Crosslinked Polyethylene (PEX) Pipe & Tubing

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Foreword

This report was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute (PPI). These members are committed to developing and improving quality products by assisting independent standards and user organizations in the development of standards, and also by developing design aids and reports to help engineers, code officials, specifying groups, contractors and users.

The purpose of this technical note is to provide general information on crosslinked polyethylene (PEX) pipe and tubing, how it is manufactured and in what applications it can be used.

The PPI has prepared this technical note as a service to the industry. The information in this report is offered in good faith and believed to be accurate at the time of its preparation, but is offered without any warranty, express or implied. Additional information may be needed in some areas, especially with regard to unusual or special applications. Consult the manufacturer or material supplier for more detailed information. A list of member manufacturers is available on the PPI website. PPI does not endorse the proprietary products or processes of any manufacturer and assumes no responsibility for compliance with applicable laws and regulations.

PPI intends to revise this report within 5 years or sooner if required, from the date of its publication, in response to comments and suggestions from users of the report. Please send suggestions of improvements to the address below. Information on other publications can be obtained by contacting PPI directly or visiting the web site.

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Background

The successful use of PEX pipe systems throughout the world along with the capabilities of PEX piping in cold and hot water environments have generated significant interest in these materials and products in the North American market. As a result of this interest a need has developed to educate the plumbing and building industries as well as the public on crosslinked polyethylene (PEX). This technical note provides an overview of PEX properties and technologies, the applications and benefits of PEX, and the qualification requirements of PEX.

What is PEX?

PEX is a polymeric material formed by the chemical joining of individual polyethylene molecules in a process called crosslinking. Crosslinking alters the performance of the original polyethylene polymer improving several key properties. PEX is a crosslinked thermoplastic PE material; since the crosslinking process is not reversible, PEX tubing becomes a thermoset material as defined by ASTM F412. The primary reason for crosslinking polyethylene (PE) is to increase the material's elevated temperature performance under load. In addition crosslinking substantially improves the pipe's environmental stress crack resistance (ESCR), resistance to slow crack growth, chemical resistance, toughness and abrasion resistance.

How does PEX improve properties from PE?

Below is a table summarizing the property change from PE to PEX:

Property	**From PE to PEX**
Density	Unchanged or Decreases
Tensile Strength @ 73°F (23°C)	Unchanged
Elongation at Break	Unchanged or Decreases
Environmental Stress Crack Resistance	Increases
Resistance to Slow Crack Growth	Increases
Creep Resistance	Increases
Hydrostatic Design Basis (HDB) • HDB @ 73°F (23°C) • HDB @ 180°F (82°C)	 Unchanged Increases
Hydrocarbon Permeation	Unchanged
Chemical Resistance *	Increases
*. The chemical resistance of thermoplastics is complex and is generally a function of the polymer's resistance to applied load, temperature and environment	

In general, 140°F (60°C) is the typical maximum service temperature for thermoplastic pressure PE pipe applications. However, once the polyethylene is crosslinked, the in-service temperature can be raised to at least 212°F (100°C) and sometimes as high as 248°F (120°C), depending on the starting density, degree of crosslinking and type of crosslinking.

How is PE Crosslinked into PEX?

Polyethylene can be crosslinked using several different technologies. All methods create bonds between the single chains of PE to form a dense network through chemical reactions. The number of links between the strands determines the crosslink density and is an important factor in determining the physical properties of the material. The minimum percent of crosslinking in the PEX pipe for each method is specified in both the ASTM and CSA standards. The three most common methods of crosslinking polyethylene are as follows:

Peroxide – This method employs organic peroxides that when heated generate reactive free radicals that splice PE chains together. This is sometimes referred to as the PEX-a Process.

Vinylsilane - This method involves grafting a reactive silane molecule to the backbone of the polyethylene. This is sometimes referred to as the PEX-b Process.

Beta Irradiation - This method involves subjecting a dose of high-energy electrons to the PE. This is sometimes referred to as the PEX-c Process.

PEX pipe produced by any of the three methods must meet the same qualification requirements as specified in the PEX standards. Although the three methods of crosslinking produce slightly different pipe characteristics, all three are commonly used to manufacture approved PEX products. As required in any manufacturing process, procedures for each technology must be established and followed with good quality control checks in place to produce quality products.

What are the typical requirements for piping made from PEX?

