

# Specification for Crosslinked Polyethylene (PEX) Line Pipe

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# Specification for Crosslinked Polyethylene (PEX) Line Pipe

## 1 Introduction

### 1.1 Purpose

The purpose of this specification is to provide standards for crosslinked polyethylene (PEX) line pipe suitable for use in conveying oil, gas, and nonpotable water in underground, aboveground, and reliner applications for the oil- and gas-producing industries.

This specification does not address all of the safety concerns associated with the design, installation, or use of products suggested herein. It is the responsibility of the user of this specification to make appropriate health and safety considerations.

All pipe produced under this specification use pressure-rated materials used in pressurized, non-pressure, and negative pressure applications.

The technical content of this document provides requirements and guidelines for performance, design, materials inspection, dimensions and tolerances, marking, handling, storing, and shipping.

### 1.2 Scope

This specification covers PEX line pipe used for the production and transportation of oil, gas, and nonpotable water. This specification does not cover pipe for chlorinated water service. The piping is intended for use in new construction, structural pressure-rated liner, line extension, and repair of both aboveground and buried-pipe applications. Equipment covered by this specification is listed as follows:

- a) PEX line pipe;
- b) fittings;
- c) metallic flange couplers for field installations and PEX face flanges used as internal diameter adapters.

### 1.3 Service Conditions

The standard service conditions for the API 15PX standard pressure rating are as follows:

- a) non-chemically-aggressive fluids;
- b) operating temperature range:  $-50\text{ }^{\circ}\text{C}$  ( $-58\text{ }^{\circ}\text{F}$ ) to  $93\text{ }^{\circ}\text{C}$  ( $200\text{ }^{\circ}\text{F}$ ) or  $95\text{ }^{\circ}\text{C}$  ( $203\text{ }^{\circ}\text{F}$ ), depending on design methodology (Section 4).

NOTE Applications above  $95\text{ }^{\circ}\text{C}$  ( $203\text{ }^{\circ}\text{F}$ ) require special design consideration; service conditions other than the standard API 15PX conditions and their effects on design are discussed in Section 4.

## 2 Normative References

This specification includes by reference, either in total or in part, the most current issue of the following standards:

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

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

ASME<sup>1</sup> B31.3, *Process Piping*

ASME Boiler and Pressure Vessel Code, Section IX, *Welding and Brazing Qualifications*

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

ASTM D1598, *Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure*

ASTM D2122,<sup>2</sup> *Standard Test Method for Determining Dimensions of the Thermoplastic Pipe and Fittings*

ASTM D2765, *Standard Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics*

ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*

ASTM D3895, *Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry*

ASTM F1055, *Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing*

ASTM F2905/F2905M, *Standard Specification for Black Crosslinked Polyethylene (PEX) Line Pipe, Fittings and Joints for Oil and Gas Producing Applications*

ASTM F3203, *Standard Test Method for Determination of Gel Content of Crosslinked Polyethylene (PEX) Pipes and Tubing*

ASTM F876, *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*

ASTM F2657, *Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing*

ASTM D4364, *Standard Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight*

DIN 16892,<sup>3</sup> *Crosslinked polyethylene (PE-X) pipes — General requirements, testing*

ISO 527-1,<sup>4</sup> *Determination of tensile properties*

ISO 1167, *Thermoplastics pipes for the conveyance of fluids — Resistance to internal pressure — Test method*

ISO 10147, *Pipes and fittings made of crosslinked PEX (PE-X) — Estimation of the degree of crosslinking by determination of the gel content*

ISO 11357-6, *Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)*

ISO 13477, *Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4 test)*

<sup>1</sup> American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016-5990, [www.asme.org](http://www.asme.org).

<sup>2</sup> ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, Pennsylvania 19248, [www.astm.org](http://www.astm.org).

<sup>3</sup> German Institute for Standardization, Am DIN-Platz, Burggrafenstrabe 6, 10787 Berlin, Germany, [www.din.de](http://www.din.de).

<sup>4</sup> International Organization for Standardization, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, [www.iso.org](http://www.iso.org).

ISO 14531-1, *Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications — Part 1: Pipes*

ISO 18553, *Method for assessment of the degree of pigment or carbon black dispersion in polyethylene pipes, fittings and compounds*

ISO 3126, *Plastics piping systems — Plastics components — Determination of dimensions*

ISO 9001, *Quality management systems — Requirements*

ISO 9080, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*

ISO TS 29001, *Petroleum, petrochemical and natural gas industries — Sector-specific quality management systems — Requirements for product and service supply organizations*

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

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

PPI TR-3,<sup>5</sup> *Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), Minimum Required Strength (MRS) Ratings, and Categorized Required Strength (CRS) for Thermoplastic Piping Materials or Pipe*

PPI 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 or Pipe*

### 3 Terms, Definitions, and Abbreviations

#### 3.1 Terms and Definitions

##### 3.1.1

##### **adapters**

Appurtenances that allow connecting components with different joining systems.

##### 3.1.2

##### **component**

Any pressure line pipe, pipe connection, fitting, flange, adapter, reducer, or end of outlet connection covered by this specification.

##### 3.1.3

##### **crosslinking**

The formation of a three-dimensional polymer by means of interchain reactions resulting in changes in physical properties.

NOTE PEX materials used in the manufacturing of PEX line pipe can be crosslinked by several industry-proven means. These include:

- a) peroxide crosslinking (PEX-a);
- b) silane crosslinking (PEX-b);

<sup>5</sup> Plastics Pipe Institute, 105 Decker Court, Suite 825, Irving, Texas 75062, [plasticpipe.org](http://plasticpipe.org).

c) irradiation (PEX-c).

### 3.1.4

#### **design service factor (DSF)**

A factor with a value less than 1.0 applied to the hydrostatic design basis (HDB) to calculate the maximum design stress of the pipe.

### 3.1.5

#### **design coefficient**

Used with the DIN 16892/3 design method, a coefficient with a value greater than 1.0 that takes into consideration service conditions as well as properties of the components of a piping system other than those represented in  $\sigma_{LPL}$ .

NOTE 1 See ISO 12162 for information regarding the minimum permissible service (design) coefficient for PEX pipes.

### 3.1.6

#### **dimension ratio (DR)**

The ratio of a pipe's outside diameter to its wall thickness.

### 3.1.7

#### **fittings**

A piping component used to join or terminate sections of pipe or to provide changes of direction or branching in a pipe system.

### 3.1.8

#### **flanges**

Appurtenances incorporating a PEX flange adapter and metallic backup ring with an ANSI B16.5 bolt hole pattern.

### 3.1.9

#### **fluid service factor (FSF)**

A factor with a value less than 1.0 applied in the determination of the maximum working pressure to account for the impact of the transported fluid on pipe performance.

### 3.1.10

#### **hydrostatic design basis (HDB)**

The categorized long-term hydrostatic strength (LTHS) at a specified temperature in the hoop direction as established by ASTM D2837.

### 3.1.11

#### **material designation code**

A set of letters and numbers consisting of the abbreviation for the type of plastic (PEX) followed by four Arabic numerals—two to describe the short-term properties, in accordance with the ASTM standard being referenced, and two to designate the hydrostatic design stress when tested in water at 23 °C (73 °F) in units of 100 psi, with any decimal figures dropped.

### 3.1.12

#### **maximum working pressure**

The maximum anticipated sustained pressure applied to the pipe in actual service when the fluid service factor (FSF) is applied.

### 3.1.13

#### **minimum required strength (MRS)**

The categorized lower prediction limit (LPL) of the long-term hydrostatic strength at 20 °C (68 °F) determined in accordance with ISO 9080 and ISO 12162.

NOTE In this specification, the equivalent MRS value is defined by reference curves in DIN 16892 and has a value of 9.5 MPa.

**3.2.14****operating temperature**

The temperature of the fluids transported by the pipeline.

NOTE This may be different from the design temperature.

**3.1.15****out of roundness**

The maximum measured outside diameter, minus the minimum measured outside diameter, divided by the average measured outside diameter, times 100, and expressed as a percentage.

