PEX Tubing for Water Service Line Applications

A presentation by
The Plastics Pipe Institute

ASPE American Society of Plumbing Engineers CEU PROVIDER

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The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry

- PPI was formed in 1950 to research and develop test methods for plastic pressure pipes
- Today: Non-profit trade association serving North America, based in Irving, TX

PPI Mission: To advance the acceptance and use of plastic pipe systems through research, education, technical expertise, and advocacy

Members: Over 170 member firms involved with the plastic pipe industry

PPI Website: www.plasticpipe.org

The Plastics Pipe Institute

PPI Building & Construction Division (BCD)

- BCD is focused on plastic pressure pipe and tubing systems used within buildings and on building premises for applications such as plumbing, water service, fire protection, hydronic heating & cooling, snow & ice melting, district energy heating & cooling, and ground source geothermal piping systems.

BCD Materials: CPVC, HDPE (Geothermal), PEX, PE-RT, PEX-AL-PEX, and PP (PP-R & PP-RCT)

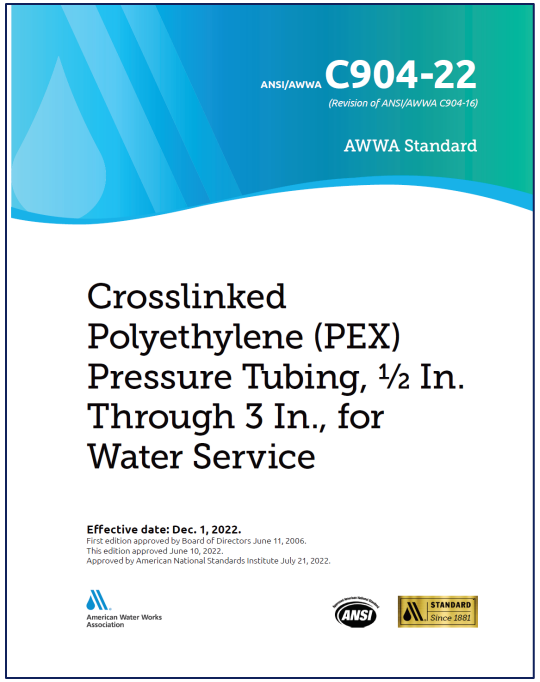
BCD homepage: *https://plasticpipe.org/BuildingConstruction*

Course Introduction

- PEX tubing is a strong, tough, reliable material with exceptional resistance to chlorine and chloramines
- PEX tubing has been used for water service line and building supply line applications in North America for over 25 years, providing safe delivery of potable water and protecting the health of building occupants

- AWWA C904, the controlling industry standard specification, was first published in 2006, updated in 2016, and revised again in late 2022

- This course demonstrates how the properties of PEX water service lines and building supply lines can protect the health, safety, and welfare of building occupants through efficient and reliable delivery of clean drinking water. It will describe material properties, joining systems, standards, installation techniques, and advantages over metallic materials.



*IIJA = U.S. Infrastructure Investment and Jobs Act

Course Introduction

- The **2021 IIJA*** includes $55 Billion for clean drinking water, including **$15 Billion** for replacement of an estimated 6 - 10 million lead service lines (LSLs) across the country
- The **EPA's Lead and Copper Rule** (LCR) is also being used to help speed LSL replacements
- PEX is an excellent material for LSL replacements and has been used successfully in service line applications in Canada and USA for over 25 years

Water Highlights of the Infrastructure Act of 2021

The U.S. Infrastructure Investment and Jobs Act, enacted in 2021, should kick-start many long overdue updates and improvements to the nation's water infrastructure. This federal law reauthorizes many existing drinking water programs, appropriates expanded funding for water infrastructure and other programs, and commits $15 billion for lead service line replacement.

Understanding the Lead and Copper Rule

Course Learning Objectives

By the conclusion of this course, participants should be able to:

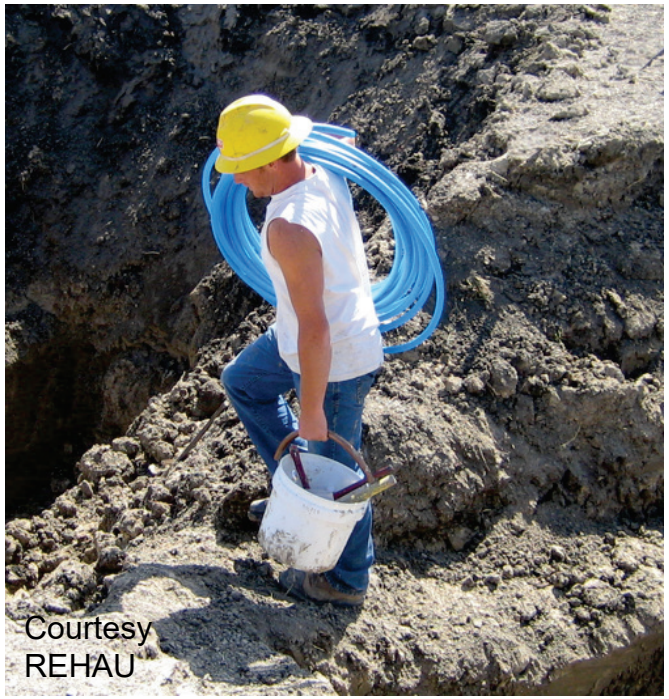
1. Discuss how the properties of PEX tubing can protect health, safety, and welfare of building occupants when used as water service lines and building supply lines
2. Describe PEX water service line standards and code compliance
3. List several joining systems that are approved for use with PEX water service tubing
4. Explain how to size PEX water service line tubing for reliable performance
5. Direct installers on correct installation techniques to ensure long-term safety and performance
6. Identify practical reasons to specify PEX water service line tubing as a replacement for lead and copper
7. Show how to access industry resources for additional material, design, and installation information

1. How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Crosslinked Polyethylene (PEX) History & Overview

- Introduced for radiant heating in the early 1970s in Europe (50+ years ago)
- Introduced to USA and Canada in the 1980s* for heating and plumbing
- PEX was approved for water service in model plumbing codes ~ 1997
- First documented installations of PEX water service line in North America were in **Kentville, Nova Scotia** and **Baltimore, Maryland** in **1997**

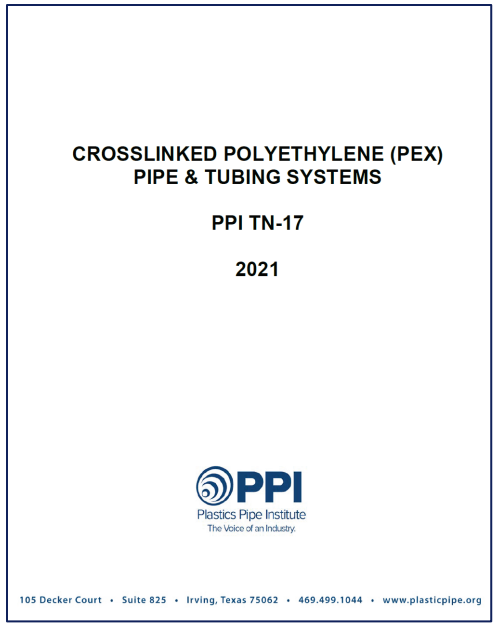
**ASTM F876, the original PEX tubing standard, was published in 1984*


Courtesy REHAU

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Crosslinked Polyethylene (PEX) History & Overview

- See **PPI TN-17** for best overview of PEX tubing & the source of the following information



CROSSLINKED POLYETHYLENE (PEX)
PIPE & TUBING SYSTEMS

PPI TN-17

2021

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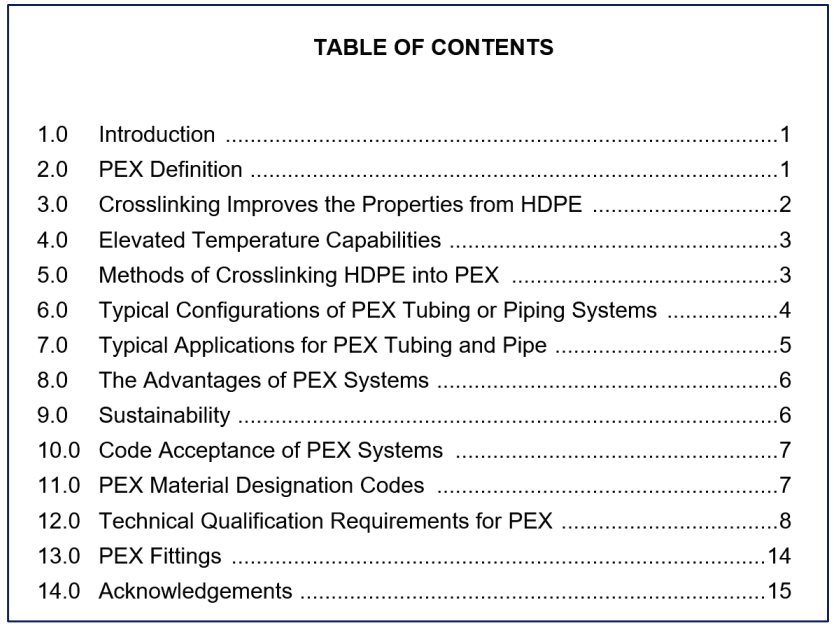

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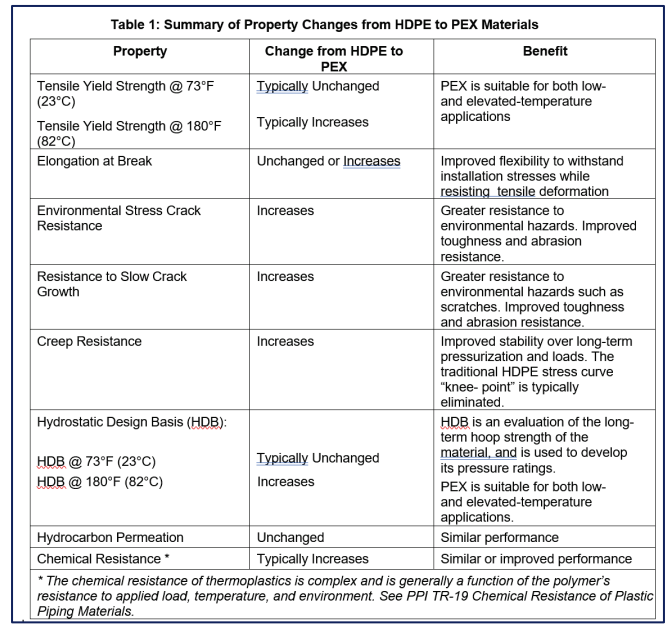


Table 1: Summary of Property Changes from HDPE to PEX Materials

Property	Change from HDPE to PEX	Benefit
Tensile Yield Strength @ 73°F (23°C) Tensile Yield Strength @ 180°F (82°C)	Typically Unchanged Typically Increases	PEX is suitable for both low- and elevated-temperature applications
Elongation at Break	Unchanged or Increases	Improved flexibility to withstand installation stresses while resisting tensile deformation
Environmental Stress Crack Resistance	Increases	Greater resistance to environmental hazards. Improved toughness and abrasion resistance.
Resistance to Slow Crack Growth	Increases	Greater resistance to environmental hazards such as scratches. Improved toughness and abrasion resistance.
Creep Resistance	Increases	Improved stability over long-term pressurization and loads. The traditional HDPE stress curve "knee- point" is typically eliminated.
Hydrostatic Design Basis (HDB): HDB @ 73°F (23°C) HDB @ 180°F (82°C)	 Typically Unchanged Increases	HDB is an evaluation of the long-term hoop strength of the material, and is used to develop its pressure ratings. PEX is suitable for both low- and elevated-temperature applications.
Hydrocarbon Permeation	Unchanged	Similar performance
Chemical Resistance *	Typically Increases	Similar or improved performance

** The chemical resistance of thermoplastics is complex and is generally a function of the polymer's resistance to applied load, temperature, and environment. See PPI TR-19 Chemical Resistance of Plastic Piping Materials.*

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Crosslinked Polyethylene (PEX) History & Overview

- PEX is a high-temperature flexible pressure piping system with exceptional resistance to slow crack growth (SCG), pressure cycling, seismic movements, and potable water disinfectants like chlorine and chloramines

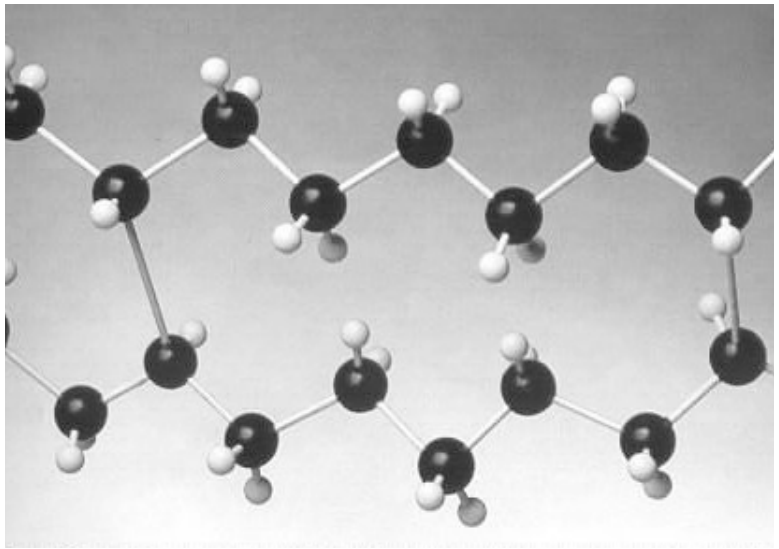
- PEX tubing systems are used for **water service lines**, hot- and cold-water distribution, residential fire protection, hydronic distribution, radiant heating & cooling, outdoor snow & ice melting, district energy distribution, geothermal ground loops, and other demanding applications

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Crosslinked Polyethylene (PEX) Definition

- Formal Definition – “PEX is a polyethylene material that has undergone a change in molecular structure through processing whereby a majority of the polymer chains are chemically linked.” *Source: ASTM F412, ASTM F876*

- “Crosslinking of polyethylene into PEX for pipe and tubing results in improved properties such as elevated temperature strength and performance, chemical resistance, flexibility, and resistance to slow crack growth.” *Source: PPI Technical Note 17*



How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

PEX Tubing Production Methods

The three common methods of crosslinking polyethylene into PEX are known as:

- **Peroxide (PEX-a) method**
- **Silane (PEX-b) method**
- **Electron beam (PEX-c) method**

- Letter designations are not related to any type of performance rating system; based on chronological dates
- PEX tubing produced by each of these methods must meet the same technical requirements as specified in the relevant industry standards (e.g., AWWA C904, ASTM F876) and codes (e.g., IPC, NSPC, UPC)

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

PEX Tubing Production Methods

The three common methods of crosslinking polyethylene into PEX are known as:

- **Peroxide (PEX-a):** *This method employs organic peroxides that generate reactive free radicals that splice PE chains together during extrusion*
- **Silane** (**PEX-b):** *Involves grafting a reactive silane molecule to the backbone of the polyethylene; crosslinking reaction is completed during moisture-curing in a steam "sauna" or hot-water bath*
- **Electron beam** (**PEX-c):** *Involves subjecting the extruded PE pipe to a dose of high-energy electrons*

See *PPI Technical Note 17* for more details about each method

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

PEX Tubing Nominal Sizing

- PEX tubing is **Nominal Tubing Size** (NTS): the actual Outside Diameter is 1/8 inch larger than the nominal size
- PEX tubing is also **Copper Tube Size** (CTS, same OD as copper tubing)
- PEX tubing has a **Standard Dimension Ratio (SDR)** of **9**
- Wall thickness is 1/9 of the average OD for consistent pressure ratings
- PEX tubing from all firms is dimensionally the same (within tight tolerances)

Example:

- 3/4 Nominal Tubing Size (NTS): Outside diameter = 0.875 +/- 0.004”
- 3/4 Nominal Tubing Size (NTS): Wall thickness = 0.097” - 0.107”
- 3/4 Nominal Tubing Size (NTS): Out-of-roundness* = ≤ 0.016”

**measured prior to coiling*

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

PEX Tubing Configurations

- PEX water service tubing is produced in nominal tubing sizes from 3/4 to 3 (copper tube size)
- PEX water service tubing is available in natural (white) or colors such as blue
- PEX tubing is available in coils or straight lengths, depending on the customer preference and application

Courtesy BOW

Courtesy REHAU

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Drinking Water Safety

- PEX tubing and fittings intended for potable (drinking) water shall meet requirements of NSF/ANSI/CAN 61 *Toxicological Evaluation for Materials in Contact with Drinking Water ("Health Effects")*

1.1 Purpose "This Standard establishes minimum health effects requirements for the chemical contaminants and impurities that are indirectly imparted to drinking water from products, components, and materials used in drinking water systems."