PEX tubing and PEX fittings come in sizes ranging from 1/4” to 2” in diameter in North America; whereas in Europe PEX pipe is available in larger sizes up to 6”. PEX tubing is manufactured to copper tubing size OD controlled (CTS-OD) dimensions and is sold in coils and straight lengths. The wall thickness is based upon SDR 9 values, which yield pressure ratings of 160 psi at 73°F and 100 psi at 180°F. Additionally, some manufacturers have their tubing rated to 200°F with an 80-psi maximum working pressure. Consult the specific PEX manufacturer’s literature for appropriate pressure ratings. Some PEX fittings shall only be joined to specific PEX tubing as recommended by the pipe manufacturer.

What are the Applications for PEX?

PEX is used in the following applications:

1. residential and commercial cold and hot water distribution systems
2. low temperature heat transfer applications
3. radiant floor heating
4. snow melting
5. ice rinks
6. high temperature distribution piping
7. hot water baseboard
8. radiators
9. water service pipes per AWWA C904 standard
10. natural gas distribution
11. industrial and mining applications

PEX is a unique material that provides you many opportunities for new applications. Please discuss your application with any PEX manufacturer to determine if PEX is the material of choice for the application.

What are the Advantages of PEX Pipe Systems?

PEX pipe systems offer the following advantages over competing materials as documented in the *PEX Design Guide* that was published by PPI, PPFA and the NAHB Research Center (please refer to the Guide for additional details):

- Speed and Ease of Installation
- Lower Material Cost
- Energy Efficiency
- Electrolysis Resistance
- Corrosion Resistance
- Durability
- Flexibility
- Chemical Resistance to most Chemicals
- Noise and Water Hammer Resistance
- No Solvent or Chemical Joining Required
- Resistance to Freeze Damage

Code Acceptance of PEX Piping

PEX plumbing systems are recognized by all major building codes, including (but not limited to) the: International Residential Code, International Plumbing Code, National Standard Plumbing Code and Uniform Plumbing Code.

What are the qualification requirements for PEX?

In order to qualify a PEX piping product for commercial market use, a manufacturer's product and piping system must be evaluated and approved to one or more of the following requirements depending on application:

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

(2) ASTM F877 - Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems,

(3) ASTM F2023 – Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Chlorinated Hot Water.

(4) ASTM D 2513 – Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings, Annex A7 "Supplemental Requirements for Gas Pressure Pipe Produced from Crosslinked Polyethylene (PEX) Material,

(5) AWWA C904 Cross-Linked Polyethylene (PEX) Pressure Pipe, ½ inch (12 mm) Through 3 inch (76 mm), for Water Service.

(6) CSA International B137.5 - Crosslinked Polyethylene Tubing Systems for Pressure Applications.

(7) PPI TR-3 - Policies and Procedures for Developing Hydrostatic Design Basis (HDB) Pressure Design Basis (PDB) Strength Design Basis (SDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe.

(8) ANSI/NSF Standard 14 – Plastics Piping System Components and Related Materials (for both potable water and radiant floor heating applications).

(9) ANSI/NSF Standard 61 - Drinking Water System Components - Health Effects (for potable water applications only).

ASTM F876

This specification covers PEX tubing that is outside diameter controlled, made in standard thermoplastic tubing dimensions ratios, and pressure rated for water at three temperatures. Included are requirements and test methods for material, workmanship, dimensions, sustained pressure, burst pressure, environmental stress cracking, stabilizer functionality, oxidative resistance to chlorinated water in potable water applications and degree of crosslinking.

ASTM F877

This specification covers requirements, test methods, and methods of marking for crosslinked polyethylene plastic hot- and cold-water distribution systems components made in one standard dimension ratio and intended for 100 psi (0.69 MPa) water service up to and including a maximum working temperature of 180°F (82°C). Components are comprised of tubing and fittings. Requirements and test methods are included for materials; workmanship, dimensions and tolerances, hydrostatic sustained pressure strength, thermocycling resistance, and fittings and bend strength. Also included are tests related to system malfunctions. The components covered by this specification are intended for use in residential and commercial, hot and cold, potable water distribution systems as well as sealed central heating, including under-floor-heating systems.

ASTM F2023

This test method describes the general requirements for evaluating the long-term oxidative resistance of cross-linked polyethylene (PEX) tubing produced in accordance with ASTM F876 or PEX tubing/fitting systems produced in accordance with ASTM F877 by exposure to hot, chlorinated water used in hot-and-cold water distribution systems. This test method is applicable to PEX tubing and systems used for transport of potable water containing free-chlorine for disinfecting purposes. The oxidizing potential of the test-fluid specified in this test method exceeds that typically found in potable water systems across the United States.