**3.1.16****standard pressure rating**

The established maximum pressure that nonaggressive fluids such as water can exert continuously without failure of the pipe.

**3.2 Abbreviations**

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing Materials
CSA	Canadian Standards Association
DIN	Deutsch Institute for Norms
DN	nominal diameter
DR	dimension ratio
FSF	fluid service factor
HDB	hydrostatic design basis
ISO	International Standards Organization
LPL	lower prediction limit
MRS	minimum required strength
NPS	nominal pipe size
PEX	cross-linked polyethylene
PE	polyethylene
PPI	Plastics Pipe Institute, Inc.
QA	quality assurance
QC	quality control
RCP	rapid crack propagation
UV	ultraviolet

**4 Design****4.1 Long-term Strength**

The long-term strength shall be measured with water as the internal pressurizing medium. Either the HDB or DIN 16892/3 long-term strength shall be used to establish the maximum working pressure of a PEX pipe. Mixing the requirements of the two standard systems to design a PEX piping system is not permitted.

The design process shall include the effects of operating temperature and the internal and external chemical environment on the long-term strength for both the HDB method and the DIN 16892/3 method. The effects of the chemical environment are accounted for by applying the FSF to the long-term strength determined by both methods. The design process shall also include consideration of the installation method.

## 4.2 Fluid Service Factors

The FSFs in Table 1 shall be used to compensate for possible effects of the transported fluid on the long-term performance of the piping and for the hazardous nature of some applications.

**Table 1—Fluid Service Factors (FSF)**

Environment	Factor	HDB	DIN 16892/3
Produced water, seawater, brine, process water, and other oilfield water-based fluids, excluding oilfield water containing > 2 % liquid hydrocarbons <sup>a</sup>	1.0	Table 2	Table 4
Dry gas gathering (no associated hydrocarbon liquids) <sup>b</sup>	1.0	Table 2	Table 4
Dry gas gathering that is subject to Canadian Federal Regulations <sup>c</sup>	1.0	Table 2	Table 4
Multiphase fluids, wet natural gas, and liquid hydrocarbons	0.5	Table 3	Table 5

<sup>a</sup> Water containing significant quantities of liquid hydrocarbons (> 2 %) shall be treated as liquid hydrocarbon. Operating conditions can result in stratification of the water/hydrocarbon mix, leading to local concentrations of much greater than 2 %. An engineering assessment of the likely impact of this possibility and the duration of the stratification should be completed before deciding on the FSF to be used. If the engineering assessment is not completed, FSF = 0.5 shall be used.

<sup>b</sup> Gas gathering in this specification refers to gas from a well or production source in a low-population-density area that is not subject to U.S. Department of Transportation, Office of Pipeline Safety, Title 49 CFR Part 192.

<sup>c</sup> CSA Z662, Clause 13.3.

## 4.3 Determining the Maximum Working Pressure

### 4.3.1 HDB Pressure Rating System

The following steps shall be followed to use the HDB pressure rating system:

**4.3.1.1** Determine the FSF to determine whether to use Table 2 or Table 3.

**4.3.1.2** Select the appropriate HDB based on the anticipated operating temperature and the material designation code as shown in the appropriate rows of Table 2 if FSF is 1.0, or Table 3 if FSF is 0.5.

**4.3.1.3** Find the DR for the pipe in the column headings in Table 2 or Table 3.

**4.3.1.4** The value for the maximum working pressure in water service is at the intersection of the DR column and the “HDB” row in Table 2, and includes the application of a DSF of 0.71.

**4.3.1.5** The value for the maximum working pressure for multiphase fluids, wet natural gas, and liquid hydrocarbons is at the intersection of the DR column and the HDB row in Table 3, and includes the application of a DSF of 0.71.

**Table 2—Standard Pressure Ratings (psi) of PEX Pipe Using the HDB Method of Design at Various Temperatures for Nonchemically Aggressive Fluids**

Temperature °C (°F)	Material Designation Code	HDB (psi)	Maximum Working Pressures (psig) for the Indicated DR				
			DR 7.4	DR 9	DR 11	DR 13.6	DR 17
23 (73)	PEX xx06	1250	277	222	178	141	111
	PEX xx08	1600	355	284	227	180	142

**Table 2—Standard Pressure Ratings (psi) of PEX Pipe Using the HDB Method of Design at Various Temperatures for Nonchemically Aggressive Fluids (Continued)**

Temperature °C (°F)	Material Designation Code	HDB (psi)	Maximum Working Pressures (psig) for the Indicated DR				
			DR 7.4	DR 9	DR 11	DR 13.6	DR 17
60 (140)	PEX xx06	800 <sup>a</sup>	178	142	114	90	71
	PEX xx08	1000 <sup>a</sup>	222	178	142	113	89
82 (180)	PEX xx06 PEX xx08	800	178	142	114	90	71
93 (200)	PEX xx06	630	140	112	89	71	56
	PEX xx08	800	178	142	114	90	71

NOTE For the working pressure of multiphase fluids, wet natural gas, and liquid hydrocarbons, refer to Table 3.

<sup>a</sup> HDB was interpolated using the HDB values at 23 °C (73 °F) and 82 °C (180 °F) for the grades with the indicated material designation code.

**Table 3—Working Pressure (psi) of PEX Pipe Using the HDB Method of Design at Various Temperatures for Multiphase Fluids, Wet Natural Gas, and Liquid Hydrocarbons**

Temperature °C (°F)	Material Designation Code	HDB (psi)	Maximum Working Pressures (psig) for the Indicated DR				
			DR 7.4	DR 9	DR 11	DR 13.6	DR 17
23 (73)	PEX xx06	1250	139	111	89	70	55
	PEX xx08	1600	178	142	114	90	71
60 (140)	PEX xx06	800 <sup>a</sup>	89	71	57	45	36
	PEX xx08	1000 <sup>a</sup>	111	89	71	56	44
82 (180)	PEX xx06 PEX xx08	800	89	71	57	45	36
93 (200)	PEX xx06	630	70	56	45	36	28
	PEX xx08	800	89	71	57	45	36

<sup>a</sup> HDB was interpolated using the HDB values at 23 °C (73 °F) and 82 °C (180 °F) for the grades with the indicated material designation code.

**4.3.1.6** When calculating an HDB between 23 °C (73 °F) and the elevated temperature at which the manufacturer has an established HDB, the HDB at any intermediate temperature shall be calculated by linear interpolation using the method described in PPI TR-3. Annex B provides guidance on the interpolation method.

**4.3.1.7** For pipe sizes not listed in this specification, the pressure ratings shall be calculated using the methods in Annex C.1.

**4.3.2 DIN 16892/3 Pressure Rating System**

The following steps shall be followed to use the DIN 16892/3 Pressure Rating System:

**4.3.2.1** Determine the FSF according to Table 1 to determine whether to use Table 4 or Table 5 to determine the maximum working pressure.

**4.3.2.2** Select the anticipated operating temperature from the row headings in Table 4 if the FSF is 1.0, or in Table 5 if the FSF is 0.5.

**4.3.2.3** Find the DR for the pipe in the column headings in Table 4 or Table 5.

**4.3.2.4** The value for the maximum working pressure in water service is at the intersection of the DR column and the “Temperature” row in Table 4.

**4.3.2.5** The value for the maximum working pressure for multiphase fluids, wet natural gas, and liquid hydrocarbons is at the intersection of the DR column and the “Temperature” row in Table 5.

**4.3.2.6** For pipe sizes not listed in this specification, the pressure ratings shall be calculated using the methods in Annex C.2.

NOTE 1 The values for the maximum working pressure listed in Table 4 and Table 5 include the application of a design coefficient of 1.25, and are for a 20-year service life for all temperatures less than 90 °C (194 °F); a 15-year service life at 90 °C (194 °F); and a 10-year service life at 95 °C (203 °F).

**4.3.2.7** The DIN 16892/3 standard states the service life to be 50 years at 70 °C (158 F) and 25 years at 80 °C (176 °F). If the producer has completed testing to validate a longer lifetime, that specific lifetime value is permitted.

