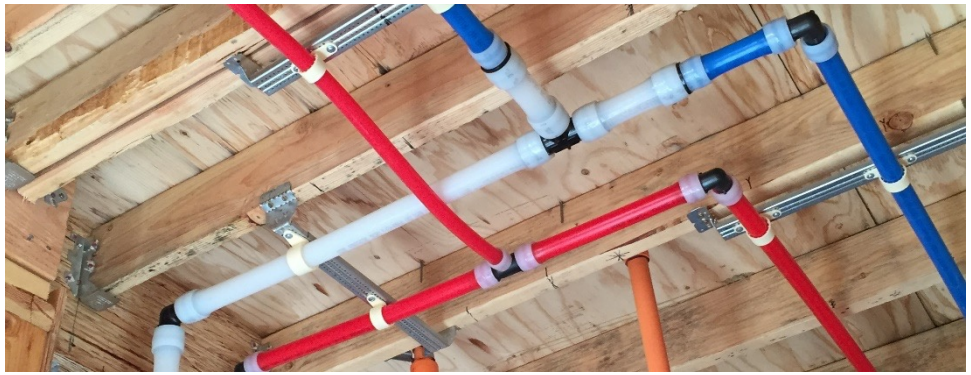
Designing PEX Plumbing Systems to Optimize Performance and Efficiency

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

- A result of modern polymer technology, PEX tubing performs in ways that provide superior reliability, durability, and safety

- PEX tubing has been used for plumbing systems in North America for over 25 years, providing safe delivery of potable water and protecting the health of building occupants

- PEX systems are well-established for residential applications and are being adopted for multi-family and commercial plumbing applications

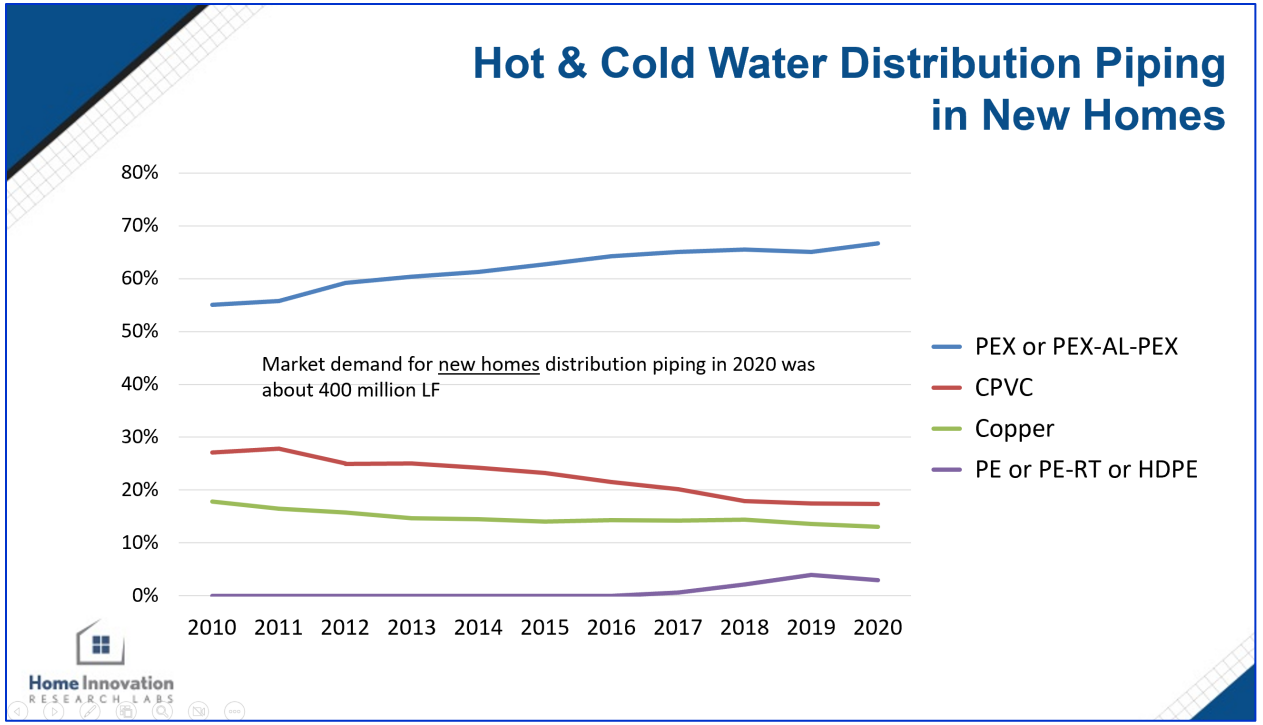
- This course demonstrates how the properties of PEX systems can protect the health, safety, and welfare of building occupants through efficient and reliable delivery of clean drinking water

Course Introduction

Proven Success

- Since 1997, the usage of PEX tubing in residential plumbing has increased from less than 10% to more than 60%