Note - Other known disinfecting systems (chlorine dioxide, ozone, and chloramines) are currently used for protection of potable water; however, free-chlorine is by far the most common system in use today. Chloramines have been tested in comparison to free-chlorine utilizing ASTM F2023 by PPI and found to be significantly less aggressive to PEX piping. Please refer to the PPI Technical Report Statement A at the PPI website for more details. Disinfecting systems other than chlorine and chloramines have not been evaluated by this method.

ASTM D2513

This specification covers requirements, test methods, and marking for PEX tubing used in the natural gas distribution industry. PEX has been used for gas distribution since the 1990's in Europe, and was first installed for natural gas distribution in North America in 2006. The most common joining method for PEX used in gas applications is electrofusion.

AWWA C 904

This standard describes Crosslinked Polyethylene (PEX) pressure pipe made from material having a standard PEX material designation code of PEX 1006 in ASTM F876

for use as underground water service lines in sizes ½ in. (12mm) through 3 in. (76mm) that conform to a standard dimension ratio of SDR9. The purpose of this standard is to provide the requirements for materials, design, testing, inspection, and shipping of PEX pipe for use as service lines in the construction of underground water distribution systems. This standard can be referenced for purchasing and receiving PEX pressure pipe and as a guide for manufacturing PEX pressure pipe.

CSA B 137.5

This Standard provides requirements for crosslinked polyethylene (PEX) pressure tubing systems. Components covered by this Standard are made in Standard Dimension Ratio 9 (SDR 9) and are intended for use in potable water distribution systems at a maximum working temperature of 82°C and at a maximum working pressure of 690 kPa. In addition the use of PEX tubing systems in applications other than potable water distribution systems, such as radiant panel heating systems, baseboard heating systems, and snow and ice melt systems, is acceptable provided that the PEX tubing systems comply with the applicable code requirements.

PPI TR-3

This technical report presents the policies and procedures used by the HSB (Hydrostatic Stress Board) of the PPI (Plastics Pipe Institute) to develop recommendations of estimated long-term hydrostatic strength for commercial thermoplastic piping materials. Recommendations are published in PPI technical report TR-4, “PPI Listing of Hydrostatic Design Basis, and Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe”.

Listings are developed from data submitted to the HSB by the manufacturer. These data are obtained according to the basic method outlined in ASTM D1598, “Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure.” The general method used to evaluate the data is described in ASTM D2837, “Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials,” with additional requirements as specified in PPI TR-3.

TR-3 and TR-4 also provide the recommended pipe material designation codes for PEX materials. An example of this pipe material designation code is as follows:

- PEX 1006 is a crosslinked polyethylene (the PEX abbreviation is in accordance with ASTM D 1600) which has a 630 psi maximum recommended HDS (0.5 design factor) at 73°F (23°C).

Unlike thermoplastic PE material designation codes, the first two digits of PEX cannot be used for its short-term properties. The first digit for PEX is for chlorine resistance tested in accordance with ASTM F 2023. A digit “1” indicates the PEX tubing has been tested and meets the F 876 requirement for minimum chlorine resistance at the end use condition of

25% at 140°F (60°C) and 75% at 73°F (23°C). A digit “0” indicates it does not meet this requirement or it has not been tested. The second digit for PEX is currently not specified, but is being considered for UV resistance. The last two digits of this number represent the PPI recommended HDS (0.5 design factor) at 73°F (23°C) divided by one hundred.

ANSI/NSF Standard 14

NSF International developed Standard 14 - Plastics Piping System Components and Related Materials in October, 1965. NSF-14 establishes minimum physical, performance, quality assurance, marking, and record keeping requirements for plastic piping components and related materials.

ANSI/NSF Standard 61

This standard is intended to cover specific materials or products that come into contact with drinking water, drinking water treatment chemicals, or both. The primary focus of the standard is on contaminants or impurities imparted indirectly to drinking water.

PEX tubing used in the transport of potable water must be marked “POTABLE” or have the seal of a lab that has evaluated the tubing against the requirements of ANSI/NSF Standard 61.

Acknowledgement

This technical note was developed, reviewed, and approved by the High Temperature Division (HTD) of the Plastics Pipe Institute.