NSF/ANSI/CAN 61 is updated regularly with stringent requirements

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Drinking Water Safety

- PEX tubing and fittings intended for potable (drinking) water shall meet requirements of NSF/ANSI/CAN 372: *Drinking Water System Components, Lead Content*

1.1 Purpose "This Standard establishes procedures for the determination of lead content based on the wetted surface area of products."

1.2 Scope "The standard applies to any drinking water system component that conveys or dispenses water for human consumption through drinking or cooking."

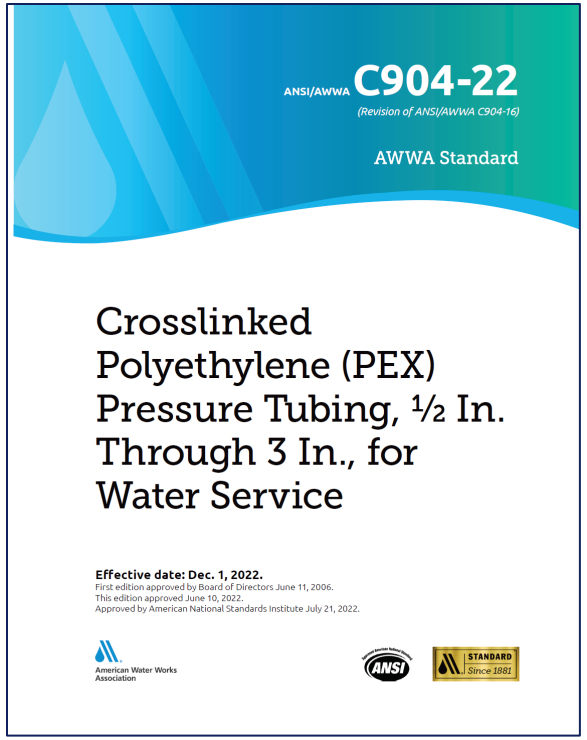
NSF/ANSI/CAN 372 is updated regularly with stringent requirements

How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Fit for Purpose and Reliability

- PEX tubing intended for water service line applications must be third-party tested and certified to meet the requirements of AWWA C904 *Crosslinked Polyethylene (PEX) Pressure Tubing, ½ In. Through 3 In., for Water Service*

- First published in 2006, first revision approved in 2016
- Third edition published late 2022
- Requirements of AWWA C904 will be described in the next Learning Objective



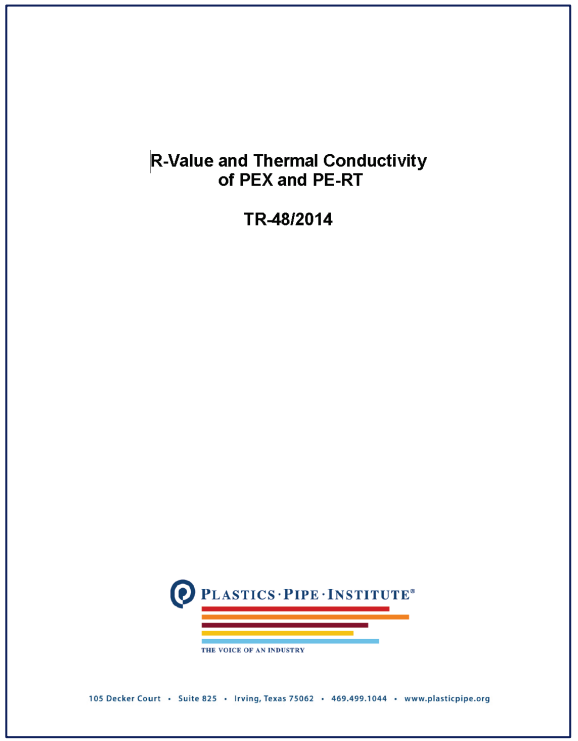
How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

PEX Property: Low Thermal Conductivity and k-value

- PPI TR-48 *R-Value and Thermal Conductivity of PEX and PE-RT* reports:

- PEX k-value = **2.86** (BTU·in)/(ft^2·hr·°F) or **0.41** W/(m·°K)
- Copper k-value = **196** (BTU·in)/(ft^2·hr·°F) or **28** W/(m·°K)

- Copper is **68 times more conductive** than PEX
- PEX delays heat transfer and can delay freezing of water within tubing
- Reliable delivery of water even in extreme weather



How the Properties of PEX Tubing Can Protect Health, Safety, and Welfare when used as Water Service Line

Summary

- PEX tubing has a long history of use around the world for drinking water and for water service lines

- Crosslinked polyethylene is a versatile piping material

- Required certifications to AWWA C904, NSF/ANSI/CAN 61, NSF/ANSI/CAN 372 and other standards ensure safety for drinking water

2. PEX Water Service Line Standards & Code Compliance

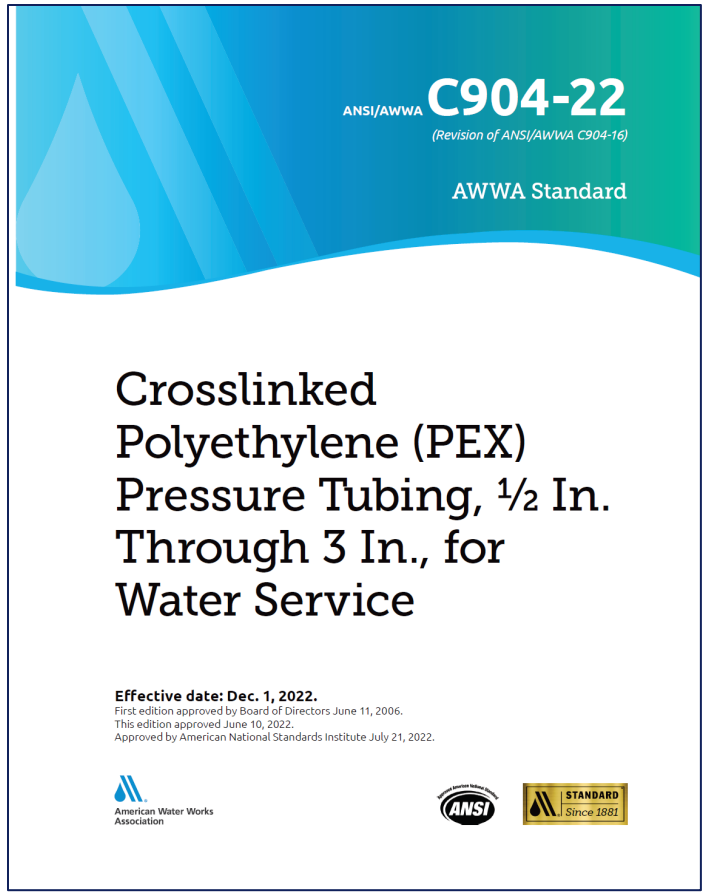
PEX Tubing Standards

- There are three primary standards for PEX tubing in North America:
  - AWWA C904 *Crosslinked Polyethylene (PEX) Pressure Tubing, ½ In. Through 3 In., for Water Service*
  - ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*
  - CSA B137.5 *Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications*
- Plumbing codes such as IPC, NSPC, UPC, and the NPC of Canada refer to these standards
- This presentation will focus on the requirements of **AWWA C904**

PEX Water Service Line Standards & Code Compliance

PEX Water Service Line Tubing Requirements: Overview

- **AWWA C904-22** establishes capabilities and test requirements, such as:
  - Dimensions
  - Design factor (DF)
  - Degree of crosslinking
  - Quick burst pressures
  - Long-term hydrostatic strength (LTHS) and pressure ratings
  - Chlorine resistance
  - UV resistance
  - Excessive pressure-temperature capability
  - Hot-bend and cold-bend tests
  - Marking requirements
  - Quality control, more…

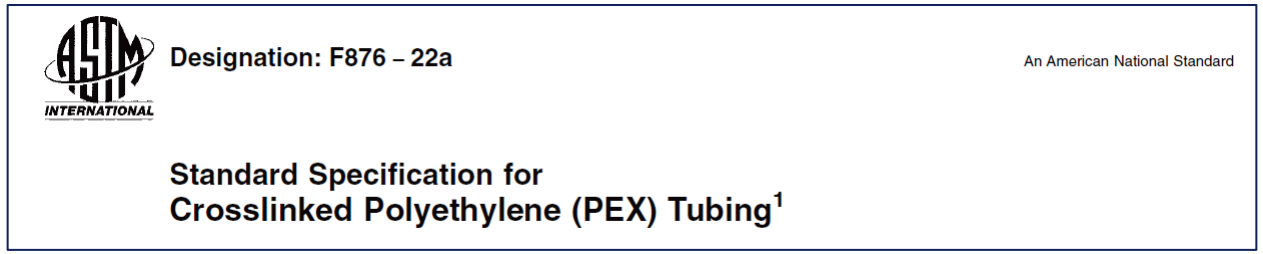


PEX Water Service Line Standards & Code Compliance

PEX Water Service Line Tubing Requirements: Degree of Crosslinking

Requirement from **AWWA C904**:

- "When tested in accordance with ASTM F876, the degree of crosslinking for PEX tubing material shall be from **65 percent to 89 percent** inclusive."


Designation: F876 – 22a

An American National Standard

Standard Specification for
Crosslinked Polyethylene (PEX) Tubing[1]

Details:

- ASTM F876 contains the technical testing details for all PEX tubing requirements
- ASTM F876 describes how crosslinking testing is performed to ensure that pipes were manufactured and processed correctly; this testing is part of standard quality control, performed frequently by manufacturers

PEX Water Service Line Standards & Code Compliance

PEX Water Service Line Tubing Requirements: Burst Pressure

Requirement from **AWWA C904** for short-term burst pressure:
- Minimum burst pressure **475 psig** at 73°F (3,270 MPa @ 23°C)

PEX tubing and fitting systems are also tested for burst pressure capabilities at high temperatures:
- Minimum burst pressure **210 psig** @ 180°F (1,450 kPa @ 82°C)
- Minimum burst pressure **180 psig** @ 200°F (1,240 kPa @ 93°C)

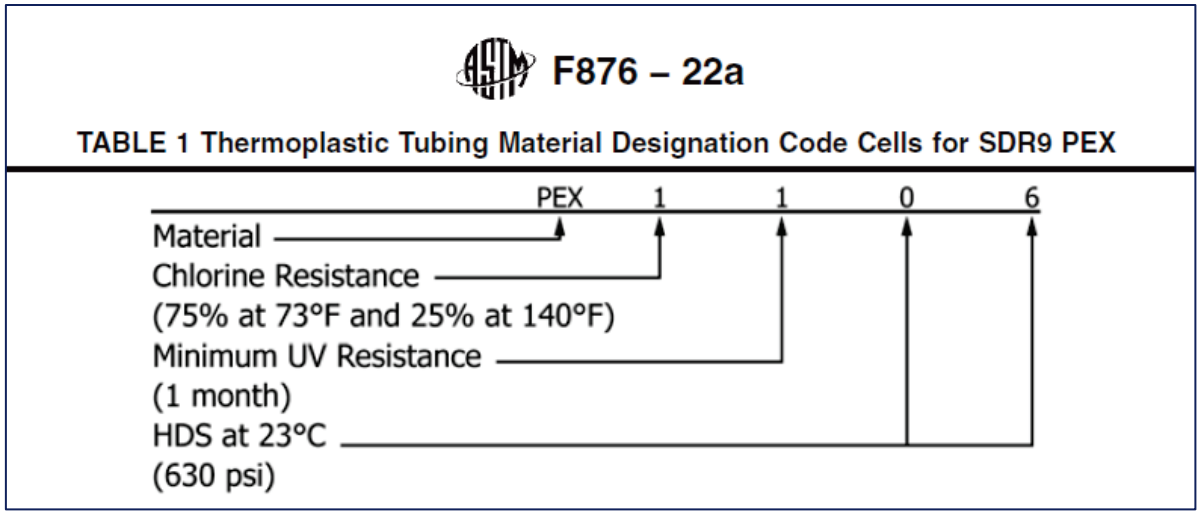
Details:
- Burst testing is performed in accordance with ASTM D1598 to test the short-term strength of the tubing

PEX Water Service Line Standards & Code Compliance

Three Key PEX Tubing Properties with Categories for Performance

1. Chlorine Resistance
2. UV Resistance
3. Hydrostatic Design Stress (HDS), related to pressure ratings

- Performance categories are defined in ASTM F876 TABLE 1 "**Thermoplastic Tubing Material Designation Code for SDR9 PEX**"



F876 – 22a

TABLE 1 Thermoplastic Tubing Material Designation Code Cells for SDR9 PEX

PEX	1	1	0	6

Material
Chlorine Resistance
(75% at 73°F and 25% at 140°F)
Minimum UV Resistance
(1 month)
HDS at 23°C
(630 psi)

PEX Water Service Line Standards & Code Compliance

Chlorine Resistance: Evaluation

Details:

- All PEX intended for use with potable water must have a minimum extrapolated lifetime of **50 years** when tested in accordance with ASTM Test Method F2023
- ASTM F2023 requires that multiple specimens of tubing are tested to failure at three pressures and three temperatures, typically 203°F, 221°F, and 239°F (95°C, 105°C, and 115°C)
- The "Extrapolated time-to-failure" of tubing at each end-use condition (e.g., **1, 3, 5**) is calculated using Miner's Rule formula, based on end-use pressure-temperature conditions of **80 psig @ 140°F**
- Extrapolated time-to-failure of tubing at **160 psig @ 73°F** is also calculated and reported

See **PPI TN-53** ***Guide to Chlorine Resistance Ratings***… for more information

PEX Water Service Line Standards & Code Compliance

Chlorine Resistance: Four (4) Categories of Performance

0 = Not tested or not rated
1 = 25% of time hot at 140°F, 75% at 73°F (e.g., intermittent hot water, ≤ 6 hours/day)
3 = 50% of time hot at 140°F, 50% at 73°F (e.g., timed hot water recirculation, ≤ 12 hours/day)
5 = 100% of time hot at 140°F (e.g., continuous recirculation of hot water, no timer)

Note: 73°F = 23°C, 140°F = 60°C

- Digit **'1'** is the **Minimum** requirement for PEX water service line tubing according to AWWA C904

- At the end-use operating condition of **160 psig @ 73°F**, the Extrapolated time-to-failure for PEX tubing is in excess of **100 years** with regards to chlorine resistance

PEX Water Service Line Standards & Code Compliance

UV Resistance: Potential Threats

- The long-term performance of PEX can be damaged by **excessive UV radiation** from sunlight, especially when tubing is used in chlorinated hot-water systems after exposure
- Overexposure to UV can lead to potential reduced pipe lifetimes
- PEX should not be stored outdoors or installed with exposure to sunlight

Solution:

- Users should keep PEX tubing stored indoors in the original packaging prior to installation for protection against UV/sunlight and other potential hazards

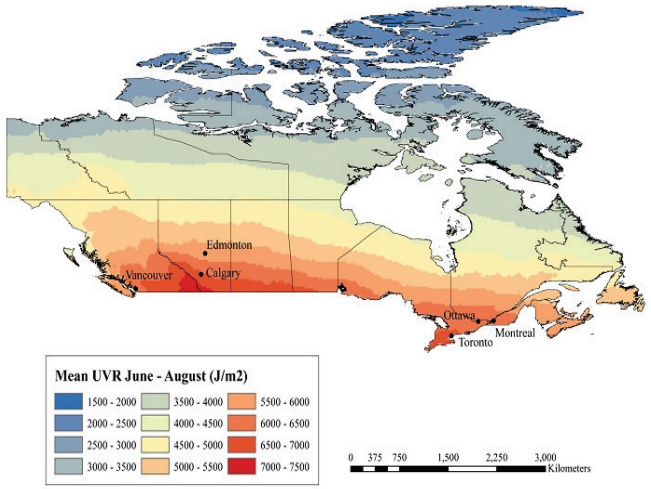
PEX Water Service Line Standards & Code Compliance

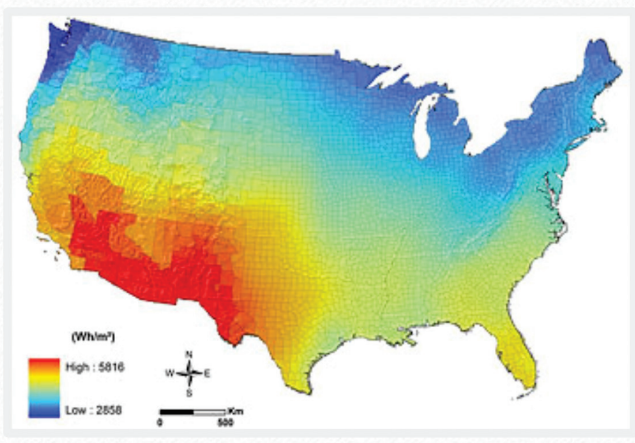
UV Resistance: Potential Threats

- Actual UV intensity varies greatly across the US and Canada
- The risk of overexposure also varies based on location

- Example Map (US): *County Level UV Exposure Data for the Continental United States*
- https://gis.cancer.gov/tools/uv-exposure/

- Example Map (Canada): *Mean ultraviolet radiation for June through August, Canada, 1980-1990*
- https://www150.statcan.gc.ca/n1/daily-quotidien/170517/mc-b001-eng.htm





PEX Water Service Line Standards & Code Compliance

UV Resistance: Evaluation

- UV resistance of PEX is evaluated according to ASTM Test Method F2657
- Natural exposure is based on worst-case North American location near Phoenix, AZ
- Tubing samples are mounted outdoors, facing **South**
- Samples are left outdoors until the required amount of UV exposure is accumulated (e.g., 30 days, 90 days)
- Then, chlorine testing is performed on exposed samples to detect any degradation in performance, as compared with tubing that was not exposed to sunlight

- Each PEX tubing manufacturer must have its tubing tested and evaluated according to ASTM F2657

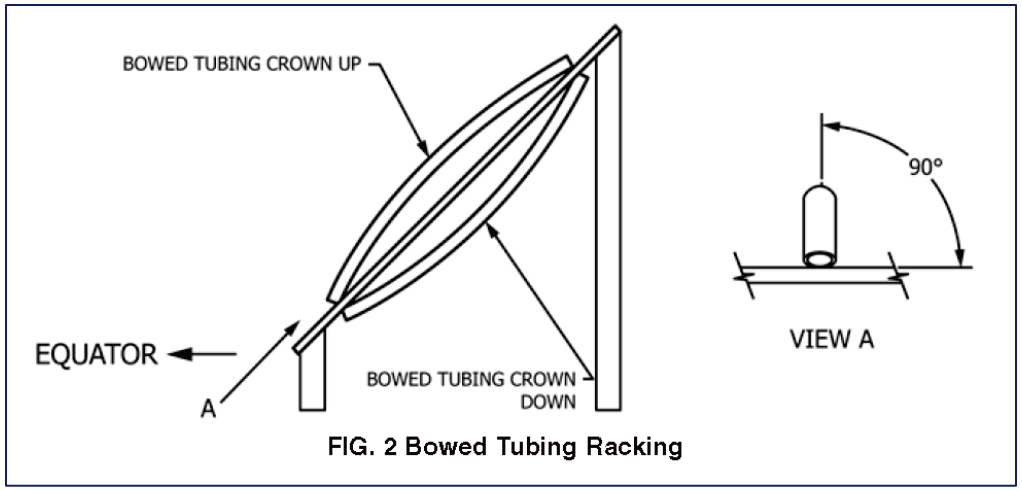


FIG. 2 Bowed Tubing Racking

Fig. 2 from ASTM F2657

PEX Water Service Line Standards & Code Compliance

UV Resistance: Four (4) Categories of Performance

0 = Not tested or not rated
1 = 1 month minimum UV resistance
2 = 3 months minimum UV resistance
3 = 6 months or more minimum UV resistance

- Digit **'3'** is the **Minimum** requirement for PEX water service line tubing according to AWWA C904

- Look for a label describing the maximum allowed UV exposure time
  Suggested label text according to ***PPI TN-32***

CAUTION

- The long-term performance of PEX will be damaged by excessive UV radiation from sunlight.
- Do not store unprotected PEX outdoors.
- Keep PEX stored indoors in the original packaging prior to installation for protection against UV/sunlight and other potential hazards.
- To prevent UV damage, ensure that exposure to sunlight during installation does not exceed the maximum recommended UV exposure time of X days.
- UV damage is not visible to the naked eye, but will degrade the material and may reduce its service life.

PEX Water Service Line Standards & Code Compliance

Sustained Pressure Ratings

Requirement from **AWWA C904** for long-term hydrostatic strength (sustained pressure) ratings:

- **160 psig @ 73°F** (1,103 kPa @ 23°C) This is the ***Pressure Class*** or ***Pressure Rating***
- **100 psig @ 180°F** (690 kPa @ 82°C) This is the *elevated temperature* capability
- PEX tubing and systems are also tested for sustained pressure capabilities at 200°F (93°C)

Details:

- Long-term Hydrostatic Strength (LTHS) testing is performed in accordance with ASTM D2837 and listed according to PPI TR-3 *Policies and Procedures for Developing Hydrostatic Design Basis (HDB) and Hydrostatic Design Stresses (HDS) for Thermoplastic Piping Materials* to demonstrate long-term pressure capabilities

PEX Water Service Line Standards & Code Compliance

Design Factor (DF)

Requirement from **AWWA C904**:

- The Design Factor for PEX tubing in AWWA C904 is **0.50**
- Pressure ratings are based on a typical Hydrostatic Design Basis (HDB) for PEX of 1,250 psi and the Design Factor of **0.50,** resulting in the Hydrostatic Design Stress (HDS) of **630 psi**
- This is the "**06**" in the PEX Tubing Material Designation Code, the minimum requirement in AWWA C904

Details:

- The Design Factor is intended to accommodate for variables in testing, production, and installation

PEX Water Service Line Standards & Code Compliance

Summary of AWWA C904 Requirements

- The performance requirements required by **AWWA C904** are comprehensive and robust

- The **minimum** Material Designation Code for PEX tubing according to AWWA C904 is **"PEX 1306"**

- Material Codes such as "**PEX 3306"** or "**PEX 5306"** exceed the minimum requirements and also comply

PEX is **Not** joined by socket fusion or butt fusion.
Electrofusion is an option

3. Joining Systems for PEX Water Service Line

PEX Fittings for Water Service Applications

- There are several types of joining techniques and fittings designed for use with PEX water service tubing
- The primary type of fitting is the brass compression-joint fitting produced according to **AWWA C800**
- Stainless steel or plastic **insert stiffeners are required** when using these fittings with HDPE or PEX
- Just as with HDPE tubing, inserts have a negligible effect on pressure loss

Courtesy REHAU

Joining Systems for PEX Water Service Line

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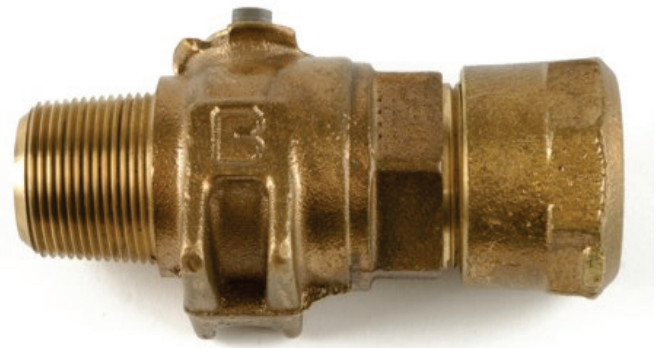

Joining Systems for PEX Water Service Line

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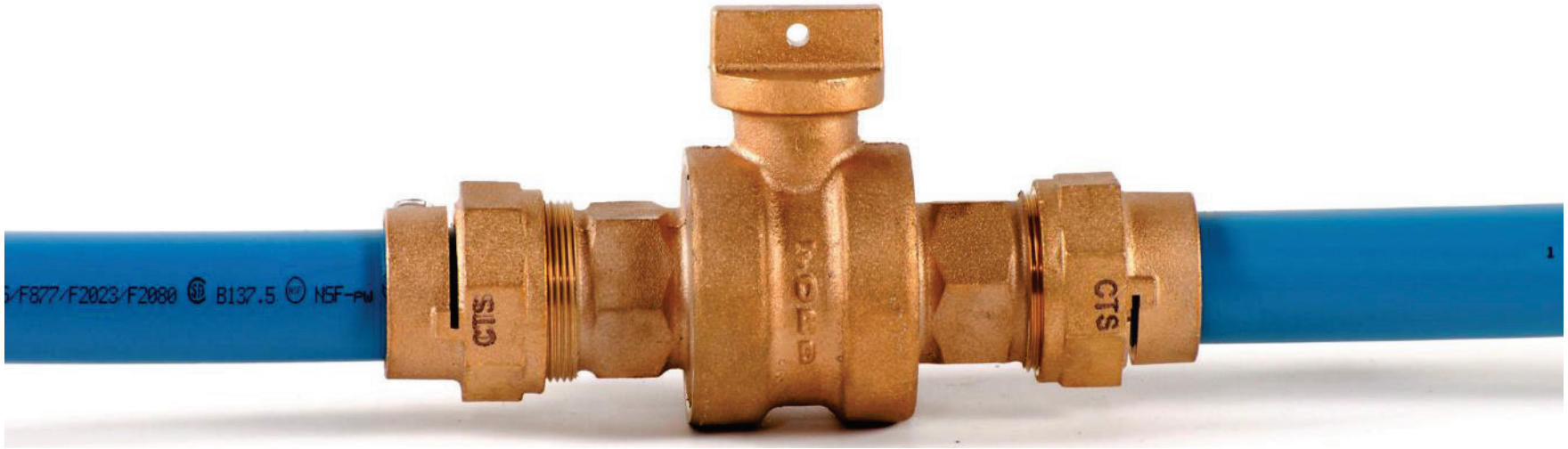


Joining Systems for PEX Water Service Line

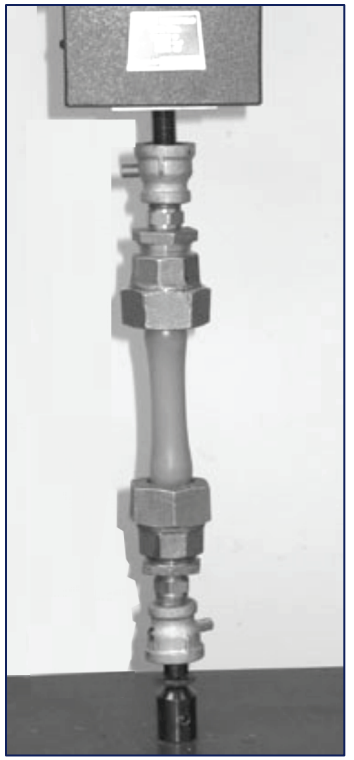
Tensile Testing: PEX Tubing with AWWA C800 Connections

- PEX was connected to standard AWWA C800 compression-joint brass fittings with standard stainless-steel inserts

- Subjected to tensile testing procedure according to ASTM Test Method D638 at independent test facility

- Set for fixed elongation rate of 2 inches per minute

- Test is run to failure of pipe or connection, whichever comes first



Joining Systems for PEX Water Service Line

Tensile Testing: Result

- **Ductile** failure of the PEX tubing – over 400% elongation

- Failure was at the connection
- PEX tubing **did not pull out** of the joint

- The tubing and insert remained within the compression joint assembly

- Test was a **success**, demonstrating the strength of the connection

Joining Systems for PEX Water Service Line

PEX Fittings for Water Service Applications

- Other PEX-specific fittings are produced from **lead-free brass alloys** and **polymers**

Joining Systems for PEX Water Service Line

PEX Fittings for Water Service Applications

- Lead-free brass alloys must be certified to NSF/ANSI/CAN 61 and NSF/ANSI/CAN 372
- Lead-free brass alloy fittings must comply with the **dezincification resistance** and **stress corrosion cracking resistance** requirements of NSF/ANSI 14