- Source: HIRL Builders Practices Report, Sept. 2021



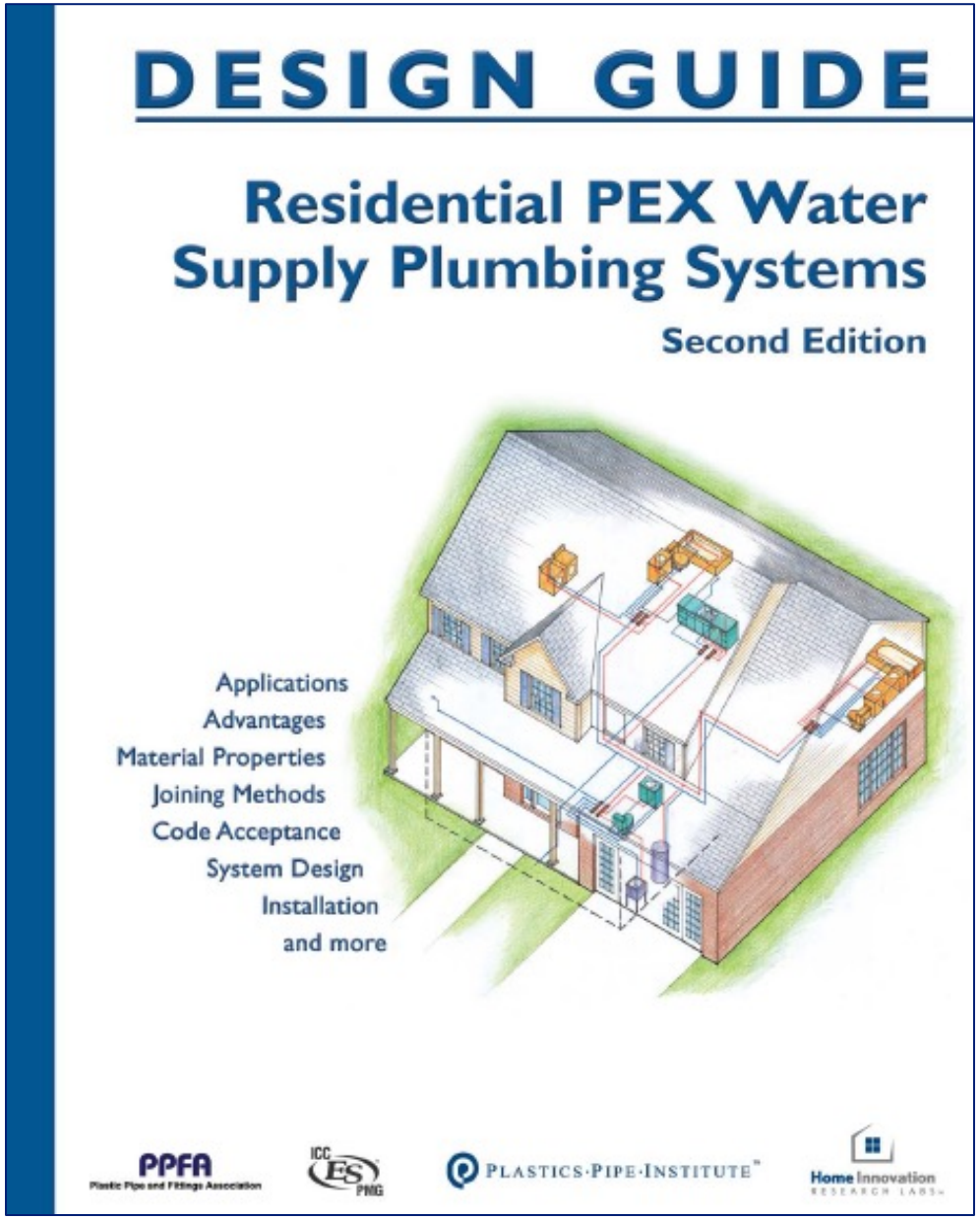
Course Background

- Much of the information in this course is taken from "DESIGN GUIDE – Residential PEX Water Supply Plumbing Systems" Second Edition

- PPI , PPFA, and ICC provided content to *Home Innovation Research Labs** which conducted the included research and prepared the publication

  **Formerly known as the NAHB Research Center*

- The DESIGN GUIDE is available as free download from https://plasticpipe.org/BuildingConstruction and www.homeinnovation.com

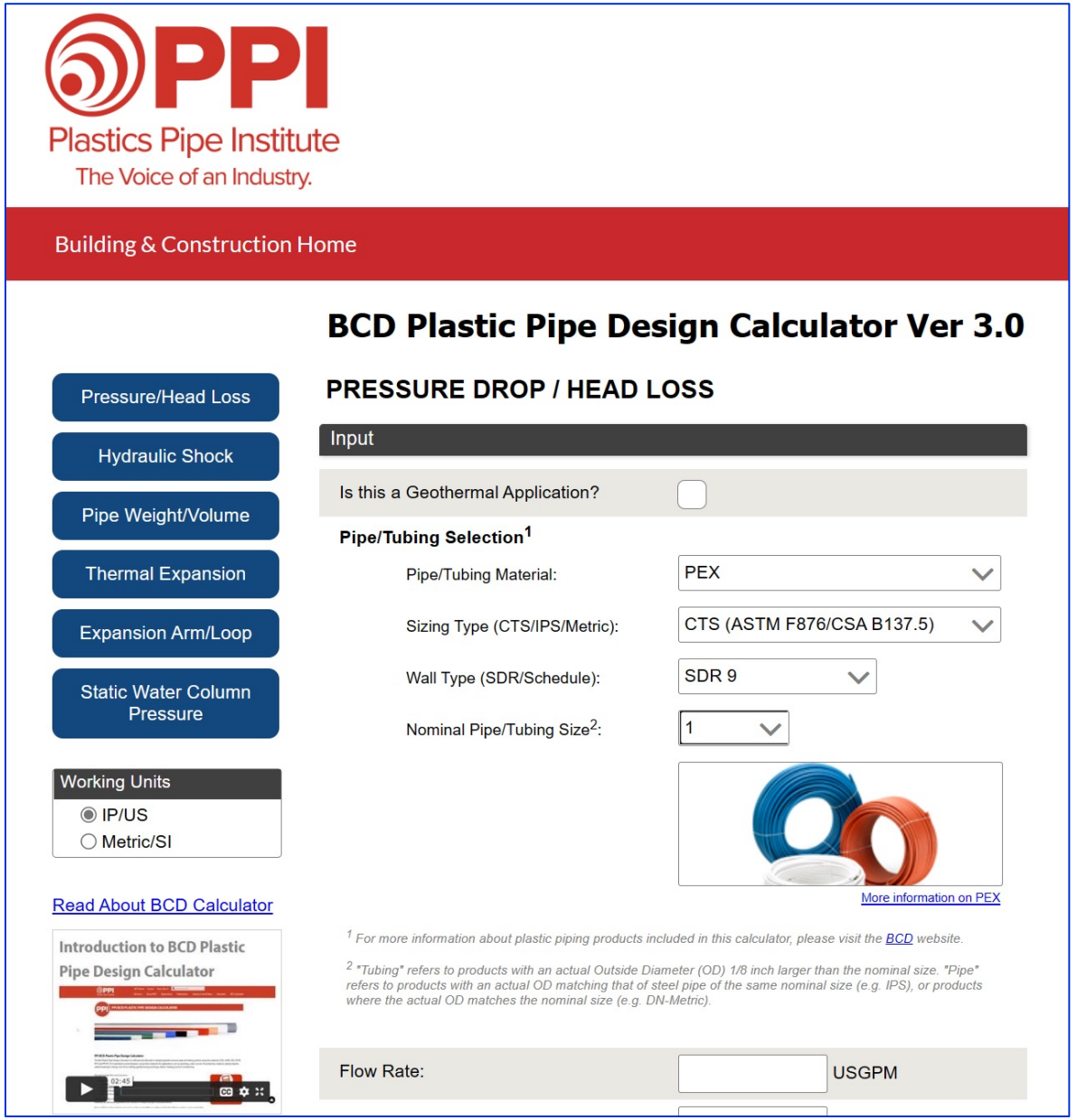


Course Background

PPI Plastic Pipe Design Calculator

- For design calculations related to:
  - Pressure drop / Head loss
  - Hydraulic shock (surge pressure)
  - Pipe Weight / Volume
  - Thermal Expansion
  - Expansion Arm / Loop Design
  - Static Water Column Pressure

