ISO). Pressure class ratings range from 40 to 250 psig.

AWWA has also published a manual M55, "PE Pipe-Design and Installation". This manual is a design and installation guide for the use of polyethylene pipe in potable water applications. The manual supplements C901 and C906 and provides specific design recommendations as it relates to the use of PE pipe in potable water systems.

Standard Plumbing Codes

Piping systems used in buildings must meet standards that are recognized by the plumbing code adopted by the jurisdiction in which the building is to be located. 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.

ASME B31.3, Chemical Plant and Petroleum Refinery Piping Code

The proper and safe usage of plastics piping in industrial applications demands that close attention be paid in the design, selection and installation of such piping. Safe design rules and guidelines are set forth in the ASME B31.3 Piping Code. In this code the requirements for plastics piping, including those for PE, are placed in a separate Chapter V1, titled "Nonmetallic Piping and Piping Lined with Nonmetals".

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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 PE 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

PE resins are produced to cover a very broad range of applications. The physical performance properties of these various formulations of PE vary significantly making each grade suitable for a specific range of applications. To that end, the PE pipe industry has worked diligently to establish effective standards and codes which

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will assist the designer in the selection and specification of piping systems produced from PE 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 PE 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, Irving, TX.
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.

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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
F 2620	Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

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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-41	Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping

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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-22	PPI Guidelines for Qualification Testing of Mechanical Couplings for PE Pipes in Pressurized Water or Sewer Service
TN-23	Guidelines for Establishing the Pressure Rating for Multilayer and Coextruded Plastic Pipes
TN-35	General Guidelines for Repairing Buried HDPE Potable Water Pressure Pipes
TN-36	General Guidelines for Connecting HDPE Potable Water pressure Pipes to DI and PVC piping Systems
TN-38	Bolt Torque for Polyethylene Flanged Joints
TN-41	High Performance PE Material for Water Piping Applications

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

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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 and Relatd Practices

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

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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

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