Joining Systems for PEX Water Service Line

PEX Fittings for Water Service Applications

- Polymer fittings must be certified to NSF/ANSI/CAN 61 and NSF/ANSI/CAN 372
- **Polysulfone** (PLS) and **polyphenylsulfone** (PPSU) are thermoplastic polymers known for their toughness, stability at high temperatures, and chlorine resistance
- PLS and PPSU fittings are available in a wide variety of sizes, shapes and adapters

Joining Systems for PEX Water Service Line

PEX Fitting Standards

- ASTM F877 *Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems*
- CSA B137.5 *Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications*

- These standards define the performance of the joints/connections such as:
  - Burst pressure, long-term sustained pressure, hot- and cold-water thermocycling, and more

Numerous individual product standards have been written for PEX fitting designs

- Examples: ASTM F1807, ASTM F1960, ASTM F2080, ASTM F2159, ASTM F3347, ASTM F3348, and ASSE 1061

Joining Systems for PEX Water Service Line

ASTM F1807 Crimp ring fitting
Available in brass or copper

ASTM F1807 *copper crimp ring (not to scale!)*

ASTM F2159 *polymer crimp fitting (black or white plastic)*

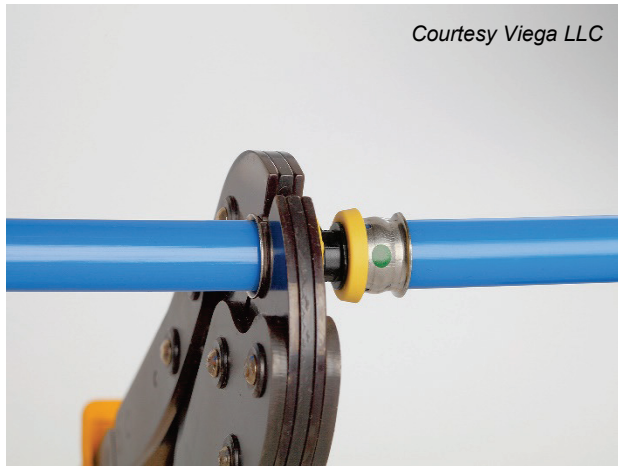
Typical Crimp ring fitting assembly tool

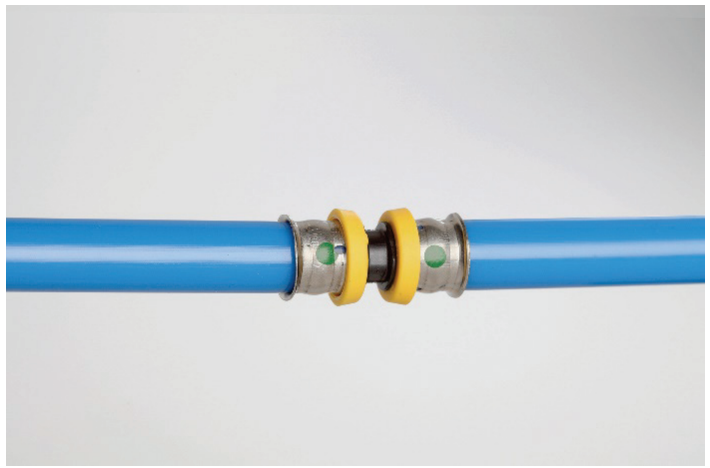
Joining Systems for PEX Water Service Line

Courtesy Uponor

ASTM F1960 Cold-expansion fitting using a PEX ring
Available in polymer and lead-free brass

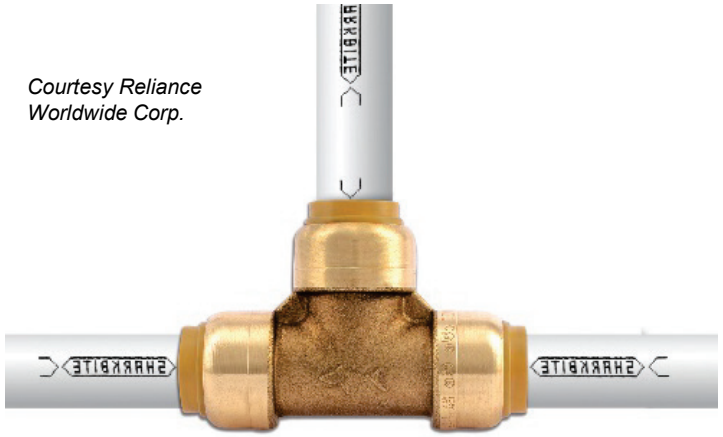
Joining Systems for PEX Water Service Line





ASTM F3347/F3348 Press fittings using stainless steel sleeve
Available in polymer and lead-free brass

Joining Systems for PEX Water Service Line



Courtesy Reliance Worldwide Corp.

ASSE 1061 Push-fit fittings
Available in polymer and lead-free brass

Joining Systems for PEX Water Service Line

PEX Fitting Standards

- Keep in mind that **not all PEX fittings are approved for use with all PEX tubing**
  - Some combinations are not approved!

- Tubing manufacturers test and certify the specific fitting designs before they may recommend them for use with their tubing

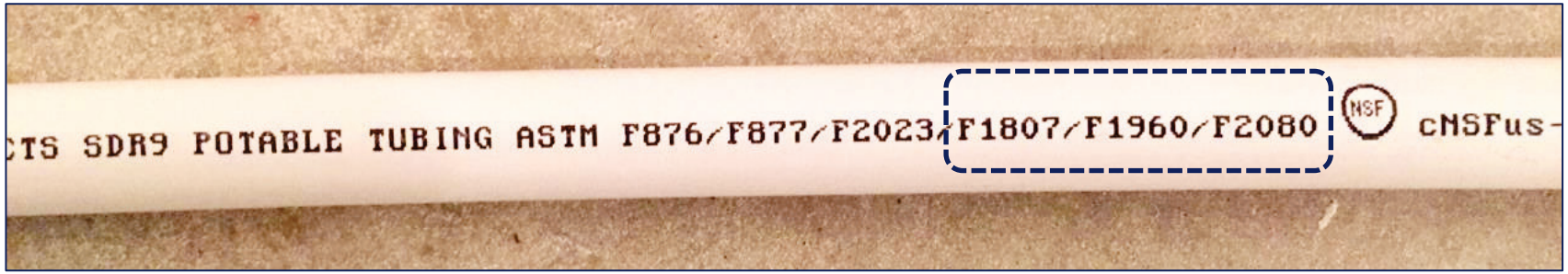
- The standard designation(s) of the fitting system(s) for which the tubing is recommended by the tubing manufacturer and that is specifically qualified for use with PEX is marked on the tubing

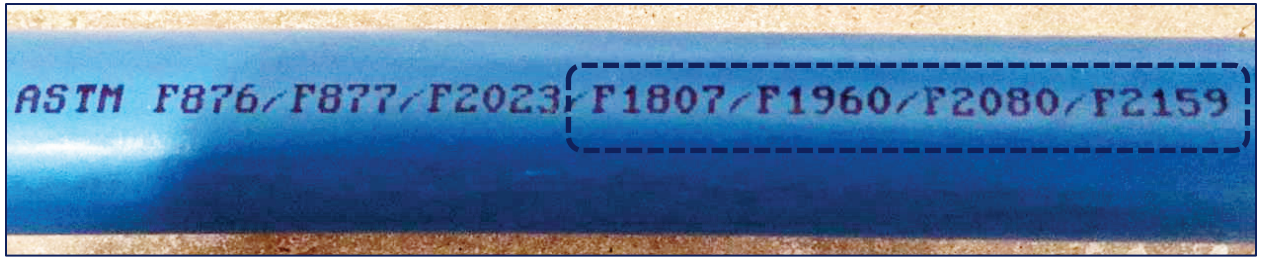
- In other words, look for markings such as “F1807”, “F1960”, “F2080”, “F2159”, “F3347”, “F3348”, or “ASSE 1061” on the tubing print line to show compatibility and approval

Joining Systems for PEX Water Service Line

PEX Fitting Standards

- Look for markings such as “F1807”, “F1960”, “F2080”, “F2159”, “F3347”, “F3348”, or “ASSE 1061” on the tubing print line to show compatibility and approval

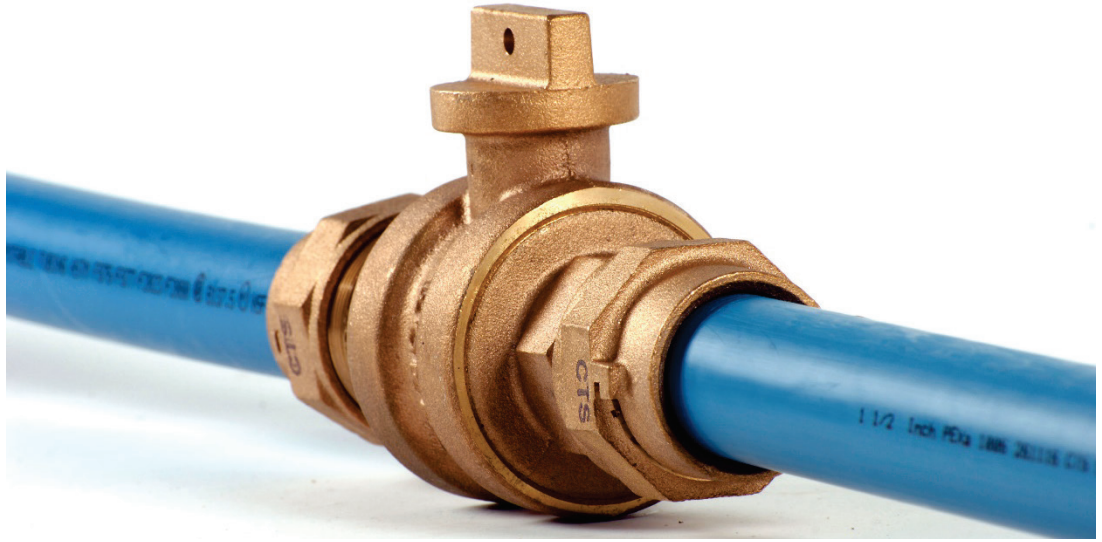




Joining Systems for PEX Water Service Line

Summary

- There are several types of joining techniques and fittings designed for use with PEX water service tubing
- The primary type of fitting is the brass compression-joint fitting produced according to **AWWA C800**
- Other fitting designs are also approved and available for this application



4. Sizing PEX Water Service Line

PEX Water Service Tubing Dimensions

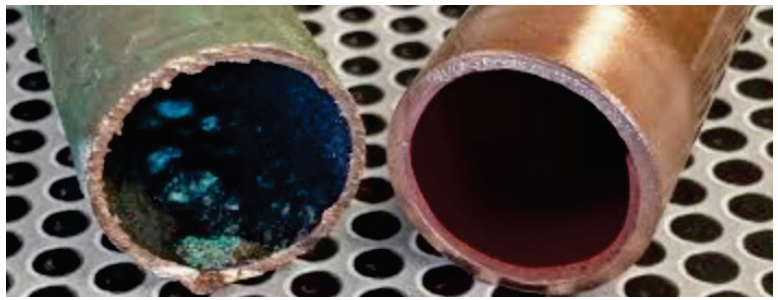
- PEX tubing dimensions are very close to copper tubing (outside diameter is identical, wall is thicker)
- Copper dimensions per CDA *Copper Tube Handbook* (2020)

PEX Inside Diameters in. (typical) and Comparisons with Copper			
Material Nominal Size	**Cu Tubing (Type K)**	**PEX SDR 9 Tubing (ASTM F876)**	**PEX SDR 9 Tubing (ASTM F876)**
1/2	0.527	0.475	90%
3/4	0.745	0.671	90%
1	0.995	0.862	87%
1 1/4	1.245	1.054	85%
1 1/2	1.481	1.244	84%
2	1.959	1.629	83%

Sizing PEX Water Service Line

PEX Water Service Tubing Resists Corrosion and Build-up

- PEX resists scaling and deposits, no mineral build-up
- Smooth interior surface of PEX provides superior flow through its entire life
- Flow calculations for PEX use **C factor** of **150**



Old and new copper tubing

Lead service line

Sizing PEX Water Service Line

PEX Water Service Tubing

- Determine pressure loss using **PPI Plastic Pipe Design Calculator**
- www.plasticpipecalculator.com
- Example: **8 GPM** through 60 ft of 1 in. PEX = **2.5 psi** drop

Results		
Flow Regime:	Turbulent	
Pressure Drop:	2.55 Psi	17.6 kPa
Head Loss:	5.88 ft water	
Velocity*:	4.40 ft/s	1.34 m/s

Calculation Details Print Email

Plastic Pipe Design Calculator

PRESSURE DROP / HEAD LOSS

Input

Is this a Geothermal Application? ☐

Pipe/Tubing Selection[1]

Pipe/Tubing Material: PEX

Sizing Type (CTS/IPS/Metric): CTS (ASTM F876/CSA B137.5)

Wall Type (SDR/Schedule): SDR 9

Nominal Pipe/Tubing Size[2]: 1

More information on PEX

[1] *For more information about plastic piping products included in this calculator, please visit the BCD website.*

[2] *"Tubing" refers to products with an actual Outside Diameter (OD) 1/8 inch larger than the nominal size. "Pipe" refers to products with an actual OD matching that of steel pipe of the same nominal size (e.g. IPS), or products where the actual OD matches the nominal size (e.g. DN-Metric).*

Flow Rate: 8 USGPM

Length of Pipe: 60 ft

Fluid Type (Water or % Antifreeze[3]): 100% Water

Average Fluid Temperature[4]: 73 °F

Sizing PEX Water Service Line

Summary

- PEX is typically sized the same as copper and other CTS piping materials
- Pressure drop calculations can be performed quickly using free online tool

Note: This PPI Calculator uses the *Darcy-Weisbach* equation

5. Installation of PEX Water Service Line

PEX Water Service Line installs much the same as HDPE and Copper

Important aspects of proper installation

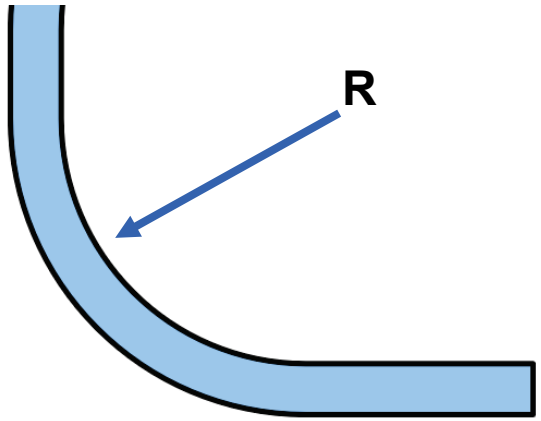
1. Bending and flexibility
2. Handling on the jobsite
3. Thermal expansion
4. Connections
5. Gooseneck
6. Pressure testing
7. Backfill and embedment
8. Thawing frozen PEX tubing