- Go to www.plasticpipecalculator.com



Course Learning Objectives

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

1. Explain how the properties of PEX tubing and fittings can protect health, safety, and welfare
2. Introduce several options of PEX fitting system designs
3. Discuss PEX system standards and code compliance
4. Describe three distinct plumbing layouts using PEX systems and compare the advantages and disadvantages of each
5. Apply test data from published research to demonstrate how design of the plumbing layout can improve system performance (e.g., flow) and provide faster delivery of hot-water with reduced water waste
6. Show how to access industry resources for additional material, design, and installation information

1. How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

This Learning Objective will explain properties of PEX system components:

a. PEX Tubing: Crosslinked Polyethylene

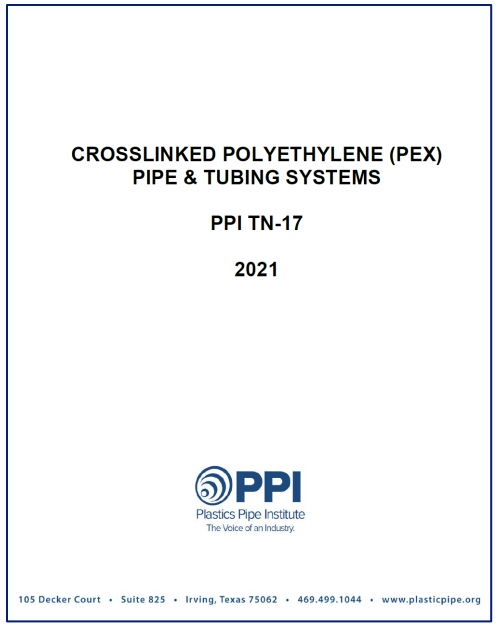
b. PEX Fittings: Brass, copper, and polymer materials

c. Plumbing Distribution Manifolds: Several designs and materials

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

a. 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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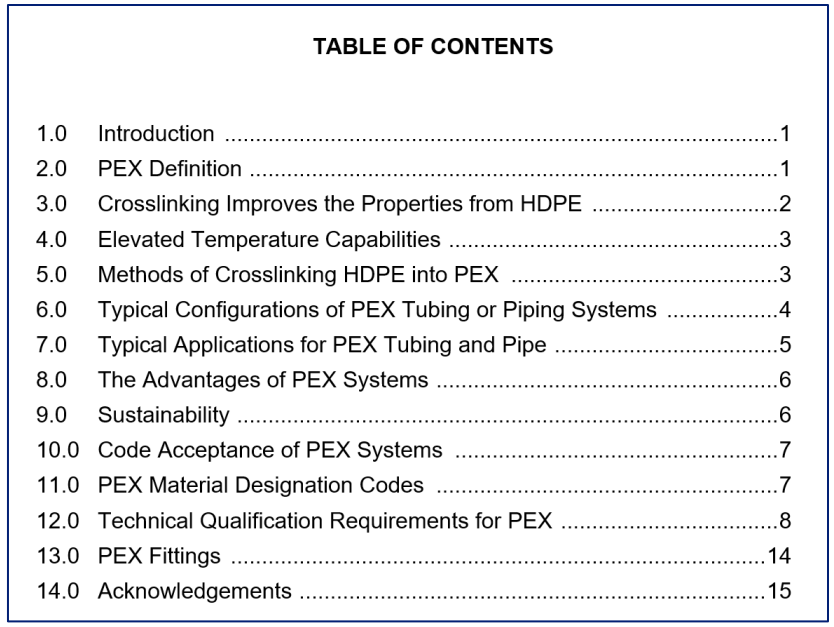

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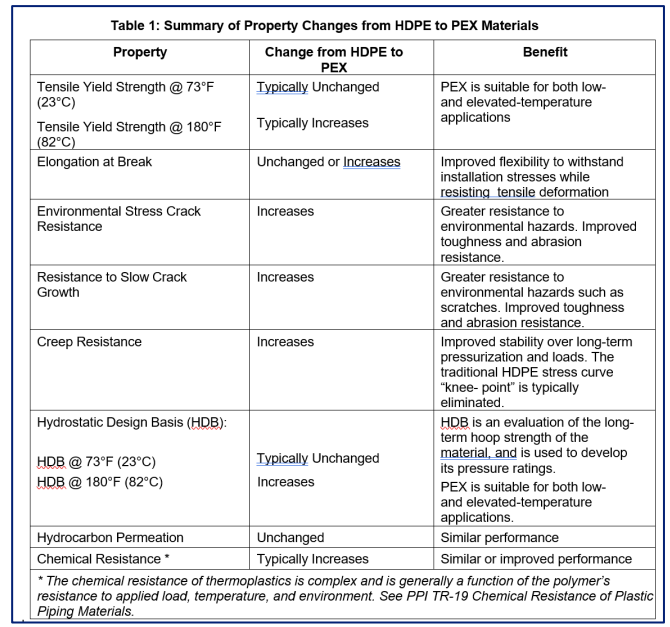

Table 1: Summary of Property Changes from HDPE to PEX Materials

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 and Fittings Can Improve Health, Safety, and Welfare

PEX Tubing: Crosslinked (X) PolyEthylene

- Formal Definition – “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 pipes 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*