NOTE 2 The DIN standard pressure ratings are based on PEX pipe with 9.5 MPa equivalent MRS. Modern PEX materials meet those requirements as defined in detail in DIN 16892 and DIN 16893.

**Table 4—Standard Pressure Ratings (psi) of PEX Pipe Using the DIN 16892/3 Method of Design at Various Temperatures for Most Fluids**

Temperature °C (°F)	Maximum Working Pressures (psig) for the Indicated DR			
	DR 7.4	DR 9	DR 11	DR 13.6
10 (50)	395.9	314.7	249.4	198.7
20 (68)	350.9	278.4	220.4	175.5
30 (86)	310.3	246.5	195.8	155.2
40 (104)	277.0	219.0	174.0	137.8
50 (122)	246.5	195.8	155.2	123.3
60 (140)	220.4	174.0	137.8	110.2
70 (158)	197.2	156.6	123.3	98.6
80 (176)	175.5	139.2	110.2	88.5
90 (194) <sup>a</sup>	159.5	126.2	100.1	79.8
95 (203) <sup>a</sup>	152.3	120.4	95.7	75.4

NOTE 1 Modern PEX products have undergone much more extensive testing, and the supplier is usually able to provide evidence for a 20-year service life.

NOTE 2 For the working pressure of multiphase fluids, wet natural gas, and liquid hydrocarbons, refer to Table 5.

<sup>a</sup> The DIN standard specifies that the service life of PEX pipe is 15 years at 90 °C (194 °F) and 10 years at 95 °C (203 °F) at the indicated dimensions and pressures, provided there is additional regression data at 110 °C (230 °F) for at least one year.

**Table 5—Maximum Working Pressure (psi) of PEX Pipe Using the DIN 16892/3 Method of Design at Various Temperatures for Multiphase Fluids, Wet Natural Gas, and Liquid Hydrocarbons**

Temperature °C (°F)	Maximum Working Pressures (psig) for the Indicated DR			
	DR 7.4	DR 9	DR 11	DR 13.6
10 (50)	197.9	157.3	124.7	99.3
20 (68)	175.5	139.2	110.2	87.7
30 (86)	155.2	123.3	97.9	77.6
40 (104)	138.5	109.5	87.0	68.9
50 (122)	123.3	97.9	77.6	61.6
60 (140)	110.2	87.0	68.9	55.1
70 (158)	98.6	78.3	61.6	49.3
80 (176)	87.7	69.6	55.1	44.2
90 (194) <sup>a</sup>	79.8	63.1	50.0	39.9

**Table 5—Maximum Working Pressure (psi) of PEX Pipe Using the DIN 16892/3 Method of Design at Various Temperatures for Multiphase Fluids, Wet Natural Gas, and Liquid Hydrocarbons (Continued)**

Temperature °C (°F)	Maximum Working Pressures (psig) for the Indicated DR			
	DR 7.4	DR 9	DR 11	DR 13.6
95 (203) <sup>a</sup>	76.1	60.2	47.9	37.7
NOTE Modern PEX products have undergone extensive testing, and the supplier is usually able to provide evidence for a 20-year service life.				
<sup>a</sup> The DIN standard specifies that the service life of PEX pipe is 15 years at 90 °C (194 °F) and 10 years at 95 °C (203 °F) at the indicated dimensions and pressures, provided there is additional regression data at 110 °C (230 °F) for at least one year.				

**4.3.3 External Collapse Rating**

Guidelines on the collapse rating of cross-linked PEX pipe are laid out in Annex A.

**4.4 External Service Environment**

The designer shall consider the effects of external UV exposure and external chemical environment on the durability of the pipe for the anticipated service life and the storage time prior to installation.

**4.5 Dimensions and Tolerances**

**4.5.1 Size**

Pipe furnished to this specification shall comply with the dimensions and tolerances given in Table 6 (inch dimensions) or Table 7 (metric dimensions) as specified on the purchase order.

In applications where special conditions or requirements dictate diameters, wall thicknesses, or dimensions other than those listed in these tables, those special sizes shall be acceptable upon agreement of the buyer and the seller provided that the PEX pipe is manufactured from PEX compounds meeting the requirements of this specification and the strength and design basis used to establish the working pressure are the same as those prescribed in Table 2, Table 3, Table 4, and Table 5.

For diameters not shown in the tables, the tolerance shall be the same percentage as shown in the tables for the next smaller listed size.

The dimensional requirements of ASTM F714 are also acceptable.

**4.5.2 Toe-in**

The outside diameter when measured at the cut end of the pipe length shall not be more than 1.5 % smaller than the outside diameter specified in Table 6 or Table 7, when measured at any point within 1.5 pipe diameters or 11.8 in. (300 mm), whichever is less, to the cut end of the pipe length. Measurements shall be made using the ASTM D2122 test method.

**Table 6—Inch Dimensions and Tolerances Based on Outside Diameters**

Nominal Size (NPS)	Outside Diameter		DR	Wall Thickness	
	in.	mm		in.	mm
0.5	0.625 ±0.004	15.88 ±0.10	9	0.070 +0.010	1.78 +0.25
0.75	0.875 ±0.004	22.22 ±0.10	9	0.097 +0.010	1.57 +0.25
1	1.125 ±0.005	28.58 ±0.12	9	0.125 +0.013	3.18 +0.33
1.25	1.375 ±0.005	34.92 ±0.12	9	0.153 +0.015	3.88 +0.38

Table 6—Inch Dimensions and Tolerances Based on Outside Diameters (Continued)

Nominal Size (NPS)	Outside Diameter		DR	Wall Thickness	
	in.	mm		in.	mm
1.5	1.625 ±0.006	41.28 ±0.16	9	0.181 +0.019	4.59 +0.48
2	2.125 ±0.006	53.98 ±0.16	9	0.236 +0.024	6.00 +0.61
2.5	2.625 ±0.007	66.68 ±0.18	9	0.292 +0.030	7.41 +0.76
3	3.500 ±0.016	88.90 ±0.41	21	0.167	4.24
			17	0.206	5.23
			13.5	0.259	6.58
			11	0.318	8.08
			9	0.389	9.88
			7.3	0.479	12.17
4	4.500 ±0.020	114.30 ±0.51	21	0.214	5.43
			17	0.265	6.73
			13.5	0.333	8.46
			11	0.409	10.39
			9	0.500	12.70
			7.3	0.616	15.65
5	5.563 ±0.025	141.30 ±0.64	21	0.265	6.73
			17	0.327	8.33
			13.5	0.412	10.46
			11	0.506	12.85
			9	0.618	15.65
			7.3	0.762	19.35
6	6.625 ±0.030	168.28 ±0.76	21	0.315	8.00
			17	0.390	9.91
			13.5	0.491	12.47
			11	0.602	15.29
			9	0.736	18.69
			7.3	0.908	23.06
8	8.625 ±0.039	219.08 ±0.99	21	0.411	10.44
			17	0.507	12.88
			13.5	0.639	16.23
			11	0.784	19.91
			9	0.958	24.33
			7.3	1.182	30.02
10	10.750 ±0.048	273.05 ±1.22	21	0.512	13.00
			17	0.632	16.05
			13.5	0.796	20.22
			11	0.977	24.82
			9	1.194	30.33
			7.3	1.473	37.41
12	12.750 ±0.057	323.85 ±1.45	21	0.607	15.42
			17	0.750	19.05
			13.5	0.944	23.98
			11	1.159	29.44
			9	1.417	35.99
			7.3	1.747	44.37
14	14.000 ±0.063	355.60 ±1.60	21	0.667	16.94
			17	0.824	20.93
			13.5	1.037	26.34
			11	1.273	32.33
			9	1.556	39.52
			7.3	1.918	48.72