Installation of PEX Water Service Line

1. Bending and Flexibility

- Minimum bending radius for PEX tubing is **8 times** the Outside Diameter of the tube (see **AWWA C904**)

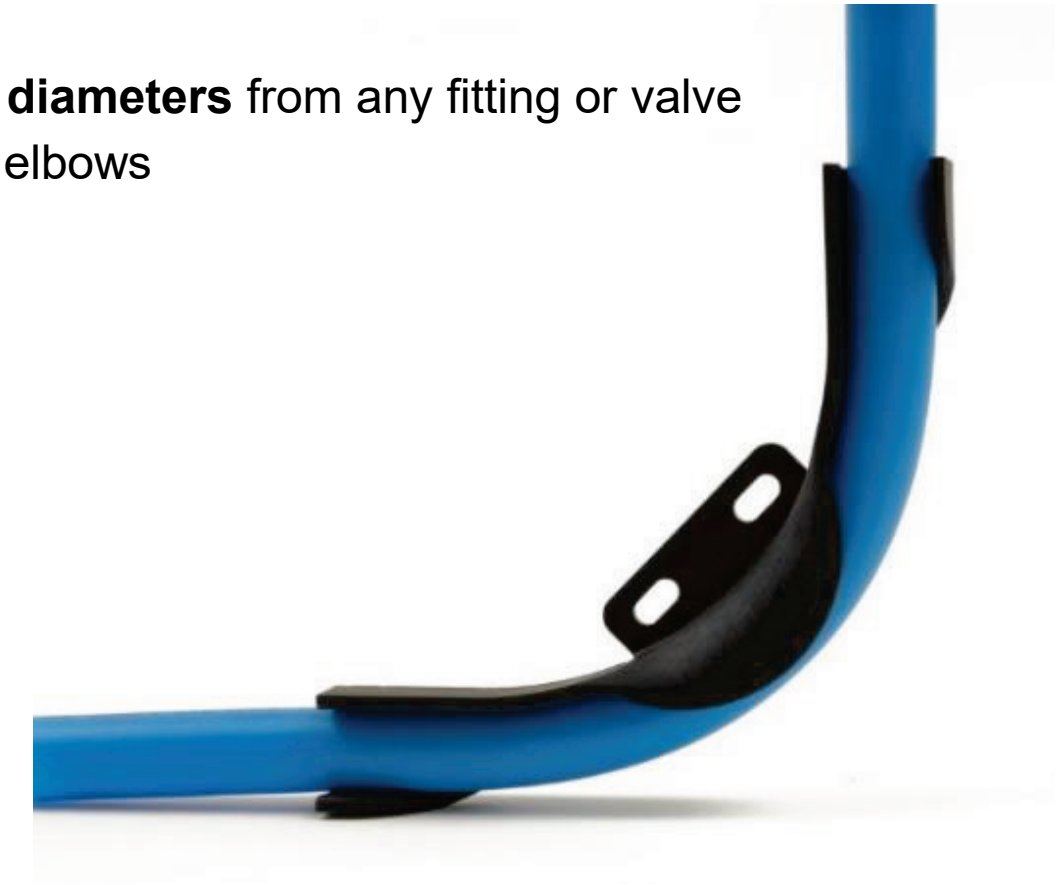
Tube Size (nominal) in.	Tube OD (actual) in.	8X Minimum Bend Radius in.
3/4	0.875	7.0
1	1.125	9.0
1 1/4	1.375	11.0
1 1/2	1.625	13.0
2	2.125	17.0
3	3.125	25.0



Installation of PEX Water Service Line

1. Bending and Flexibility

- Bends in PEX tubing are not permitted closer than **10 pipe diameters** from any fitting or valve
- Bend supports / bend guides may be used to replace most elbows



Installation of PEX Water Service Line

2. Handling on the Jobsite

- Store tubing to protect against damage from crushing, excessive heat, harmful chemicals, or overexposure to sunlight

- Prevent cuts, scratches, nicks, and gouges in the tubing

- Do not drag tubing over rough ground or pull through bored holes containing sharp-edged material, to prevent abrasion

- Uncoil tubing carefully to avoid kinking

Installation of PEX Water Service Line

3. Thermal Expansion

- Linear expansion rate of PEX: **1.1 inch per 10°F per 100 ft. length**

Example:

- 60 ft PEX service line installed at 90°F; Service water temperature is 60°F
- 30°F temperature reduction will result in a tubing length reduction of:
- 1.1 x 3 [30°F/10°F] x 0.6 [60 ft/100 ft] = **2 inches** reduction in length

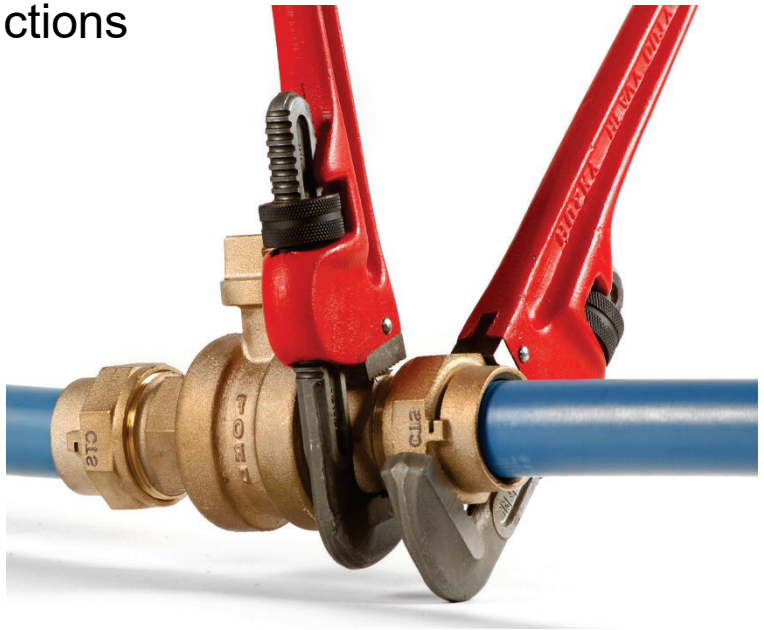
Recommendation

- Installers should allow a **slight curve** while laying tubing in a trench to accommodate changes in length when put into service
- Use www.plasticpipecalculator.com for these calculations

Installation of PEX Water Service Line

4. Connections

- **Use a proper tubing cutter!** PEX tubing must be cut **squarely** and **cleanly** before any connection
- When compression joint fittings are used, be sure to install an **insert stiffener**
- Insert tubing into fitting or valve ends, then tighten fitting nuts per instructions



Installation of PEX Water Service Line

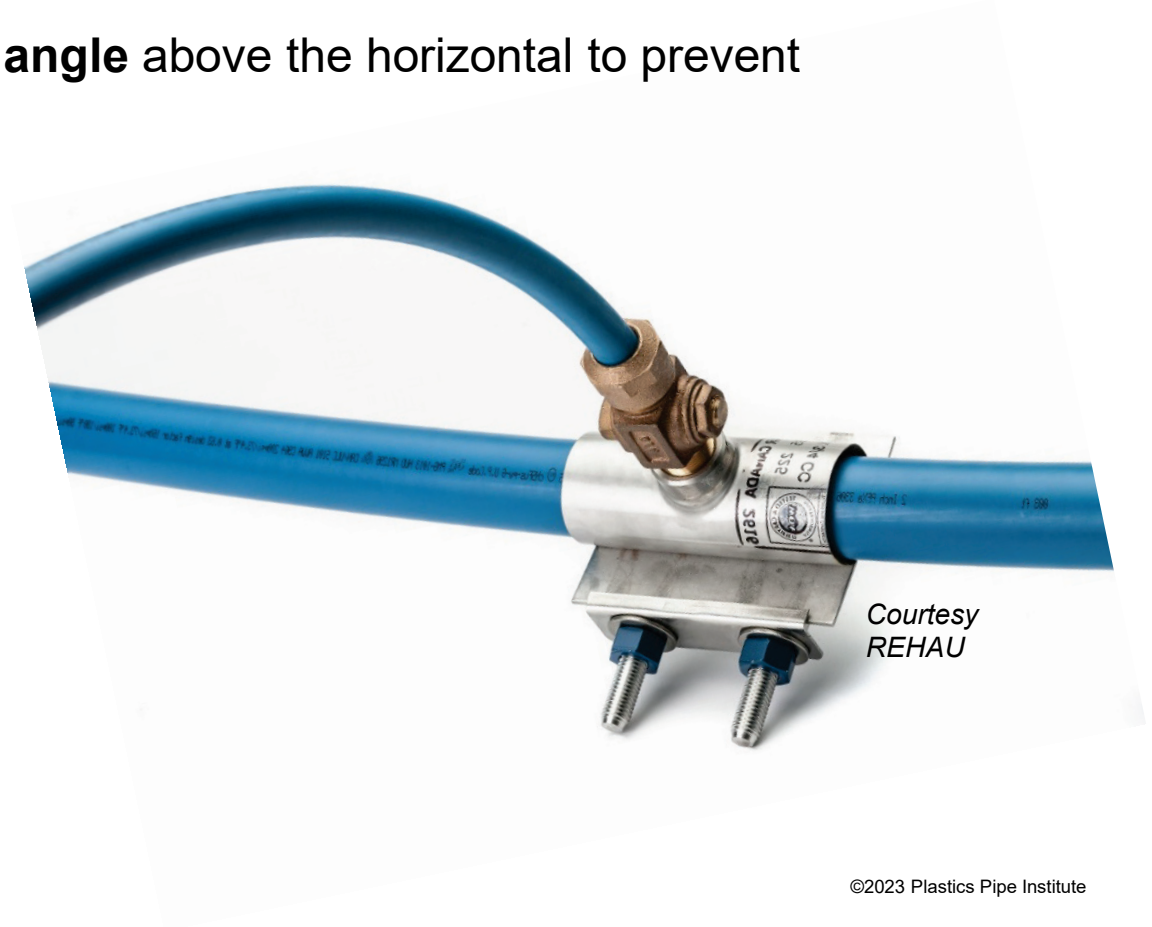
4. Connections

- **Use a proper tubing cutter!** PEX tubing must be cut **squarely** and **cleanly** before any connection
- For other PEX fittings, follow **AWWA C904** and the manufacturer's instructions for assembly

Installation of PEX Water Service Line

5. Gooseneck

- PEX should leave the water main at a **10- to 20-degree angle** above the horizontal to prevent stress on the connection
- It is not required to use the higher 45-degree gooseneck common with copper service line



Courtesy REHAU

Installation of PEX Water Service Line

6. Pressure Testing according to AWWA C904

- "Test pressure shall be at least equal to the expected working pressure (main pressure), but not less than 40 psi and not greater than 1.25 times working pressure at 73°F for a minimum duration of 15 minutes and maximum of 2 hours."

- "Do not allow the water in system to freeze."

- "Suitable precautions should be taken to eliminate hazards to personnel in the proximity of lines being tested in the event of tubing system rupture."

- See also ASTM F2164 *Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure*

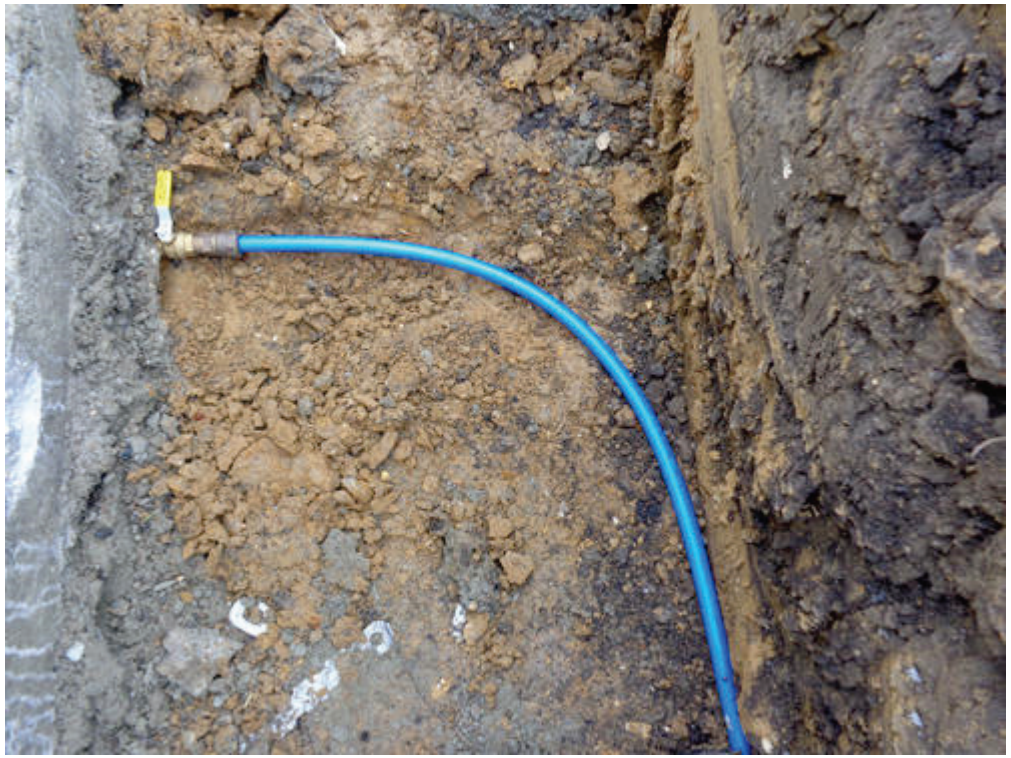
Installation of PEX Water Service Line

7. Embedment of PEX Tubing according to AWWA C904

- "To prevent freezing in the water lines, the tubing should be installed below the frost line."

- "The initial backfill, from 3 in. (76 mm) below the pipeline to 4 in. to 6 in. (100 mm to 150 mm) above the tubing, should be sand or other materials, as allowed in ASTM D2774 or as approved by the tubing manufacturer."

- "If the installation is to be subjected to surface traffic, a minimum cover of 24 in. (610 mm) should be provided, and trench backfill in the tubing zone should be compacted to at least 90 percent of the laboratory maximum density of the backfill soil."



Installation of PEX Water Service Line

8. Thawing Frozen PEX

In the unlikely event of a freeze, several suitable methods exist to thaw water frozen inside PEX tubing:

- Use a commercial hot-water injection system that pumps heated water through the tubing to the ice blockage and returns the cooled water for reheating
- Expose the buried tubing and apply wet hot towels
- Expose the buried tubing and apply hot water
- Expose the buried tubing and use a hand-held hair dryer or electric heat gun
- Expose the buried tubing and apply low-wattage electrical heating tape
- Do Not apply open flame!