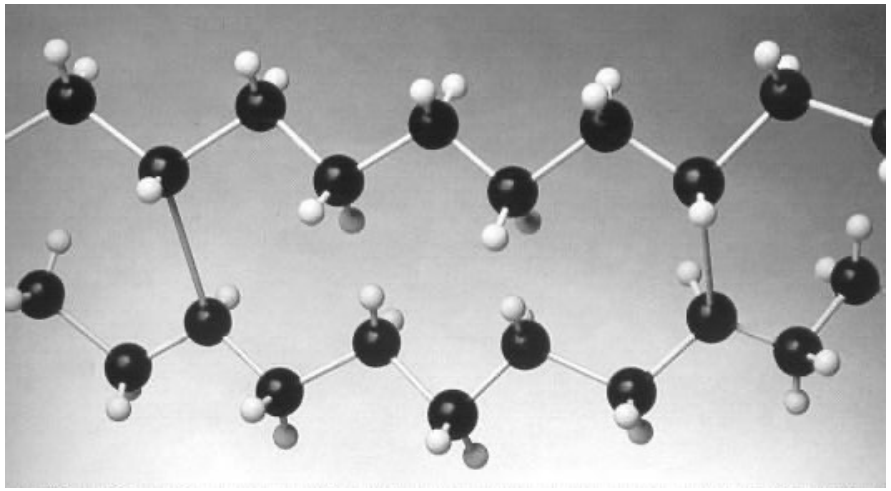

Illustration of a PEX “molecule”

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Tubing History & Overview

- PEX was introduced for radiant heating in the early 1970s in Europe
- Introduced to USA and Canada in 1980s* for heating and plumbing
- PEX is a high-temperature flexible pressure pipe material
- PEX tubing systems are used for water service lines, hot- and cold-water distribution, radiant heating & cooling, outdoor snow & ice melting, residential fire protection, geothermal ground loops and other demanding applications

**The original tubing standard ASTM F876 first published in 1984*

Courtesy Viega

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Tubing Production Methods

The three common methods of crosslinking polyethylene 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., ASTM, AWWA, CSA) and codes (e.g., IPC, NPC, NSPC, UPC)

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Tubing Production Methods

The three common methods of crosslinking polyethylene are known as:

- **Peroxide (PEX-a):** *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 and Fittings Can Improve Health, Safety, and Welfare

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 and Fittings Can Improve Health, Safety, and Welfare

PEX Tubing Configurations

- PEX plumbing tubing is currently produced in nominal tubing sizes from 1/4 to 4 (copper tube size)
- PEX is available in natural (white) or colors such as red, white, blue, black, orange
- PEX tubing is available in coils or straight lengths, depending on the customer preference and application

Courtesy BOW

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

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 61 is updated regularly with stringent requirements

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

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 372 is updated regularly with stringent requirements

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Property: Bending and Flexibility

- Minimum bending radius is **6** to **8 times** the Outside Diameter of the tube
- Consult with tubing manufacturer for the minimum bend radius of their tubing

Example of bundles of PEX tubing run together No elbows

Tube Size (nominal) in.	Tube OD (actual) in.	6X Minimum Bend Radius in.	8X Minimum Bend Radius in.
3/8	0.500	3.0	4.0
1/2	0.625	3.8	5.0
3/4	0.875	5.3	7.0
1	1.125	6.8	9.0
1 1/4	1.375	8.3	11.0
1 1/2	1.625	9.8	13.0
2	2.125	12.8	17.0

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Property: Bending and Flexibility

- Minimum bending radius is **6** to **8 times** the Outside Diameter of the tube
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Example of tight bend radius possible with ¾ PEX tubing

Tube Size (nominal) in.	Tube OD (actual) in.	6X Minimum Bend Radius in.	8X Minimum Bend Radius in.
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1 1/2	1.625	9.8	13.0
2	2.125	12.8	17.0

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Property: Bending and Flexibility

- Bend supports (a.k.a. support bends, sweeps) may be used to replace most elbows
- These accessories can save the time and cost of installing elbows

Courtesy REHAU x 3

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Property: Longitudinal Expansion and Contraction

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

Example 1:

- **100 ft** PEX water 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 **1.0** [100 ft/100 ft] = **3.3 inch** reduction in length

Example 2:

- **120 ft** PEX water line installed at **70°F**; Service water temperature is **130°F**
- **60°F** temperature increase will result in a tubing length increase of:
- **1.1** x **6** [60°F/10°F] x **1.2** [120 ft/100 ft] = **7.9 inch increase** in length

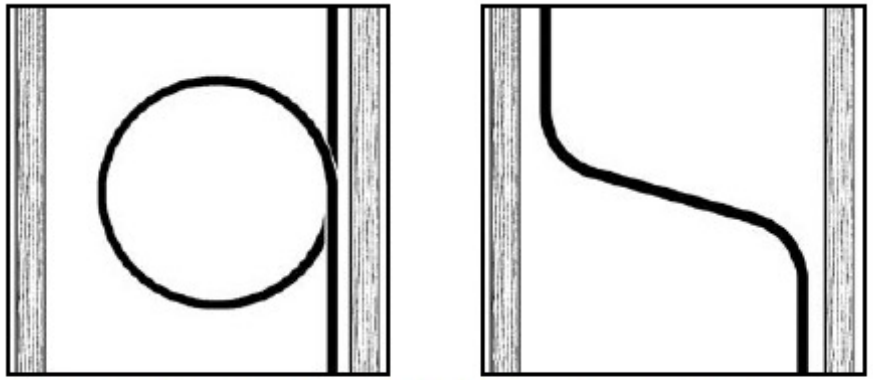
How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Property: Longitudinal Expansion and Contraction

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

Solution:

- Expansion is usually accommodated by the tubing's flexibility for sizes ≤ 1 in.
- Allow 1/8 inch slack per foot of installed tubing
- Offsets and loops can accommodate most thermal expansion and contraction



How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

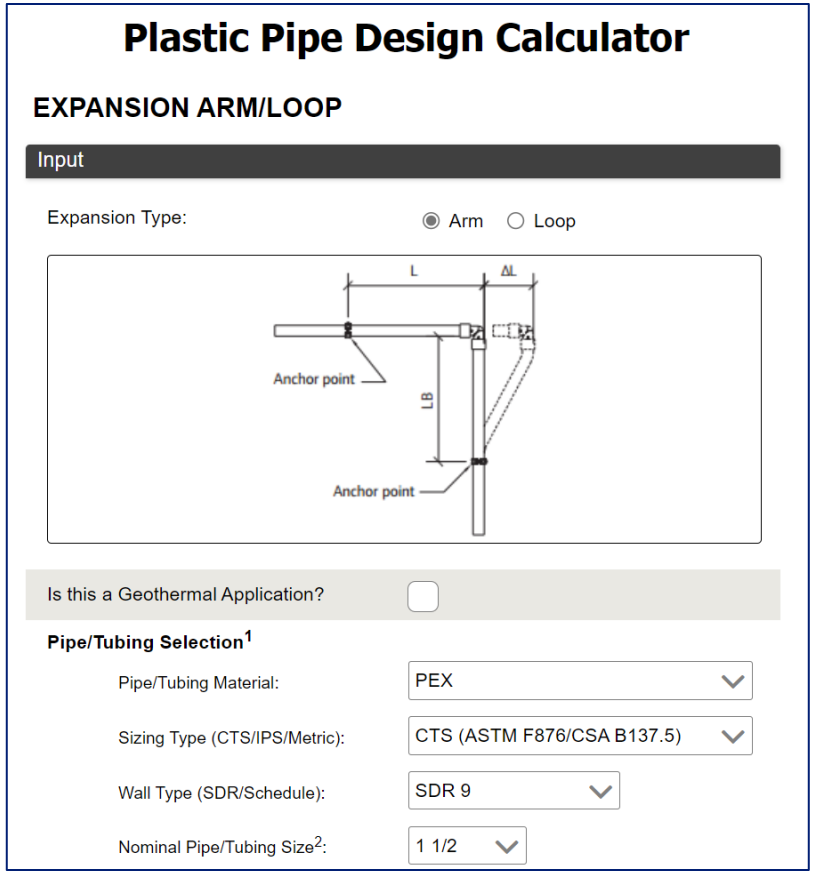
PEX Property: Longitudinal Expansion and Contraction