**Table 6—Inch Dimensions and Tolerances Based on Outside Diameters (Continued)**

Nominal Size (NPS)	Outside Diameter		Wall Thickness				
	in.	mm	DR	in.	mm		
16	16.000 ±0.072	406.40 ±1.83	21	0.762	19.35		
			17	0.941	23.90		
			13.5	1.185	30.10		
			11	1.455	36.96		
			9	1.778	45.16		
			7.3	2.192	55.68		
18	18.000 ±0.081	457.20 ±2.05	21	0.857	21.77		
			17	1.059	26.90		
			13.5	1.333	33.86		
			11	1.636	41.55		
			9	2.000	50.80		
			7.3	2.466	62.64		
20	20.000 ±0.090	508.00 ±2.29	21	0.952	24.18		
			17	1.176	29.87		
			13.5	1.481	37.62		
			11	1.818	46.18		
			9	2.222	56.44		
22	22.000 ±0.099	558.80 ±2.51	21	1.048	26.62		
			17	1.294	32.87		
			13.5	1.618	41.10		
			11	2.000	50.80		
			9	2.444	62.08		
24	24.000 ±0.108	609.60 ±2.74	21	1.143	29.03		
			17	1.412	35.86		
			13.5	1.778	45.16		
			11	2.182	55.42		
			9	2.667	67.74		
26	26.000 ±0.117	660.40 ±2.97	21	1.283	32.59		
			17	1.529	38.84		
			13.5	1.926	48.92		
			11	2.364	60.05		
28	28.000 ±0.126	711.20 ±3.20	21	1.333	33.86		
			17	1.647	41.84		
			13.5	2.074	52.68		
			11	2.545	64.65		
30	30.000 ±0.135	762.00 ±3.43	21	1.429	36.30		
			17	1.765	44.82		
			13.5	2.222	56.44		
			11	2.727	69.27		
32	32.000 ±0.144	812.80 ±3.66	21	1.524	38.71		
			17	1.882	47.81		
			13.5	2.370	60.20		
			11	2.909	73.89		
34	34.000 ±0.153	863.60 ±3.89	21	1.619	41.12		
			17	2.000	50.80		
			13.5	2.519	63.98		
			11	3.091	78.51		
36	36.000 ±0.162	914.40 ±4.11	21	1.714	43.54		
			17	2.118	53.79		
			13.5	2.667	67.74		
			11	3.273	83.13		

**Table 6—Inch Dimensions and Tolerances Based on Outside Diameters (Continued)**

Nominal Size (NPS)	Outside Diameter		DR	Wall Thickness	
	in.	mm		in.	mm
42	42.000 ±0.189	1066.80 ±4.80	21 17	2.000 2.471	50.80 62.75
48	48.000 ±0.216	1219.20 ±5.49	21 17	2.286 2.824	58.06 71.72
54	54.000 ±0.243	1371.60 ±6.17	21 17	2.571 3.176	65.30 80.68

NOTE Pipe dimensions and schedules listed are those most commonly used by the oil and gas industries. Additional sizes and schedules are available. The other lists of sizes and schedules are in the following ASTM standards:

ASTM F2788, *Standard Specification for Metric and Inch-sized Crosslinked Polyethylene (PEX) Pipe*

ASTM F2829, *Standard Specification for Metric-Sized Crosslinked Polyethylene (PEX) Pipe Systems*

ASTM F2968/F2968M, *Standard Specification for Black Crosslinked Polyethylene (PEX) Pipe, Fittings and Joints for Gas Distribution Applications*

ASTM F2905/F2905M, *Standard Specification for Black Crosslinked Polyethylene (PEX) Line Pipe, Fittings and Joints for Oil and Gas Producing Applications*

**Table 7—Metric Dimensions and Tolerances Based on Outside Diameters**

Diameter Nominal (DN)	Outside Diameter (mm)	Minimum Wall Thickness (mm)				
		Tolerance is plus 12%, rounded to the nearest 0.1 mm				
		DR 7.4	DR 9	DR 11	DR 13.6	DR 17
16	16.15 ±0.15	2.3	2.0	—	—	—
20	20.15 ±0.15	3.0	2.3	2.0	—	—
25	25.15 ±0.15	3.5	3.0	2.3	2.0	—
32	32.15 ±0.15	4.4	3.6	3.0	2.4	2.3
40	40.20 ±0.20	5.5	4.5	3.7	3.0	2.8
50	50.20 ±0.20	6.9	5.6	4.6	3.7	3.4
63	63.20 ±0.20	8.6	7.1	5.8	4.7	4.3
75	75.25 ±0.25	10.3	8.4	6.8	5.6	5.1
90	90.30 ±0.30	12.3	10.1	8.2	6.7	6.1
110	110.35 ±0.35	15.1	12.3	10.0	8.1	7.4
125	125.40 ±0.40	17.1	14.0	11.4	9.2	8.3
140	140.45 ±0.45	19.2	15.7	12.7	10.3	9.3
160	160.50 ±0.50	21.9	17.9	14.6	11.8	10.6
180	180.55 ±0.55	24.6	20.1	16.4	13.3	11.9
200	200.60 ±0.60	27.4	22.4	18.2	14.7	13.2
225	225.70 ±0.70	30.8	25.2	20.5	16.6	14.9
250	250.75 ±0.75	34.2	27.9	22.7	18.4	16.4
280	280.85 ±0.85	38.3	31.3	25.4	20.6	18.4
315	315.95 ±0.95	43.1	35.2	28.6	23.2	20.7
355	356.10 ±1.10	48.5	39.7	32.2	26.1	23.4
400	410.20 ±1.20	54.7	44.7	36.3	29.4	23.7
450	451.35 ±1.35	61.5	50.3	40.9	33.1	29.5
500	501.50 ±1.50	—	55.8	45.4	36.8	32.8
560	561.70 ±1.70	—	62.5	50.8	41.2	36.7
630	631.90 ±1.90	—	70.3	57.2	46.3	41.3
710	713.20 ±3.20	—	79.3	64.5	52.2	46.5

**Table 7—Metric Dimensions and Tolerances Based on Outside Diameters (Continued)**

Diameter Nominal (DN)	Outside Diameter (mm)	Minimum Wall Thickness (mm)				
		Tolerance is plus 12%, rounded to the nearest 0.1 mm				
		DR 7.4	DR 9	DR 11	DR 13.6	DR 17
800	813.60 ±3.60	—	89.3	72.6	58.8	52.3
900	904.05 ±4.05	—	—	81.7	66.2	58.8
1000	1004.50 ±4.50	—	—	90.2	72.5	65.4

### 4.5.3 Eccentricity

The wall thickness variability as measured and calculated in accordance with the ASTM D2122 test method in any diametrical cross-section of the pipe shall not exceed 12 % unless otherwise specified elsewhere in this specification.

### 4.5.4 Length

Pipe shall be furnished in cut lengths or coils as specified on the purchase order and agreed between the purchaser and the supplier.

### 4.5.5 Out of Roundness (Ovality)

The out of roundness or ovality of the pipe shall not exceed the tolerance in ASTM F2905.

NOTE Other factors, such as installation, coiling, compaction, static soil loading, exposure to high ambient temperature, and vehicular loads, can increase ovality during use beyond the requirements of the standard.

## 5 Process of Manufacture

### 5.1 General

Pipe furnished to this specification shall be produced by extrusion.

Rework or recycled material shall not be used.

Fittings shall be manufactured using polymers, metals, or composites and shall comply with the relevant product standards for that fitting type.

PEX pipes shall be crosslinked to the minimum level specified in this standard prior to installation.

### 5.2 Pipe Compound

PEX pipe shall be made from PEX compounds that have been crosslinked by means such that the pipe meets the performance requirements of this section.

The manufacturing process shall result in a PEX pipe capable of obtaining the pressure ratings as shown in 4.3 when tested in accordance with procedures no less restrictive than those of PPI TR-3.

### 5.3 Pipe Compound Requirements

#### 5.3.1 Long-term Hydrostatic Strength

The long-term strength of the material shall be established by the manufacturer in accordance with PPI TR-3 using ASTM D2837 or ISO 9080 methodology. PEX materials meeting the requirements of this specification shall

be tested for long-term hydrostatic strength witnessed or tested by a certified third-party auditing agency that conforms to ISO/IEC 17020 and/or ISO/IEC 17065, or have an HDB and/or MRS listed in PPI TR-4.

If using the DIN 16892 standard for design, the material shall have a minimum LPL of 9.5 MPa at 20 °C (68 °F) as shown by the reference curves presented in DIN 16892.