Courtesy Magikist

- *See PPI TR-52 and consult with tubing manufacturer for more information*

Installation of PEX Water Service Line

Summary: PEX Water Service Line installs much the same as HDPE and Copper

Important aspects of proper installation

1. Bending and flexibility
2. Handling on the jobsite
3. Thermal expansion
4. Connections
5. Gooseneck
6. Pressure testing
7. Backfill and embedment
8. Thawing frozen PEX tubing

6. Practical Reasons to Specify PEX Water Service Line

Safety and Security

- Safety of potable water as required by extensive certifications (e.g., AWWA C904, NSF/ANSI/CAN 61, NSF/ANSI/CAN 372)
- Proven long-term reliability – over 25 years of successful usage in water service line applications in North America

Resistant to Corrosion

- Does not corrode in soil or aggressive water conditions

Resistant to Erosion Corrosion

- Withstands velocities in excess of 12 feet per second, per **PPI TN-26**

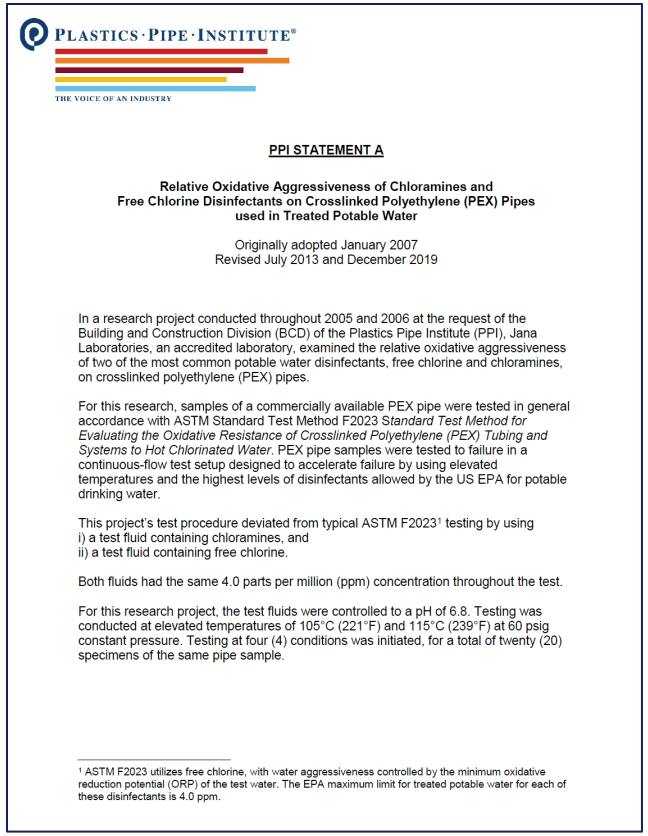
Practical Reasons to Specify PEX Water Service Line

Resistant to Potable Water Disinfectants

- Highly resistant to elevated levels (up to 4.0 ppm) of free chlorine
- Highly resistant to elevated levels of chloramines (see **PPI Statement A**)

Excerpt from PPI Statement A:

"Based on these results, it is the position of PPI BCD that chloramines are less aggressive than free chlorine to PEX pipes. Testing of oxidative resistance using free chlorine, in accordance with ASTM F2023, will provide a conservative estimate of the time-to-failure for PEX pipes when used with the disinfectant chloramines."



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PPI STATEMENT A

Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants on Crosslinked Polyethylene (PEX) Pipes used in Treated Potable Water

Originally adopted January 2007
Revised July 2013 and December 2019

In a research project conducted throughout 2005 and 2006 at the request of the Building and Construction Division (BCD) of the Plastics Pipe Institute (PPI), Jana Laboratories, an accredited laboratory, examined the relative oxidative aggressiveness of two of the most common potable water disinfectants, free chlorine and chloramines, on crosslinked polyethylene (PEX) pipes.

For this research, samples of a commercially available PEX pipe were tested in general accordance with ASTM Standard Test Method F2023 *Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water*. PEX pipe samples were tested to failure in a continuous-flow test setup designed to accelerate failure by using elevated temperatures and the highest levels of disinfectants allowed by the US EPA for potable drinking water.

This project's test procedure deviated from typical ASTM F2023[1] testing by using
i) a test fluid containing chloramines, and
ii) a test fluid containing free chlorine.

Both fluids had the same 4.0 parts per million (ppm) concentration throughout the test.

For this research project, the test fluids were controlled to a pH of 6.8. Testing was conducted at elevated temperatures of 105°C (221°F) and 115°C (239°F) at 60 psig constant pressure. Testing at four (4) conditions was initiated, for a total of twenty (20) specimens of the same pipe sample.

[1] ASTM F2023 utilizes free chlorine, with water aggressiveness controlled by the minimum oxidative reduction potential (ORP) of the test water. The EPA maximum limit for treated potable water for each of these disinfectants is 4.0 ppm.

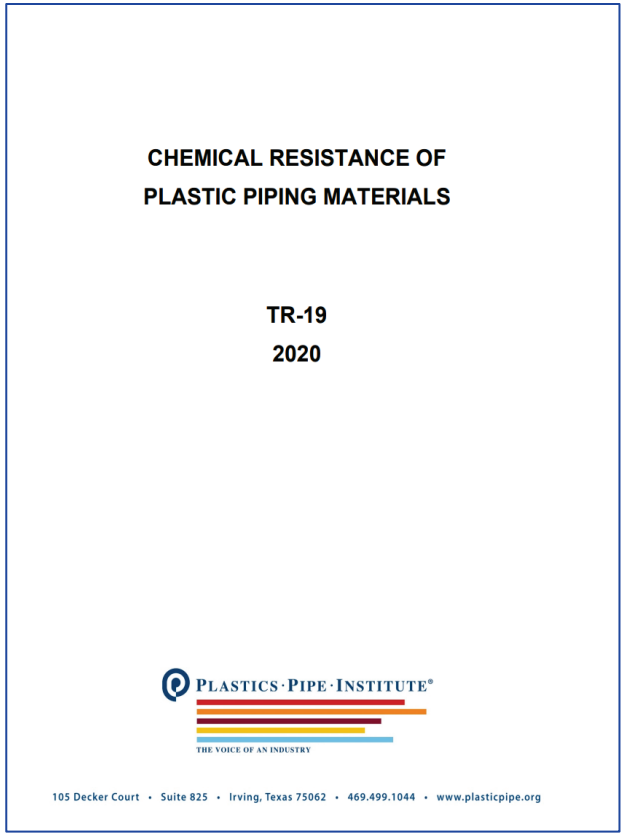
Practical Reasons to Specify PEX Water Service Line

Chemical Resistance

- PEX tubing is resistant to a wide range of chemicals
- *See **PPI TR-19 Chemical Resistance of Plastic Piping Materials** for details*

Table 3: List of Chemical Resistances (°F)

Chemical Formula	Concentration	ABS	CPVC	PP (PP-R, PP-RCT)	PVC	PE (MDPE, HDPE, PE-RT)	PB	PVDF	PEX	PA (PA11, PA12)	PSU
Acetaldehyde	40%	---	N	---	L to 73	R to 73	---	N	R to 73	---	---
CAS# 75-07-0	Pure	---	N	R to 140	N	L to 73	L to 73	---	L to 140	L to 176	R to 73
CH_3CHO											
Acetamide											
CAS# 60-35-5	5%	R to 120	---	R to 140	---	R to 140	---	---	R to 140	---	---
CH_3CONH_2											



Practical Reasons to Specify PEX Water Service Line

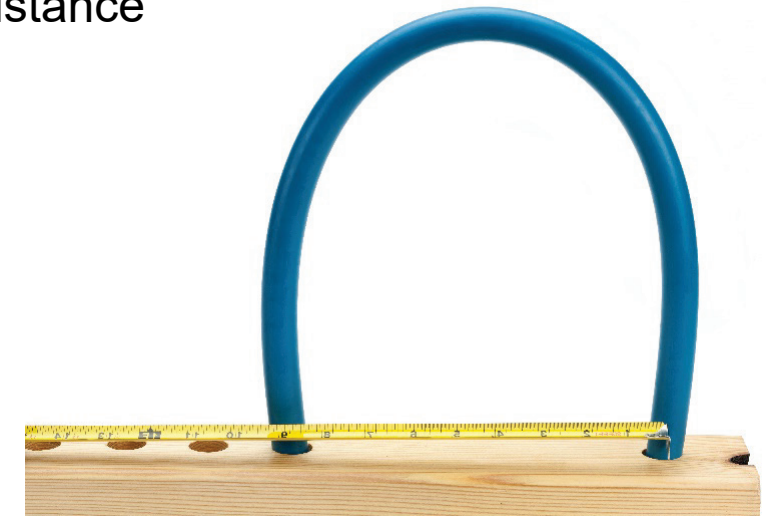
Toughness

- Exceptional resistance to slow crack growth (SCG), scratches, gouges, typical field damage
- Suitable for horizontal directional drilling (HDD)
- Follow same practices as with HDPE

Practical Reasons to Specify PEX Water Service Line

Flexibility

- Easier to uncoil and bend when needed
- Tighter bend radius than HDPE or copper
- Faster installations, especially in tight areas
- Absorbs surge pressures and pressure cycles
- Superior seismic resistance



Practical Reasons to Specify PEX Water Service Line

Light Weight

- Weighs five to six times less than copper
- Reduces shipping costs and potential delays
- Handles more easily on jobsites, especially in longer coils
- Available in longer coil lengths than copper, reduces couplings

Continuous Footage Markings

- Tubing length is marked at least every five feet
- Reduces waste by identifying coil lengths
- Saves installation time and scrap

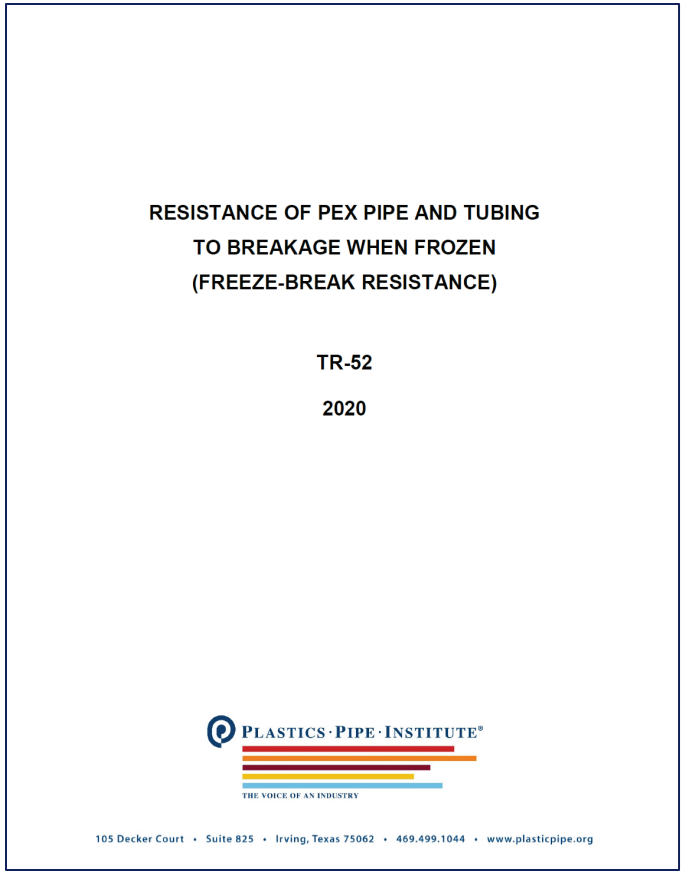

Courtesy REHAU

Practical Reasons to Specify PEX Water Service Line

Freeze-break Resistance

- PEX is less susceptible to the effects of cold temperatures, retaining flexibility even below freezing (i.e., does not become brittle)
- Insulating properties help PEX prevent the freezing of water
- If water-filled PEX tubing freezes, the elasticity of the material typically allows it to **expand without cracking** or splitting
  - Tube will return to its original size upon thawing
- This applies when PEX tubing has room to expand evenly along its length, as is typical when installed in the ground

- *See **PPI TR-52** and consult with tubing manufacturer for more information*



Practical Reasons to Specify PEX Water Service Line

Cost-effective Alternative to Copper

- Much lower pricing, relatively stable material cost
- Produced in standard Copper Tube Sizes (CTS)
- Compatible with AWWA C800 compression joint fittings
- No special fittings or adapters required (options are available)
- Resistant to scale and mineral deposits
- Lower thermal conductance and freeze resistance
- No intrinsic scrap value; not likely to be stolen from a jobsite
- Resistant to all types of corrosion

Practical Reasons to Specify PEX Water Service Line

PEX Advantages as a Water Service Line

- PEX tubing as compared with high-density polyethylene (HDPE), from **PPI TN-17, Table 1**

Table 1: Summary of Property Changes from HDPE to PEX Materials

Property	Change from HDPE to PEX	Benefit
Tensile Yield Strength @ 73°F (23°C) Tensile Yield Strength @ 180°F (82°C)	Typically Unchanged Typically Increases	PEX is suitable for both low- and elevated-temperature applications
Elongation at Break	Unchanged or Increases	Improved flexibility to withstand installation stresses while resisting tensile deformation
Environmental Stress Crack Resistance	Increases	Greater resistance to environmental hazards. Improved toughness and abrasion resistance.
Resistance to Slow Crack Growth	Increases	Greater resistance to environmental hazards such as scratches. Improved toughness and abrasion resistance.