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

Solution:

- Expansion loops or arms may be needed, depending on installation type, expected temperature changes, tubing size
- www.plasticpipecalculator.com helps with these calculations

- Example: **Expansion Arm** calculation shown



How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Property: Longitudinal Expansion and Contraction

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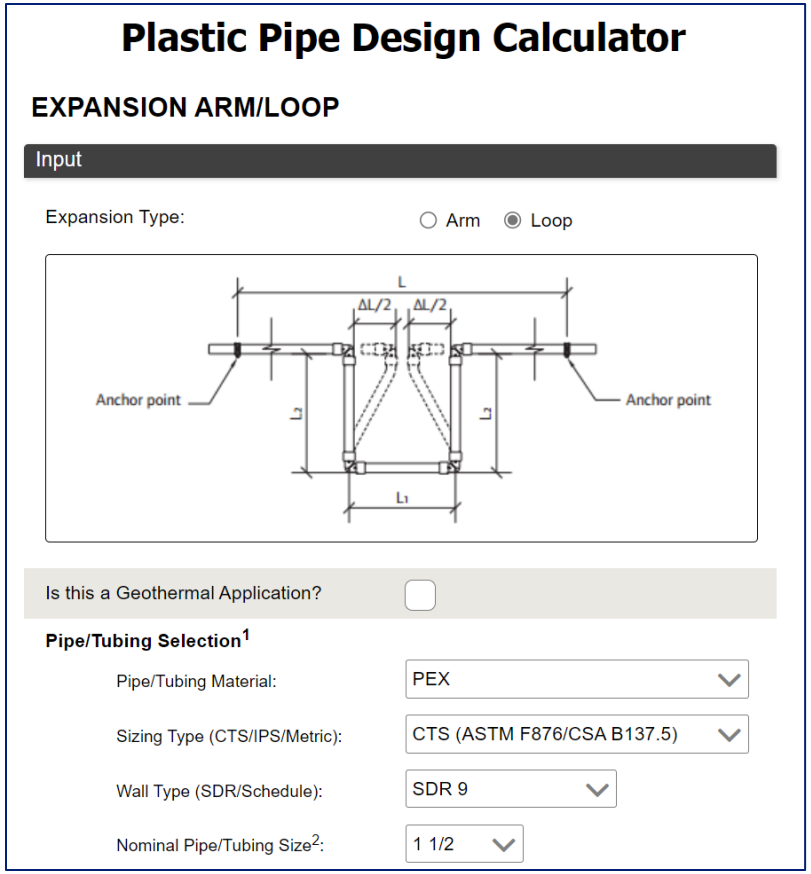
- Example: **Expansion Loop** calculation shown



How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

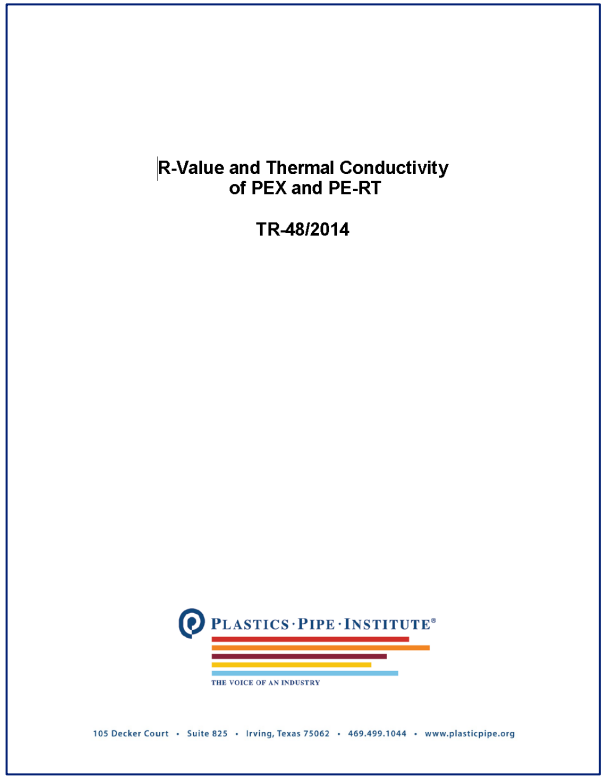
PEX Property: Low Thermal Conductivity and k-value

- 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

Note: Although PEX tubing has inherent insulating properties, insulation is still recommended when required by code and in certain installations. See ***PPI TN-65***

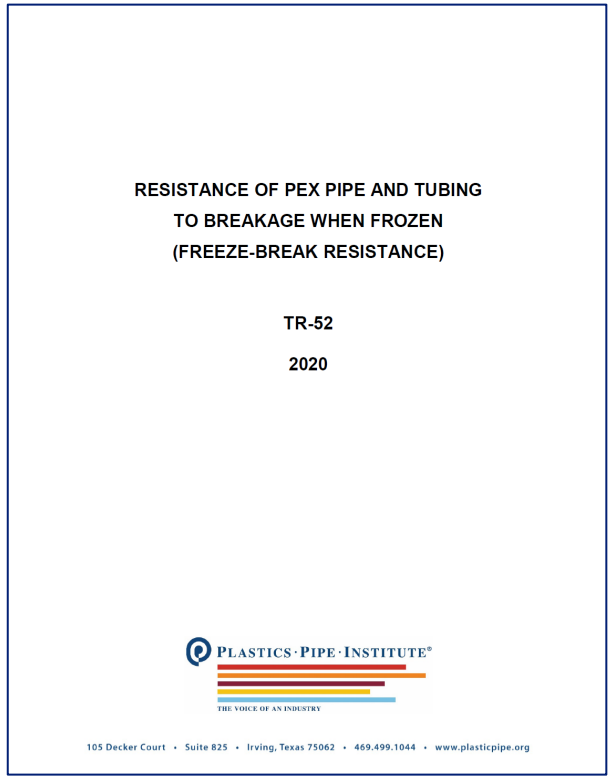


How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Property: 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 *does freeze*, 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 walls or ceilings