### 5.3.2 Thermal Oxidative Stability

For conformance to the 95 °C (203 °F) temperature requirements of this specification, thermal stability of the pipe compound shall be demonstrated per DIN 16892 (Table 1) or per ASTM F2905 (Section 7.10), except that one of the following conditions shall be used:

- a) 2.8 MPa hoop stress at 110 °C (230 °F), survival to 8000 hours;
- b) 2.5 MPa hoop stress at 110 °C (230 °F), survival to 8760 hours.

For applications with high potential for oxidative attack, the formulation shall sustain 2.4 MPa hoop stress at 110 °C (230 °F) survival to 15,000 hours.

NOTE An engineering assessment is typically done to determine if the application requires this additional level of testing.

If the compound has an ASTM F876 chlorine resistance cell value of 5, this requirement is waived.

The indicated hoop stress values are used to calculate the test pressure using Equation (1):

$$p = 10\sigma \frac{2e_{min}}{d_{em} - e_{min}} \quad (1)$$

Where:

- $p$  is the test pressure (bars);
- $\sigma$  is the hoop stress to be induced by the applied pressure, in megapascals;
- $d_{em}$  is the mean outside diameter of the test piece, in millimeters;
- $e_{min}$  is the minimum wall thickness of the free length of the test piece, in millimeters.

To calculate the test pressure in psi, multiply the result in bars by 14.5.

To calculate the test pressure in MPa, divide the test pressure in bars by 10.

#### 5.3.2.1 Oxidation Induction Time

The pipe shall have an oxidation induction time of >20 minutes when tested at 200 °C (392 °F) per ISO 11357-6 or ASTM D3895. Testing at 210 °C (410 °F) is permissible if correlation with 200 °C data can be demonstrated. In cases of dispute, testing shall be performed at 200 °C.

### 5.3.3 Rapid Crack Propagation (RCP) Resistance

Per ISO 13477, the critical temperature shall be lower than the minimum design temperature, but in no case higher than -20 °C (-4 °F). Critical temperature shall be measured on DR11 pipe with a nominal OD of either 4 in. or 110 mm.

### 5.3.4 UV Weathering Protection

The pipe shall be protected against UV weathering. Pipe formulations containing well-dispersed N550 or smaller particle size carbon black at 2.0 % shall be considered to have met this requirement. Dispersion shall comply

with ISO 18553 requirements. In all other cases, the manufacturer shall determine retention of properties based on the testing of UV exposed pipe in accordance with ASTM F2657, ISO 14531-1 (Annex C), or ASTM D4364. Exposed pipe shall also have an elongation at break according to ASTM D638 or ISO 527-1 of not less than 50 % of the elongation at break of unexposed pipe.

### **5.3.5 Color**

If the color of the pipe is black, the formulation shall contain carbon black meeting the requirements of 5.3.4.

## **5.4 Finish and Workmanship**

### **5.4.1 Pipe Ends**

Pipe ends shall be plain and squared, or with flared ends, for use with flange connections. Cut pipe ends shall be clean, without ledges, shaving tails, burrs, or cracks.

Other pipe end conditions shall be agreed between the purchaser and the seller.

### **5.4.2 Finish**

The interior and exterior of the pipe shall be uniform in finish, without voids, cracks, crazing, foreign inclusions, or scratches.

### **5.4.3 Workmanship**

The pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The pipe shall be uniform in color, opacity, density, and other physical properties.

## **6 Fittings**

### **6.1 General**

All fittings, plastic or metallic, shall be demonstrated by the pipe manufacturer to meet or exceed the thermal and mechanical properties of the pipe.

### **6.2 Electrofusion Fittings**

Electrofusion fittings furnished for use with this specification shall meet the requirements of ASTM F1055 or ISO 14531-2. Electrofusion fittings shall not be used in services with H<sub>2</sub>S content of 100 ppm or higher.

**NOTE** If the specified electrofusion fittings are HDPE or PEX fittings and do not have the same high-temperature capabilities of the PEX pipe with which they will be used, the designer is cautioned that the system design pressure and temperature are limited by the lowest rated component.

### **6.3 Metallic Fittings**

#### **6.3.1 Welding of Fittings**

Fittings fabricated with pressure-containing welds shall require qualification to a weld procedure specification in accordance with local pipeline regulatory requirements or, at a minimum, in accordance with ASME BPVC, Section IX. Weld inspection shall be performed in accordance with the local pipeline regulatory requirements, or in accordance with ASME B31.3 or API 1104 requirements as applicable.

#### **6.3.2 Corrosion Resistance**

Steel selection shall consider corrosive attack appropriate to the environment to which the fitting is exposed.

### 6.3.3 Cathodic Charging

All metallic fitting components designed for, or that can be exposed to, cathodic protection shall be made of materials that are resistant to hydrogen embrittlement in the applicable environment.

The steel fittings shall be subject to qualification testing to confirm that the potential hydrogen evolution resulting from cathodic charging does not result in hydrogen embrittlement. The testing shall be conducted on degreased samples loaded to 75 % actual yield stress and immersed in de-aerated seawater (minimum 3 % NaCl) with an applied potential of 1.05 V versus saturated calomel electrode. The cathodic charging shall be applied for a minimum duration of 150 hours. Post-test examination shall be conducted to confirm that no hydrogen blistering or cracking of the sample has occurred.

### 6.4 PEX Fittings

Reducers are component fittings that allow two pipes of different diameters to be connected. Thermoformed reducers and elbows made of PEX pipes may be used.

Molded or fabricated PEX fittings may be used. PEX fittings shall be manufactured according to applicable ASTM or ISO standards, or in compliance with the manufacturer's documented procedures approved by the customer, whichever is more restrictive. The PEX compound used for the fittings shall comply with all the compound requirements of this specification. When conflicts arise between standards or procedures, this document's requirements shall be followed.

The design and pressure rating of the fitting is beyond the scope of this specification and shall be established by the fitting manufacturer. Fittings shall meet or exceed the pressure design requirements of the system.

## 7 Quality Management Program

### 7.1 General

Products meeting this specification shall be manufactured in a facility that maintains a written quality management system in accordance with API Q1, ISO TS 29001, or ISO 9001.

### 7.2 Quality Records Retention

Quality records shall remain legible, readily identifiable, and retrievable for a period of not less than 10 years.

### 7.3 Quality Control Tests

#### 7.3.1 Dimensional Analysis

Samples for quality control testing shall be conditioned in accordance with ASTM D2122 or ISO 3126.

#### 7.3.2 Physical Properties

- a) Pipe: Refer to Table 8 for physical testing requirements for PEX pipe.
- b) Fittings: Fittings intended for use with PEX pipe shall meet the dimensional, design, and performance requirements of the applicable fitting product standard, and shall have dimensions that are compatible with the pipe manufactured to this specification.
- c) Retesting: If the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again in accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting tests that are a part of the specification; substituting or modifying a test method; or changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in the

specification shall be followed. If, upon retest, failure occurs, the quantity of the product represented by the test(s) does not meet the requirements of this specification and shall be rejected.