Table 1: Summary of Property Changes from HDPE to PEX Materials

Property	Change from HDPE to PEX	Benefit
Creep Resistance	Increases	Improved stability over long-term pressurization and loads. The traditional HDPE stress curve "knee- point" is typically eliminated.
Hydrostatic Design Basis (HDB): HDB @ 73°F (23°C) HDB @ 180°F (82°C)	 Typically Unchanged Increases	HDB is an evaluation of the long-term hoop strength of the material, and is used to develop its pressure ratings. PEX is suitable for both low- and elevated-temperature applications.
Hydrocarbon Permeation	Unchanged	Similar performance
Chemical Resistance *	Typically Increases	Similar or improved performance

Practical Reasons to Specify PEX Water Service Line

Sustainability

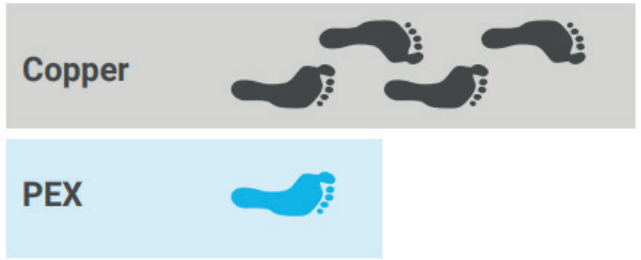
- Safety of potable water and long-term reliability
- Resistant to disinfectants chlorine and chloramines
- Lower energy cost to produce PEX as compared with copper (i.e., lower carbon footprint, better LCA results)
- Smooth wall and excellent flow characteristics reduce pumping costs
- Lighter weight reduces transportation costs, better safety
- Flexibility can dampen water hammer, reducing pressure spikes
- Does not add minerals to drinking water or support biofilm growth
- Proven long life and durability provides reliability and value
- No scrap value helps to prevent jobsite theft
- PEX systems protect **health** and **drinking water safety**

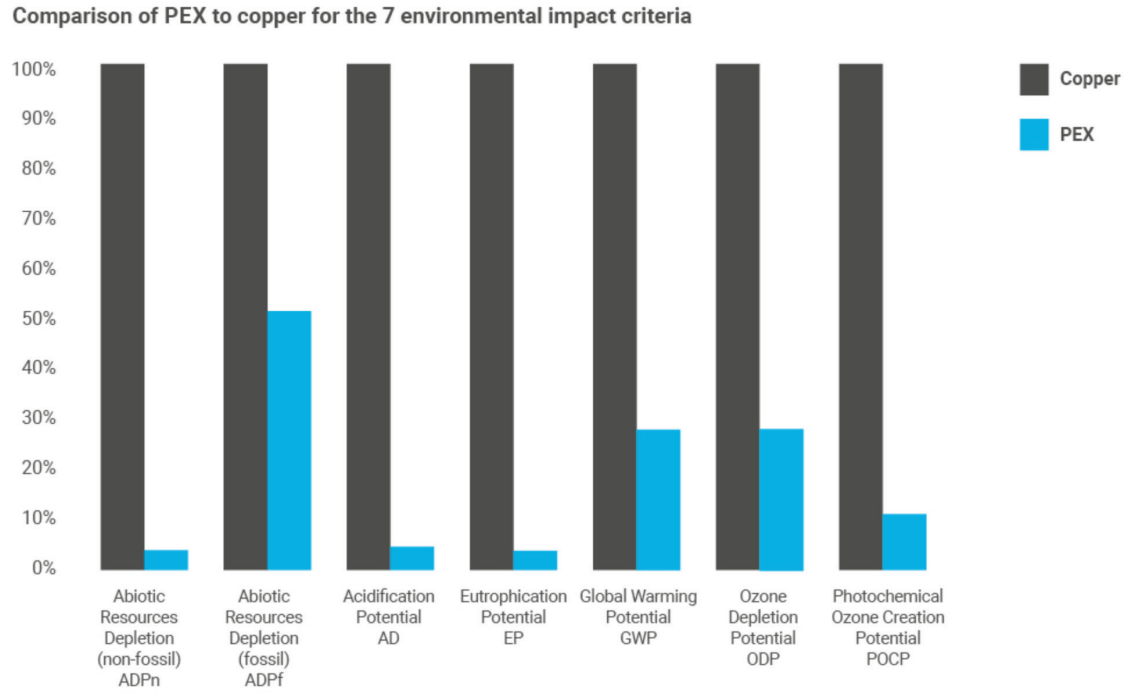
Practical Reasons to Specify PEX Water Service Line

Sustainability

- Numerous peer-reviewed Life Cycle Analysis (LCA) reports clearly demonstrate that plastic piping systems have lower embodied carbon and require fewer resources to produce than traditional metallic piping
- Example: **PEX vs. Copper**

"An independent study following EN 15804 methodology by the world-renowned Flemish Institute for Technological Research (VITO), and validated by the Denkstatt sustainable development institute in Austria, is conclusive in its findings that plastic plastic pipe systems made from cross-linked polyethylene (PEX) for plumbing hot and cold solid wall applications have a lower environmental impact than those made from copper"





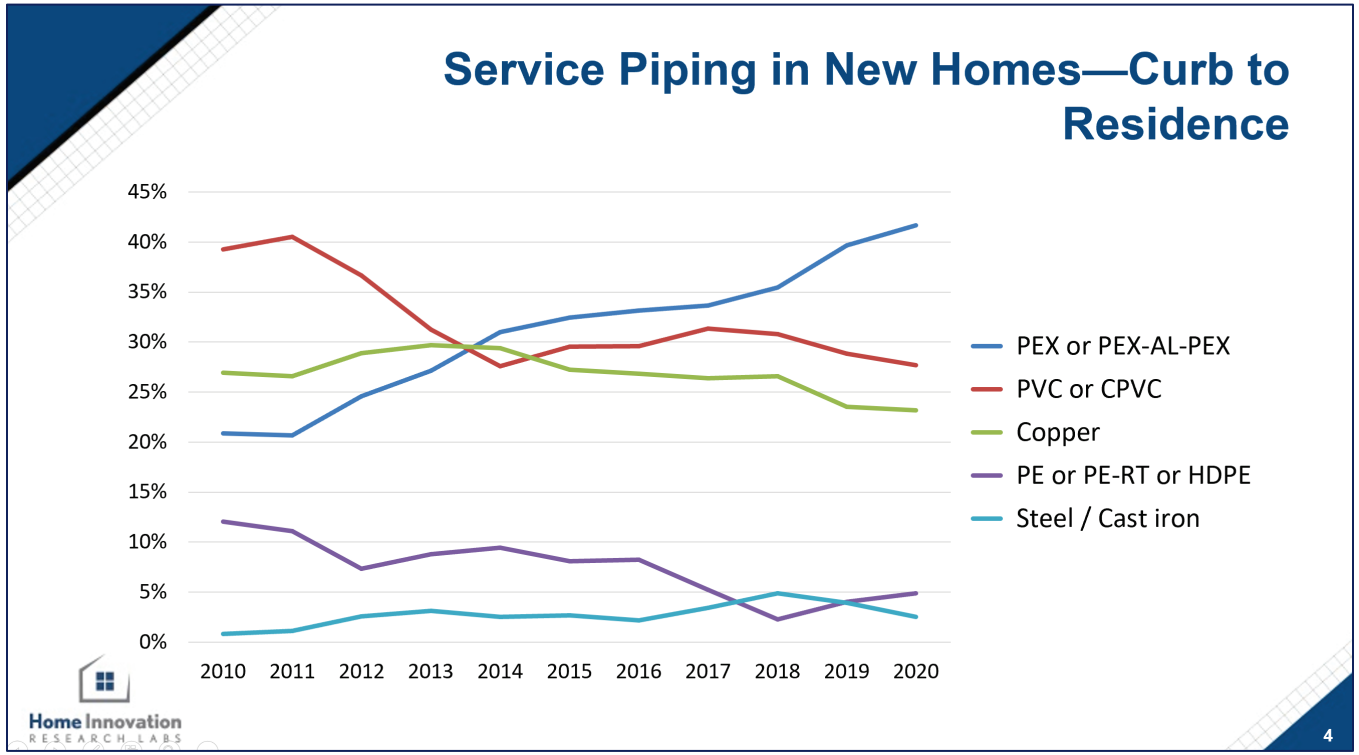
Practical Reasons to Specify PEX Water Service Line

PEX is a Proven Success

- Since 2010, the usage of PEX water service tubing in new homes across USA has increased from 20% to **more than 40%**

- The benefits of PEX water service line are being recognized!

(Source: HIRL Builders Practices Survey, Sept. 2021)

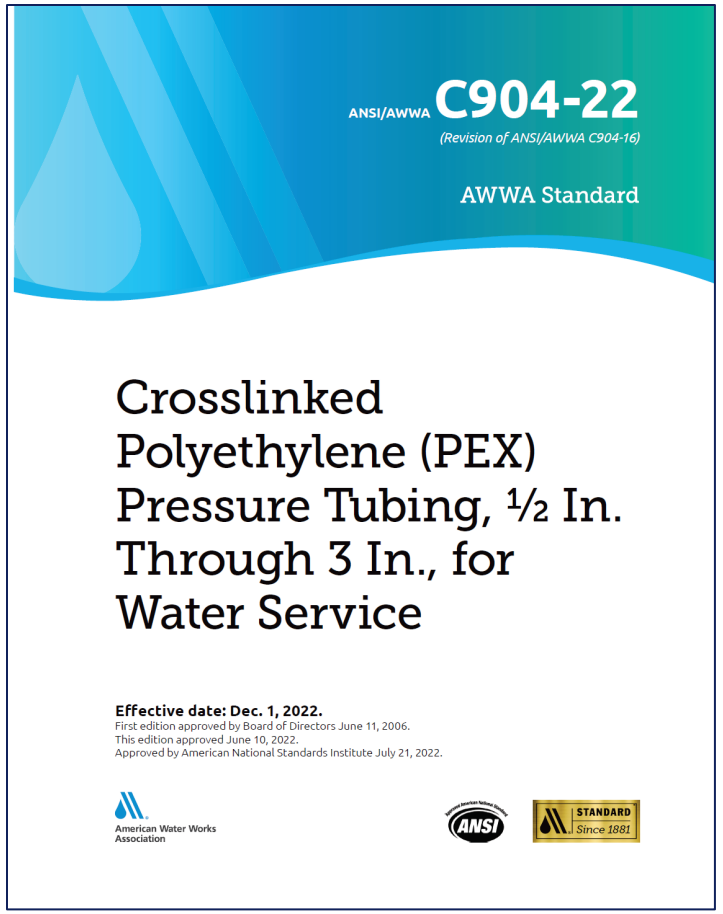


7. Industry Resources

Where to go for additional information

- AWWA C904, Appendix A "Design and Installation…"

- Material Properties
- Dimension and Pressure Loss tables
- Design information
- Installation
- Operations & Repair
- Sample Specification
- Available at www.awwa.org



ANSI/AWWA C904-22

(Revision of ANSI/AWWA C904-16)

AWWA Standard

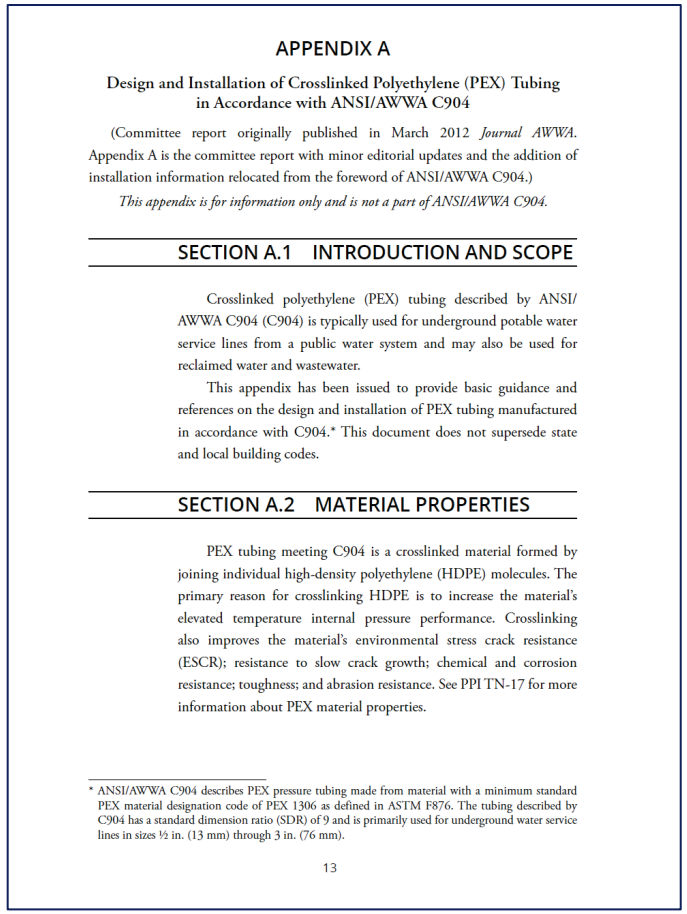
Crosslinked Polyethylene (PEX) Pressure Tubing, ½ In. Through 3 In., for Water Service

Effective date: Dec. 1, 2022.
First edition approved by Board of Directors June 11, 2006.
This edition approved June 10, 2022.
Approved by American National Standards Institute July 21, 2022.

American Water Works Association

ANSI

STANDARD Since 1881



APPENDIX A

Design and Installation of Crosslinked Polyethylene (PEX) Tubing in Accordance with ANSI/AWWA C904

(Committee report originally published in March 2012 *Journal AWWA*. Appendix A is the committee report with minor editorial updates and the addition of installation information relocated from the foreword of ANSI/AWWA C904.)

This appendix is for information only and is not a part of ANSI/AWWA C904.

SECTION A.1 INTRODUCTION AND SCOPE

Crosslinked polyethylene (PEX) tubing described by ANSI/AWWA C904 (C904) is typically used for underground potable water service lines from a public water system and may also be used for reclaimed water and wastewater.

This appendix has been issued to provide basic guidance and references on the design and installation of PEX tubing manufactured in accordance with C904.* This document does not supersede state and local building codes.

SECTION A.2 MATERIAL PROPERTIES

PEX tubing meeting C904 is a crosslinked material formed by joining individual high-density polyethylene (HDPE) molecules. The primary reason for crosslinking HDPE is to increase the material's elevated temperature internal pressure performance. Crosslinking also improves the material's environmental stress crack resistance (ESCR); resistance to slow crack growth; chemical and corrosion resistance; toughness; and abrasion resistance. See PPI TN-17 for more information about PEX material properties.

* ANSI/AWWA C904 describes PEX pressure tubing made from material with a minimum standard PEX material designation code of PEX 1306 as defined in ASTM F876. The tubing described by C904 has a standard dimension ratio (SDR) of 9 and is primarily used for underground water service lines in sizes ½ in. (13 mm) through 3 in. (76 mm).