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


RESISTANCE OF PEX PIPE AND TUBING
TO BREAKAGE WHEN FROZEN
(FREEZE-BREAK RESISTANCE)

TR-52

2020

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How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

b. PEX Fittings for Plumbing Distribution

- There are several types of fittings designed for use with PEX tubing
- PEX fittings are produced from **lead-free brass alloys** and **polymers**

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Fittings for Plumbing Distribution

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

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Fittings for Plumbing Distribution

- 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

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

c. PEX Distribution Manifolds

- Several styles of manifolds are available in various materials
  - Copper, polymer (PLS, PPSU)
- PEX manifolds must be certified to the same standards as PEX fittings
  - e.g., NSF/ANSI/CAN 61, NSF/ANSI/ CAN 372

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

PEX Distribution Manifolds

- Several styles of manifolds are available in various configurations
    - Valved, valveless

How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

Summary

- PEX tubing has a long history of use around the world for drinking water applications

- PEX fittings and manifolds are proven safe for plumbing

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

2. PEX Fitting Systems

Introduction

- There are several types of fittings designed for use with PEX tubing
- Many of these fitting designs are produced to specific ASTM or ASSE standard specifications
- PEX fitting systems are tested to harmonized performance testing

PEX Fitting Systems

PEX Fitting System Testing

- 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 and test methods, including:
  - Burst pressure strength
  - Long-term sustained pressure strength
  - Hot- and cold-water thermocycling

- PEX fittings must also meet NSF/ANSI/CAN 61 (health effects) and NSF/ANSI/CAN 372 (lead-free)

PEX Fitting Systems

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

PEX Fitting Systems

ASTM F2098 stainless steel clamps *are used with F1807 and F2159 crimp fittings as an alternative for the copper crimp ring*

ASTM F1807 *brass fitting*

OR

ASTM F2159 *polymer fitting*

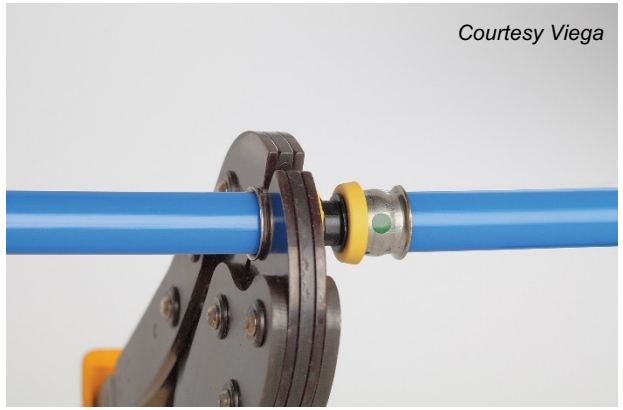
Special tools are used for these s/s clamps – each type of clamp specifies its own tool

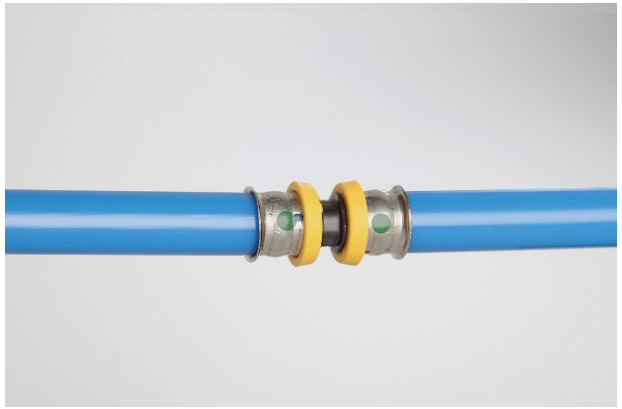
PEX Fitting Systems

Courtesy Uponor

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

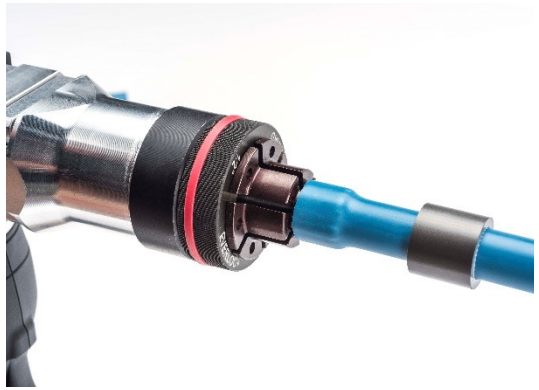
PEX Fitting Systems

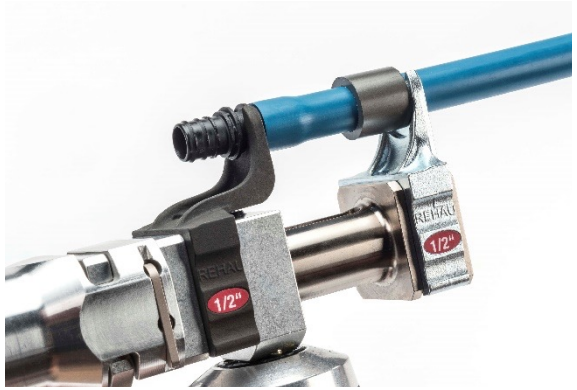




ASTM F3347/F3348 Press fittings using stainless steel sleeve
Available in polymer and lead-free brass

PEX Fitting Systems

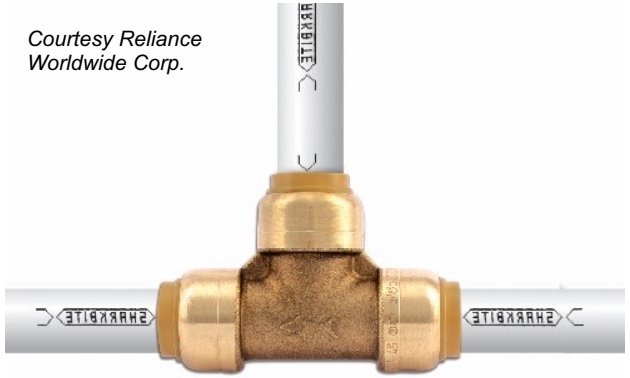




Courtesy REHAU

Cold-expansion fitting with PEX compression-sleeve
Available in polymer and lead-free brass

PEX Fitting Systems



Courtesy Reliance Worldwide Corp.