**Table 8—Test Description and Frequency for PEX Pipe**

Test Description	Test Method/Conditions	Frequency	Minimum Requirements
Outside diameter	ASTM D2122 or ISO 3126	Once every 2 hours	Dimensions specified in Table 5 or 6.
Wall thickness	ASTM D2122 or ISO 3126	Once every 2 hours	Dimensions specified in Table 5 or 6.
Out of roundness (ovality)	ASTM F2905	Once every 2 hours or once/coil, whichever is less frequent	For straight lengths of pipe, the requirements of ASTM F2905 shall be met. For coiled pipe, out of roundness shall be agreed on between the manufacturer and the buyer
Crosslinking degree	ASTM F3203, ASTM D2765 Method B, or ISO 10147	Once per three days per extrusion line	PEX-a ≥ 70 % PEX-b ≥ 65 % PEX-c ≥ 60 %
Sustained pressure test	ISO 1167 or ASTM D1598 667 psi (4.6 MPa) <sup>a</sup> hoop stress at 203 °F (95 °C)	Once per two weeks per extrusion line	Minimum time before failure: 165 hours and ductile behavior
Sustained pressure test	ISO 1167 or ASTM D1598 638 psi (4.4 MPa) <sup>a</sup> hoop stress at 203 °F (95 °C)	Once per year per extrusion line	Minimum time before failure: 1000 hours and ductile behavior
<p><sup>a</sup> The indicated hoop stress values are used to calculate the test pressure using the following equation:</p> $p = 10\sigma \frac{2e_{min}}{d_{em} - e_{min}}$ <p><i>P</i> = test pressure (bars);  <i>σ</i> = hoop stress to be induced by the applied pressure, in megapascals;  <i>d<sub>em</sub></i> = mean outside diameter of the test piece, in millimeters;  <i>e<sub>min</sub></i> = minimum wall thickness of the free length of the test piece, in millimeters.            To calculate the test pressure in psi, multiply the result in bars by 14.5            To calculate the test pressure in MPa, divide the test pressure in bars by 10.</p>			

## 8 Product Marking

### 8.1 Manufactured Pipe

#### 8.1.1 Manufacturer Markings

Pipe manufactured in conformance with this specification shall be marked by the manufacturer as specified.

- Pressure rating markings are prohibited.
- The pipe shall be marked with the maximum permissible UV weathering exposure time in years as determined by the manufacturer.
- The required print line markings on pipe shall be legible, visible, and permanent, and spaced at intervals of not more than 5 ft. (1.5 m).

The permanency of the marking shall be such that it can only be removed by physically removing part of the pipe wall thickness. The marking shall not reduce the pipe wall thickness to less than the minimum value required for the pipe or tubing. It shall not have an effect on the long-term strength of the pipe and shall not provide channels for leakage when elastomeric gasket compression fittings are used to make joints.

### 8.1.2 Print String

The print string on each length of pipe or fitting shall include in any sequence:

- a) manufacturer's name, product name, or trademarks;
- b) API 15PX;
- c) nominal diameter (NPS or DN);
- d) dimension ratio (DR);
- e) if using the HDB method: material designation code (e.g. PEX0006, PEX0008);
- f) UV weathering exposure time allowed in years (e.g., ten years);
- g) date of manufacture in year-month-day format (e.g., 19 Mar 06);
- h) manufacturer's lot number that designates the lot of pipe or fittings manufactured under the same conditions of production.

Additional markings, except pressure ratings, as agreed upon between manufacturer and purchaser, are permitted.

API 15PX is a stand-alone specification and is the primary manufacturing standard. A manufacturer may dual-mark a product as long as the manufacturer meets the requirements of API 15PX and the additional standard(s) (e.g., ASTM F2905).

## 9 Handling, Storage, and Installation

### 9.1 Storage

PEX pipe products shall be protected against deterioration from exposure to ultraviolet light and weathering effects to the time limit stated on the print line. Color and black products are typically compounded with antioxidants, thermal stabilizers, and UV stabilizers. Color products use sacrificial UV stabilizers that absorb UV energy, and are eventually depleted. In general, non-UV-protected products shall not remain in unprotected outdoor storage.

### 9.2 Handling

PEX piping materials are lightweight compared with similar piping materials made of steel, but larger pieces and components can be heavy. Equipment such as a forklift, crane, side boom tractor, or extension boom crane are used for unloading. Lifting and handling equipment shall have adequate rated capacity to safely lift and move components from the truck to onsite or temporary storage.

When using a forklift, or forklift attachments on equipment such as articulated loaders or bucket loaders, lifting capacity shall be adequate at the load center on the forks. Before lifting or transporting the load, forks should be spread as wide apart as practical and should extend completely under the load, and the load should be as far back on the forks as possible. Care should be taken not to damage the load with the forks.

### 9.3 Installation

Installation shall be done according to the manufacturer's instructions and guidelines.

## 10 Integrity Management

See Annex F for informative guidance on integrity management.

## Annex A (informative)

### External Pressure Rating (Collapse Pressure)

In certain applications, PEX pipe may be subjected to a negative pressure that could cause the collapse of the pipe. A negative pressure situation exists where the external loading on the pipe is greater than the internal pressure in the pipe, which can result in pipe collapse if the external hydraulic pressure exceeds the flattening resistance of the pipe. Flattening resistance should be considered for gravity flow lines, vacuum lines, submerged lines, and any line where the internal pressure has the potential to be less than the static external hydraulic load. Flattening resistance is usually not a consideration where the end of the line is open to an external water environment. Open-ended lines are pressure balanced, and the static head in a full pipe crossing a water body will usually be the same or higher than the water height above the pipeline.

A few examples of where negative pressure situations may occur are as follows.

- a) aboveground or buried gravity flow lines;
- b) a vacuum line—a water suction line submerged 23 feet in a lake (equivalent to 10 psi external loading) and that is operating under a partial vacuum of 5 psi. The net negative pressure is 15 psi;
- c) a water line going over a hill. The velocity of the water flow down the hill can exceed the velocity of the water coming up the hill and cause a negative pressure to occur.

Excessive external pressure or net internal vacuum pressure can cause pipe flattening or collapse. The maximum external load is determined not by material strength but by the pipe's stiffness. The pipe will flatten if the bending moment due to the load exceeds the resisting moment due to the elastic stresses in the pipe. The critical external pressure above which round pipe will flatten or collapse can be estimated by using Love's equation; see Equation (A.1):

$$P_{cr} = \frac{2E}{1 - \mu^2} \left( \frac{1}{DR - 1} \right)^3 \quad (\text{A.1})$$

Where:

$P_{cr}$	is the critical flattening pressure, lb./in. <sup>2</sup> ;
$E$	is the elastic modulus, lb./in. <sup>2</sup> ;
$\mu$	is Poisson's ratio (0.40 for PEX under long-term stress; 0.35 for PEX under short-term stress);
$DR$	is the pipe dimension ratio.

An appropriate safety factor should be applied when using this equation for design. If short-term modulus is used in the calculation, a safety factor of 3 would be typical. If a long-term value of modulus is available, this may be reduced to 1.5.

For aboveground lines, increased temperatures will decrease the pipe's collapse resistance; in buried lines, pipe deflection will reduce flattening resistance.

## Annex B (informative)

### Interpolation of the HDB

HDB values at temperatures between two other temperatures at which HDBs have been experimentally determined can be calculated by interpolation using Equation (B.1). This method is similar to the method established in PPI TR-3, which uses the LTHS values for interpolation, then categorizes the interpolated LTHS into the HDB.

$$HDB_T = HDB_L - \frac{(HDB_L - HDB_H) \left( \frac{1}{T_L} - \frac{1}{T_T} \right)}{\left( \frac{1}{T_L} - \frac{1}{T_H} \right)} \quad (B.1)$$

Where:

$HDB_T$	HDB at the interpolation temperature (psi);
$HDB_L$	HDB at the lower temperature (psi);
$HDB_H$	HDB at the higher temperature (psi);
$T_T$	interpolation temperature (K);
$T_L$	lower temperature (K);
$T_H$	higher temperature (K).

## Annex C (normative)

### Calculation of Pressure Ratings for Pipe Sizes Not Listed in this Specification

The various pressure-rating tables in this specification contain pressure ratings for a limited range of wall thicknesses. The HDB and DIN 16892/3 methods provide a means of calculating the maximum working pressure for nonstandard sizes that are not listed in this specification. In this annex, methods are described to calculate maximum working pressure if certain information is available about the pipe and operating conditions.

#### C.1 Pressure Rating Based on HDB

Knowing the HDB and DR enables calculation of the maximum working pressure for a given fluid environment. Equation (C.1) defines the relationship between maximum working pressure and the DR, HDB, and fluid environment.

$$MWP = \frac{2HDB \cdot DSF \cdot FSF}{DR - 1} \quad (C.1)$$

Where:

<i>MWP</i>	maximum working pressure (psi);
<i>HDB</i>	hydrostatic design basis (psi);
<i>DR</i>	dimension ratio: (average outside diameter)/(minimum wall thickness);
<i>DSF</i>	system design factor: 0.71 for this specification;
<i>FSF</i>	fluid service factor according to Table 1.