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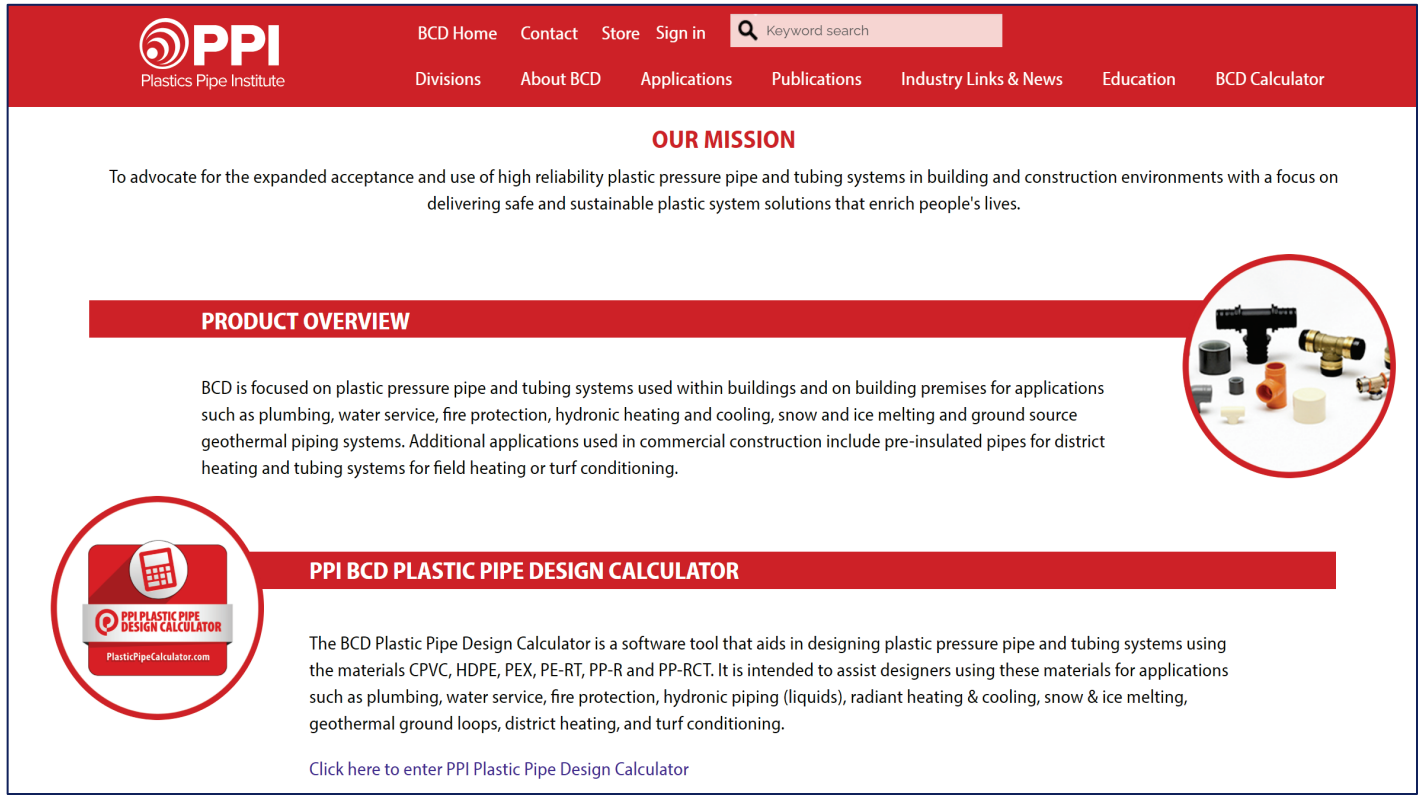
Industry Resources

PPI's Building & Construction Division (BCD) webpages provide access to:

- ***BCD Homepage*** →
- Technical Publications
- Plastic Pipe Design Calculator
- Presentations and recorded webinars
- Educational videos
- Case studies
- Industry Links

- www.plasticpipe.org/buildingconstruction



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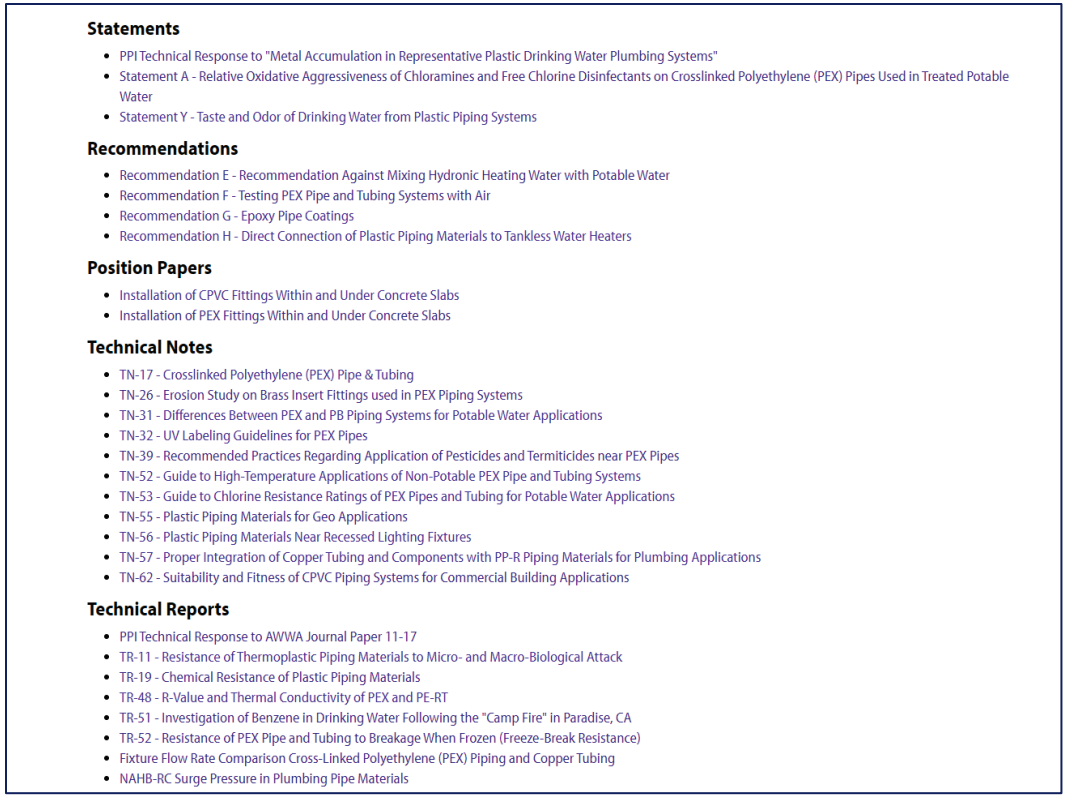


Statements

- PPI Technical Response to "Metal Accumulation in Representative Plastic Drinking Water Plumbing Systems"
- Statement A - Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants on Crosslinked Polyethylene (PEX) Pipes Used in Treated Potable Water
- Statement Y - Taste and Odor of Drinking Water from Plastic Piping Systems

Recommendations

- Recommendation E - Recommendation Against Mixing Hydronic Heating Water with Potable Water
- Recommendation F - Testing PEX Pipe and Tubing Systems with Air
- Recommendation G - Epoxy Pipe Coatings
- Recommendation H - Direct Connection of Plastic Piping Materials to Tankless Water Heaters

Position Papers

- Installation of CPVC Fittings Within and Under Concrete Slabs
- Installation of PEX Fittings Within and Under Concrete Slabs

Technical Notes

- TN-17 - Crosslinked Polyethylene (PEX) Pipe & Tubing
- TN-26 - Erosion Study on Brass Insert Fittings used in PEX Piping Systems
- TN-31 - Differences Between PEX and PB Piping Systems for Potable Water Applications
- TN-32 - UV Labeling Guidelines for PEX Pipes
- TN-39 - Recommended Practices Regarding Application of Pesticides and Termiticides near PEX Pipes
- TN-52 - Guide to High-Temperature Applications of Non-Potable PEX Pipe and Tubing Systems
- TN-53 - Guide to Chlorine Resistance Ratings of PEX Pipes and Tubing for Potable Water Applications
- TN-55 - Plastic Piping Materials for Geo Applications
- TN-56 - Plastic Piping Materials Near Recessed Lighting Fixtures
- TN-57 - Proper Integration of Copper Tubing and Components with PP-R Piping Materials for Plumbing Applications
- TN-62 - Suitability and Fitness of CPVC Piping Systems for Commercial Building Applications

Technical Reports

- PPI Technical Response to AWWA Journal Paper 11-17
- TR-11 - Resistance of Thermoplastic Piping Materials to Micro- and Macro-Biological Attack
- TR-19 - Chemical Resistance of Plastic Piping Materials
- TR-48 - R-Value and Thermal Conductivity of PEX and PE-RT
- TR-51 - Investigation of Benzene in Drinking Water Following the "Camp Fire" in Paradise, CA
- TR-52 - Resistance of PEX Pipe and Tubing to Breakage When Frozen (Freeze-Break Resistance)
- Fixture Flow Rate Comparison Cross-Linked Polyethylene (PEX) Piping and Copper Tubing
- NAHB-RC Surge Pressure in Plumbing Pipe Materials

Industry Resources

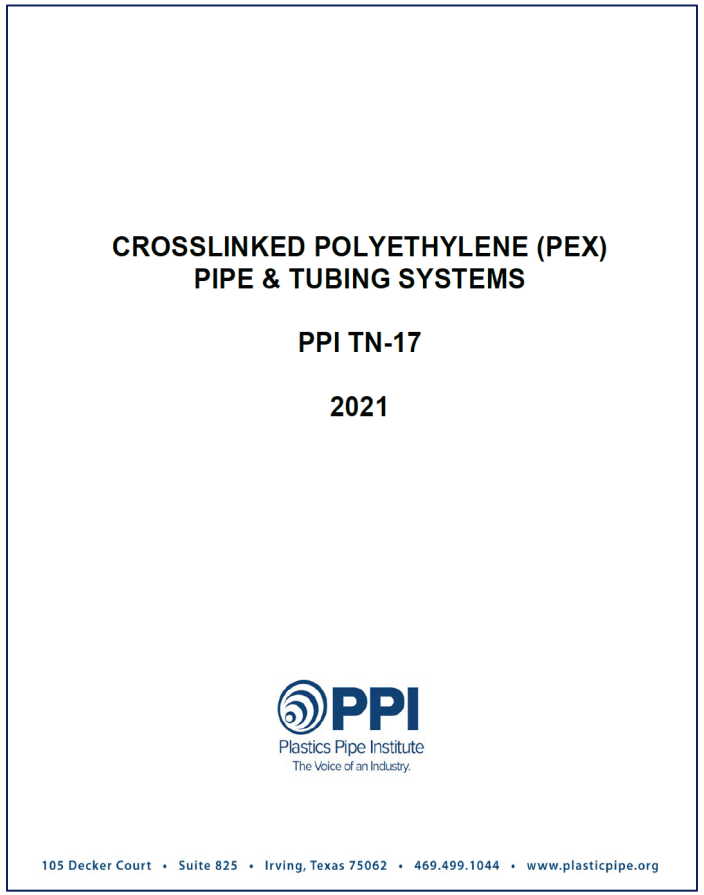
PPI Technical Notes and Reports

PPI TN-17*: Crosslinked Polyethylene (PEX) Pipe & Tubing Systems*

1.0 INTRODUCTION

The successful use of crosslinked polyethylene (PEX) systems throughout the world in numerous applications, along with the capabilities of PEX pipe and tubing in cold- and hot-water pressure piping environments, have generated significant interest and growth in the usage in these materials across North America.

To answer common questions about PEX materials from installers, designers, builders, engineers and specifiers, as well as the public, this technical note provides an overview of PEX properties and capabilities, the applications and benefits of PEX, and the technical requirements for PEX systems. Several product standards are listed as references.

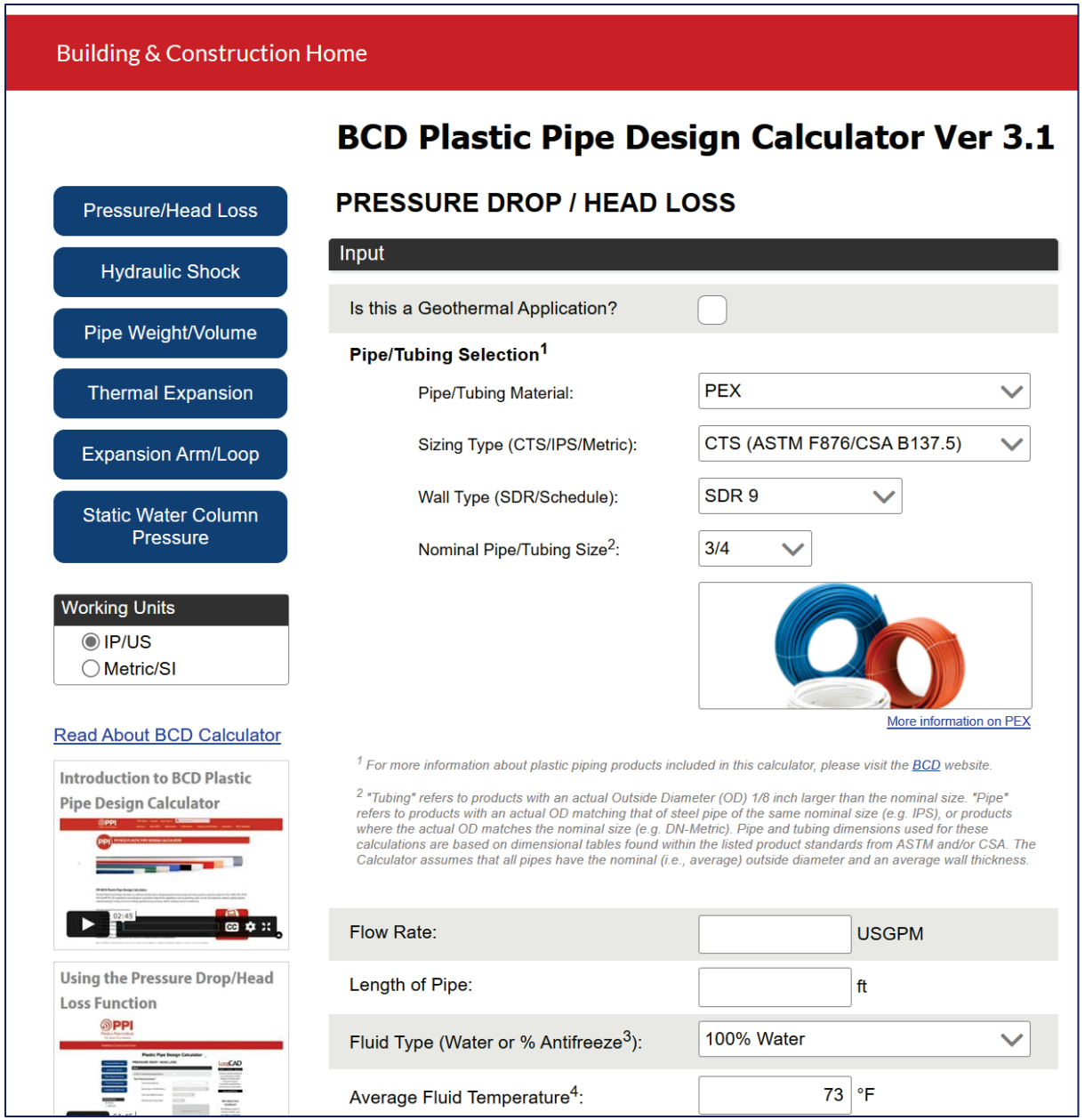


Industry Resources

PPI BCD Plastic Pipe Design Calculator

- Six types of design calculations (blue buttons)

- Go to www.plasticpipecalculator.com



Course Summary

By this time, participants should be able to:

1. Discuss how the properties of PEX tubing can protect health, safety, and welfare of building occupants when used as water service lines and building supply lines
2. Describe PEX water service line standards and code compliance
3. List several joining systems that are approved for use with PEX water service tubing
4. Explain how to size PEX water service line tubing for reliable performance
5. Direct installers on correct installation techniques to ensure long-term safety and performance
6. Identify practical reasons to specify PEX water service line tubing as a replacement for copper
7. Show how to access industry resources for additional material, design, and installation information

PEX Tubing for Water Service Line Applications

A presentation by
The Plastics Pipe Institute

ASPE American Society of Plumbing Engineers CEU PROVIDER

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