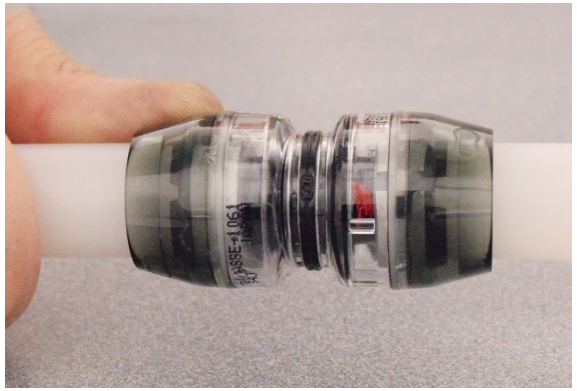
ASSE 1061 Push-fit fittings
Available in polymer and lead-free brass

PEX Fitting Systems

Courtesy Reliance Worldwide Corp.

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

PEX Fitting Systems



Courtesy Legend

ASSE 1061 Push-fit non-removal fittings with internal stainless steel clamp
Available in polymer
Note: This style of ASSE 1061 fitting is for PEX and PE-RT tubing only, not for copper or CPVC.

PEX Fitting Systems

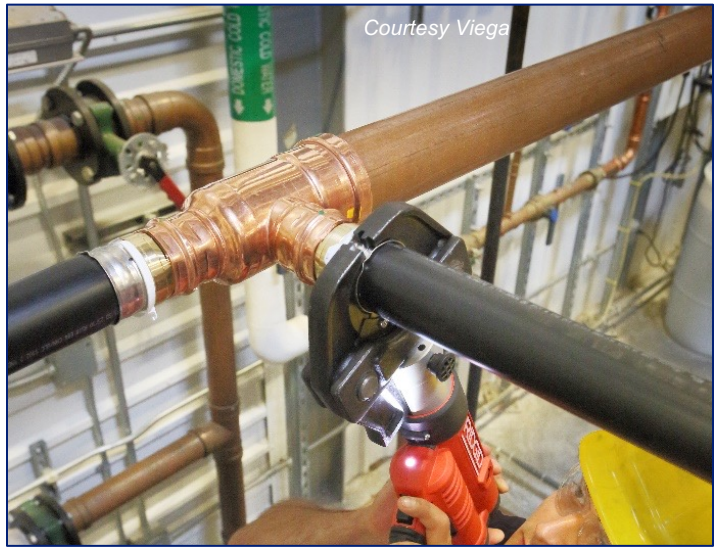
Wide range of PEX fitting types is available

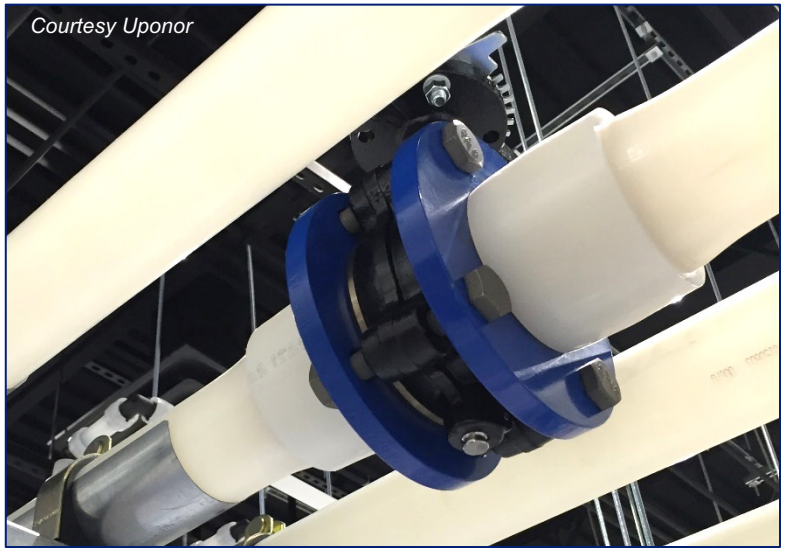
- Shapes such as tees, elbows, couplings, plugs, reducers available
- Various adapters: Copper sweat/street, MPT, FPT, drop-ear elbows, etc.

PEX Fitting Systems

Commercial Applications – Adapting to Other Piping Materials

- Various adapters: Press fittings, Flanges, Grooved, MPT and FPT adapters are available





PEX Fitting Systems

PEX Fittings Standards

- Not all PEX fittings are approved for use with all PEX tubing
  - Not all combinations are approved!

- Tubing manufacturers must 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 that PEX tubing, is marked on the tubing

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

PEX Fitting Systems

PEX Fittings Standards

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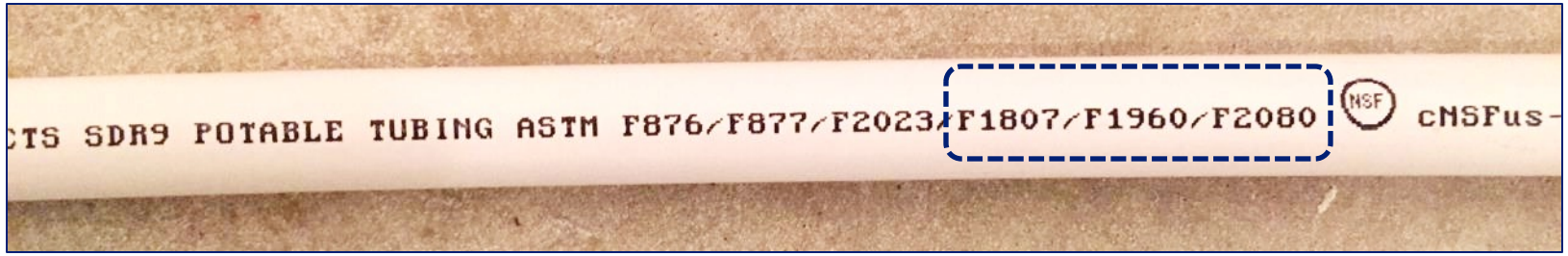