#### C.2 Pressure Rating Based on DIN 16892/3

The DIN 16892/3 pressure rating method is based on the long-term hydrostatic strength performance compared to reference lines published in DIN 16892/3 that relate the long-term hydrostatic pressure resistance of the pipe to the measured rupture time. It is necessary to use the reference lines to calculate the maximum working pressure for a known pipe diameter and wall thickness. Equation (C.2) is derived from the equation in the DIN standard.

$$MWP = \frac{16\sigma \cdot t}{d - t} \cdot FSF \quad (C.2)$$

Where:

<i>MWP</i>	maximum working pressure (bars)
$\sigma$	long-term hydrostatic pressure resistance from reference lines (N/mm <sup>2</sup> );
<i>t</i>	minimum pipe wall thickness (mm);
<i>d</i>	average pipe diameter (mm);
<i>FSF</i>	fluid service factor according to Table 1.

## Annex D (informative)

### Purchasing Guidelines

Table D.1 provides recommended guidelines for inquiry and purchase of API 15PX pipe or fittings.

**Table D.1—Purchasing General Guidelines**

Pipe Design Parameter	Design Conditions
Specification	API 15PX
Material	PEX
Design pressure	
Maximum operating pressure	
Pressure cycles	
Design temperature	
Maximum operating temperature	
Temperature cycles	
Service fluid composition (% liquid hydrocarbons)	
Aboveground or buried	
Fittings requirements	
Isometric drawing	

An important consideration for purchasing quality materials for application in oil and gas gathering is the selection of a quality vendor. Vendors should have an understanding of the necessary quality control testing and be capable of performing the testing required by standards (see Section 2, Normative References).

Vendors should be able to provide records showing that a detailed QA/QC program is in place that utilizes the testing required by API 15PX.

Appropriate records of in-plant inspection and testing and QA/QC testing should be available to demonstrate that the manufacturer's piping products meet the requirements of this specification.

Vendors should have the ability to provide sound technical support for their products in field applications.

## **Annex E** **(informative)**

### **Installation**

#### **E.1 Support Spacing**

Aboveground applications frequently require noncontinuous support for PEX pipe. These types of applications usually involve piping in pipe racks, trestles, on sleepers, or suspended from overhead structures. Where applicable, the structures should provide proper pipeline support, accommodate thermal expansion and contraction, and provide structural support spacing that limits the vertical deflection and movement between supports.

Supports for PEX pipe should cradle at least the bottom 120° of the pipe and be at least  $\frac{1}{2}$  pipe diameter wide. Edges should be rounded or rolled to prevent cutting into the pipe. Commercial pipe supports, such as U-bolts, narrow strap-type hangers, and roller type supports, are unsuitable unless modified for width and cradling. The weight of the pipe and its contents should be distributed over a broad surface. Narrow support surfaces can produce high concentrated stress (point loading) and can possibly lead to pipeline failure.

Pipes supported in an overhead rack require design consideration for both support spacing and thermal length change. Support beams are spaced according to vertical deflection limits, and the rack width accommodates the total thermal expansion offset plus the diameter of the pipe. Pipe supports should be allowed to move along support beams or otherwise accommodate horizontal movement as the pipe deflects laterally with changing temperature.

When not supported continuously in horizontal runs, hangers and brackets should be used at approximately the spacing given by the pipe supplier.

#### **E.2 Joining**

##### **E.2.1 General**

PEX pipe can be joined to other PEX pipe or fittings, or to pipe or appurtenances of other materials, by selecting one or more of the following joining systems: electrofusion, mechanical methods, flanges, mechanical joint adapters, and compression couplings. Conventional butt fusion and melt fusion techniques are not suitable for PEX pipe. Joining and connection methods may vary depending upon requirements for internal or external pressure, leak tightness, restraint against longitudinal movement (thrust load capacity), gasketing requirements, construction and installation requirements, and the product.

When present, liquid hydrocarbons may permeate (solvate) PEX pipe. Liquid hydrocarbon permeation may occur when liquid hydrocarbons are present in the pipe, when soil surrounding the pipe is contaminated with liquid hydrocarbons, or when liquid hydrocarbon condensates form in gas pipelines.

Electrofusion joining to liquid hydrocarbon permeated pipes may result in a low-strength joint. Hydrocarbon permeated lines requiring repair should not be repaired using electrofusion joining methods. Mechanical fittings should be used to join or repair hydrocarbon permeated lines.

##### **E.2.2 Electrofusion**

The electrofusion welding procedure differs somewhat from the conventional fusion joining procedures used for other thermoplastic piping systems. The main difference between conventional heat fusion and electrofusion is

the method by which the heat is applied. In conventional heat fusion joining, a heating tool is used to heat the pipe and fitting surfaces. The electrofusion joint is heated internally, either by a conductor at the interface of the joint, or, as in one design, by a conductive polymer. Heat is created as an electric current is applied to the conductive material in the fitting.

Electrofusion is frequently used in oilfield applications where liquid hydrocarbon permeation has occurred in the interior pipe wall. It is also used where both pipes are constrained, such as for repairs or tie-in joints in the trench. Where appropriate, joints made between PEX and conventional polyethylene are also made using electrofusion. Consult the electrofusion fitting manufacturer for procedures.

For guidance on the use of electrofusion in H<sub>2</sub>S-containing service, see Section 6.

### E.2.3 Flanging

Flanging is used when it is necessary to join PEX to another PEX segment, or to steel, fiberglass, and other piping materials that require an ANSI 150-lb flange connection. Flanging is also an option when it is required that a pipe section is capable of being disassembled for maintenance or where calculated accelerated wear requires fitting removal. The PEX flange adapter is thermoformed at the end of a PEX pipe segment and provided with an ANSI-compatible bolt pattern backup ring. Consult the PEX pipe supplier for guidance on the fabrication and use of PEX flange adapters, including required bolt torque and installation guidance.

PEX flanges that do not incorporate the use of a backup ring are not recommended because PEX flanges require uniform pressure over the entire sealing surface. Without a backup ring, a PEX flange could leak between the bolts.

A flange gasket may not be required for flanging PEX to PEX. Gasket manufacturers may be contacted to ensure that the intended service is recommended for the gasket material chosen and to confirm that the gasket material hardness is correct for the bolting pressures. Hard gaskets that require high bolting pressures may not seal when used with PEX flange adapters.

## E.3 Trench Installation

Underground installations usually require trench excavation, placing pipe in the trench, and then placing backfill to the required finished grade.

There are many site- and project-specific parameters that affect the installation of PEX pipe. Pipe application and service requirements, size, type, soil conditions, burial depth, and joining requirements all affect the installation.

Trench width varies depending on the depth of burial and the soil conditions. The width should be adequate to allow compaction in and around the pipe. If used, bedding material should be free of large clumps, oversize rock, and other foreign materials. The bedding should consist of free-flowing material such as gravel, sand, or similar material. More information can be found on suitable backfill and bedding materials in the standards mentioned below. Field bending the pipe can accommodate slight directional changes.

The care taken by the installer during installation can have a dramatic effect on how the system performs. A conscientious, high-quality installation in accordance with ASTM recommendations, engineering requirements, and manufacturers' specifications can ensure the PEX products perform as designed. On the other hand, a low-quality installation can cause substandard product performance. Additional information on the underground installation of PEX pipe can be found in ASTM D2774, *Standard Practice for Underground Installation of Thermoplastic Pressure Piping*; ASTM D2321, *Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications*; and ASTM F1668, *Standard Guide for Construction Procedures for Buried Plastic Pipe*.

## **E.4 Leak Test (Hydrostatic and Pneumatic Testing)**

### **E.4.1 General**

The manufacturer should provide the maximum hydrostatic leak test pressure for the system.

The premise of a leak test for a PEX piping system is to locate any unacceptable fault in the system before it is put into service. A leak test should not be used to verify a system pressure rating on existing pipe or potential application for service in existing pipe. The system design and the pipe pressure ratings using the equations found in Section 4 and Annex C of this specification determine the system pressure rating and long-term performance. If leaks exist, they usually occur in the joints or in connection with appurtenances in the system.

Pipeline failure during a leak test can be violent and dangerous, especially if one is using pressurized gas for testing, such as compressed air or nitrogen. When testing with compressed gas, both the pressure stress on the system and the energy used to compress the gas are released at failure. The release is potentially violent and can be catastrophic. Where possible, a hydrostatic leak test should always be considered before a compressed gas leak test. Hydrostatic leak testing with water is the recommended and preferred method of testing.

### **E.4.2 Precautions**

Where hydrostatic leak testing is required, the following precautions are recommended. A more detailed procedure may be obtained by checking either ASTM F2164 or the PPI Handbook of PE Pipe, Chapter 2.

- a) The piping system under test should be checked to ensure that sections are fully restrained against sudden movement in case of rupture.
- b) All air should be removed from the system before hydrostatic leak testing begins.
- c) All electrofusion joints should be fully cooled before testing begins.
- d) Mechanical connections should be restrained and tied-in.
- e) All fittings and appurtenances in the system should be verified to meet the test pressure.
- f) All safety precautions to protect personnel in case of rupture should be in place, including suitable personal protective gear to prevent injury.
- g) Keep personnel a safe distance away during pneumatic testing.

### **E.4.3 Test Pressure**

The maximum hydrostatic test pressure should be measured at the lowest point in the system.

The maximum hydrostatic leak test pressure should be provided by the manufacturer.

The authority having jurisdiction may determine the maximum test pressure, as long as the test pressure does not exceed the maximum pressure recommended by the manufacturer.

Elevated temperatures may reduce the maximum test pressure allowed depending on the specific site conditions.

#### E.4.4 Test Procedure (Hydrostatic)

Hydrostatic leak testing is described in ASTM F2164, *Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure*. An overview of the procedure discussed in ASTM F2164 is provided below:

- 1) Observe all safety precautions and site-specific safety regulations.
- 2) Remove all air from the test section by slowly filling with water and allowing entrapped air to escape through air release devices.
- 3) When the line is filled with water and all air is removed, gradually fill the pipe to the test pressure.
- 4) Maintain the pipe at test pressure for three hours. This is called the initial expansion phase. During this phase, the PEX will expand slightly and the pressure will decrease. To maintain test pressure, additional fluid will be required. It is not necessary to monitor the amount of water added during the initial expansion phase.
- 5) Immediately after the three-hour initial expansion phase is complete, the test phase begins.
  - a) Reduce the test pressure by 10 psi (6.9 kPa, 0.069 bar).
  - b) Do not increase pressure or add additional make-up water.
  - c) Monitor the gauge for the next hour and record if the pressure remains steady (within 5 % of the test pressure).
- 6) If no visual leakage is indicated and the test pressure remains within 5 % of the test pressure value, the test is declared successful.

#### E.4.5 Test Procedure (Pneumatic)

Pneumatic leak testing is described in ASTM F2786, *Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Gaseous Testing Media Under Pressure (Pneumatic Leak Testing)*. An overview of the procedure discussed in ASTM F2786 is provided below:

- 1) Carefully consider if pneumatic testing should be authorized.
  - a) Approval should be sought from the owner and the project engineer.
- 2) Observe all safety precautions and site-specific safety regulations.
- 3) Keep personnel a safe distance away during pneumatic testing.
- 4) Maximum permissible test pressure per ASTM F2786 is temperature dependent, as well as a function of the total test duration.
- 5) Gradually increase test pressure in small increments (10 % of the target test pressure).
- 6) The pressure in the test section should be slowly increased and to the test pressure in three steps (10 % of the leak test pressure, 50 % of the leak test pressure, and 100 % leak test pressure) and a leakage examination performed at each step.
- 7) Leakage examination consists of visual examination or the inability to maintain test pressure within 5 % of the test phase pressure for one hour.

- a) All safety precautions to protect personnel in case of rupture should be in place, including suitable personal protective gear to prevent injury if failure occurs.

NOTE The total time under test should not exceed eight hours at 1.5 times the system pressure rating. If the test is not completed during this time frame (due to leakage, equipment failure, etc.), the test section should be depressurized and permitted to “relax” for eight hours prior to the next test sequence. Refer to ASTM F2786 for more complete guidance on this topic.

## E.5 Thermal Expansion and Contraction

The coefficient of thermal expansion and contraction for PEX pipe is about 10 times that of steel pipe. This means that an unrestrained PEX line will expand or contract about 10 times the distance of a comparable steel pipe. When PEX pipe is restrained, the stresses developed due to expansion and contraction are considerably less than those of a steel line. This is due to the lower modulus of elasticity of PEX pipe compared to steel pipe. When PEX is properly anchored and restrained, changes in temperature and the related expansion and contraction have no adverse effect.

The equation to calculate expansion and contraction for PEX is given by Equation (E.1):

$$\Delta L = L \cdot \alpha \cdot \Delta T \quad (E.1)$$

Where:

$\Delta L$	length change;
$L$	pipe length;
$\alpha$	thermal expansion coefficient (this information can be obtained from the PEX supplier);
$\Delta T$	temperature change.

## **Annex F** (informative)

### **Integrity Management**

#### **F.1 Introduction**

Many users of this specification are more familiar with metallic pipe that is stress rated by calculating a fixed percentage of the specified minimum yield stress of the alloy. Provided that the wall thickness does not decrease or there is a defect in a weld, the pipe will retain its stress rating indefinitely. Consequently, integrity management practices are centered around measuring wall thickness, usually caused by corrosion, and inspecting welds for cracks or other defects.

While metallic pipe often fails by wall loss caused by corrosion, plastic pipe does not corrode. The largest obstacle to conventional integrity management of plastic pipe is inspection. In-line inspection tools comparable to those used in metallic pipe are not available.

The principal long-term failure mode of plastic pipe is stress regression, which is the gradual loss of strength over time. At this time, it is not possible to inspect plastic pipe for progress along the stress regression curve.

Because nondestructive in-line inspection techniques are not available for plastic piping systems, the product standards are constructed such that there is a very large amount of long-term testing required to qualify pipe and fitting systems.

Once a pipe has been used for multiphase fluids, wet natural gas, and liquid hydrocarbons, it is always considered to have the maximum working pressure of a pipe transporting those fluids, even if the pipe is later used for transporting fluids that do not require the more conservative FSF.

#### **F.2 Integrity Inspection**

PEX pipe is joined using electrofusion couplers and mechanical couplers. These components cannot be inspected for integrity during operation except by direct observation. Capabilities for direct observation should be accounted for in the system design, and can be accomplished by removing a coupon from a test coupon holder similar to that used for metallurgical coupons, or by removing a short test piece, or sacrificial spool, of the same materials or components as the rest of the PEX piping system.

Deterioration of properties caused by exposure to incompatible chemicals is possible, and this is normally accounted for in the design process; however, pipe material coupons can be placed in the flow stream and removed for destructive testing that may reveal useful information about the condition of the pipeline. The coupon dimensions should be adequate for the types of testing that are planned. The PEX pipe or material supplier should be consulted for advice regarding the tests and coupon characteristics.

Integrity management for PEX piping systems also relies on the maintenance of good records of temperature, pressure, and composition of the transported fluid. Periodic evaluation of these records may reveal conditions that exceeded the design assumptions, requiring a change in operating procedures and a reevaluation of the design life.

PEX pipelines transporting slurries or gases with entrained sand may cause pipe wall erosion. The design should account for this wall loss. Inspection of wall thickness may be done using ultrasonic measurement devices, but the nature of erosion makes it difficult to know the location of the highest erosion rates.

### **F.3 Repairs and Maintenance**

Repairing PEX piping can be done in some applications and situations. Repair procedures should be qualified before being applied to the pipe. Pipe wall damage can be repaired using electrofusion saddles over the damage site, and full encirclement sleeves have been used to repair larger damaged areas. Repair tools and methods are beyond the scope of this specification. Metallic or abrasive pigs should not be used as they may damage the interior surface. Soft foam pigs may be used.

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