PEX Fitting Systems

Summary

- There are several types of fittings designed for use with PEX tubing
- Variety of materials and configurations
- Many of these fitting designs are produced to specific ASTM or ASSE standard specifications
- PEX fitting systems are tested to harmonized performance testing as per ASTM F877

3. PEX System Standards and Code Compliance

PEX Tubing Standards

- There are three primary standards for PEX tubing and systems in North America:
  - ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*
  - 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*

- Model plumbing codes such as IPC, NSPC, UPC, and the NPC of Canada refer to these standards

PEX System Standards and Code Compliance

PEX Tubing Standards

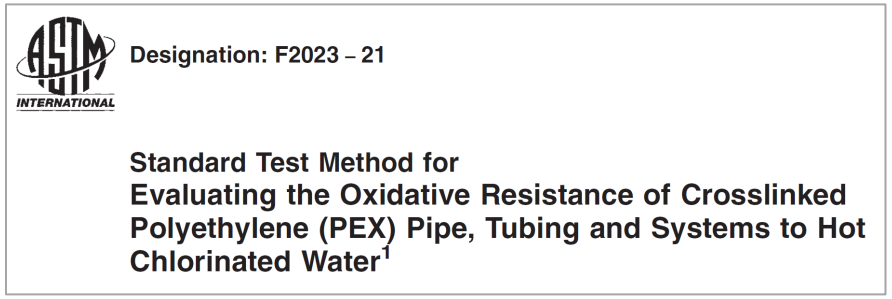
- ASTM F876 and CSA B137.5 establish capabilities and test requirements, such as:
  - Dimensions
  - Degree of crosslinking
  - Quick burst pressures
  - Long-term pressure ratings
  - Chlorine resistance
  - UV resistance
  - Excessive pressure-temperature capability
  - Hot-bend and cold-bend tests
  - Marking requirements
  - Even more…

PEX System Standards and Code Compliance

PEX Tubing Standards: Test Methods

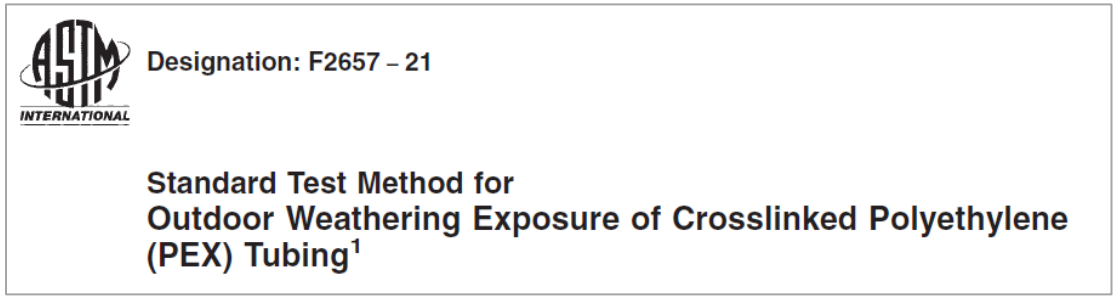
- ASTM F2023 *Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Chlorinated Hot Water*

- ASTM F2657 *Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene Tubing*



Designation: F2023 – 21

Standard Test Method for
Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water[1]



Designation: F2657 – 21

Standard Test Method for
Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing[1]

PEX System Standards and Code Compliance

PEX Tubing Standards: Degree of Crosslinking

The Minimum and Maximum Degree of Crosslinking are prescribed in product standards

Requirements from ASTM F876:

- Peroxide method (PEXa), allowable range = 70% - 89%
- Silane method (PEXb), allowable range = 65% - 89%
- Electron-beam method (PEXc), allowable range = 65% - 89%

Details:

- Crosslinking testing is performed in accordance with ASTM Test Method D2765 Method B

PEX System Standards and Code Compliance

PEX Tubing Requirements: Burst Pressure

Requirement from ASTM F876 for short-term burst pressure:

- Minimum burst pressure **475 psig @ 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:

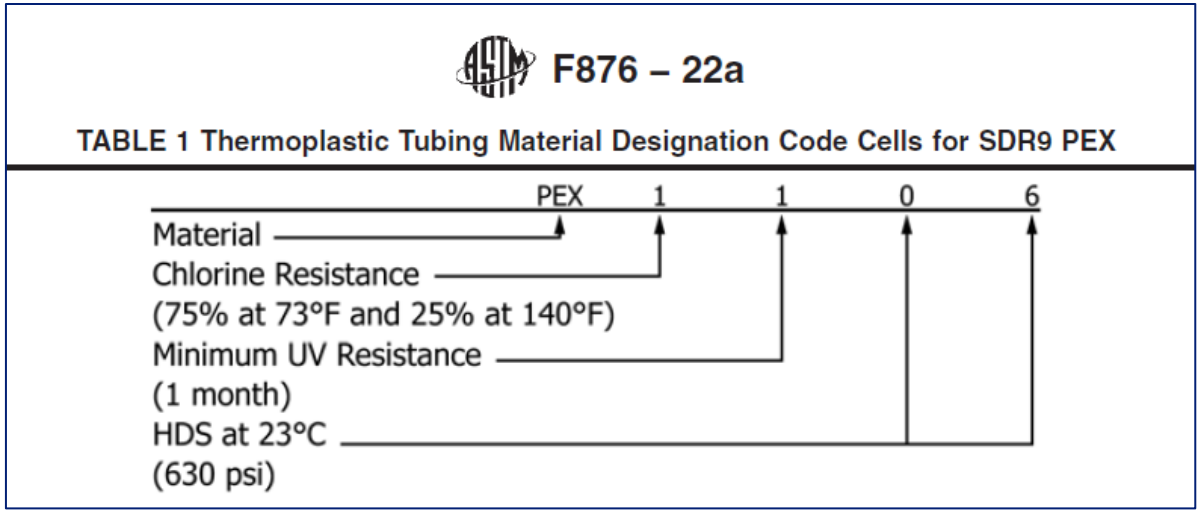
- Burst testing is performed in accordance with ASTM D1598 to test the short-term strength of the tubing

PEX System Standards and 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**"



PEX System Standards and 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 System Standards and 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 plumbing tubing according to ASTM F876

PEX System Standards and 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

Storing PEX tubing outdoors is not permitted!

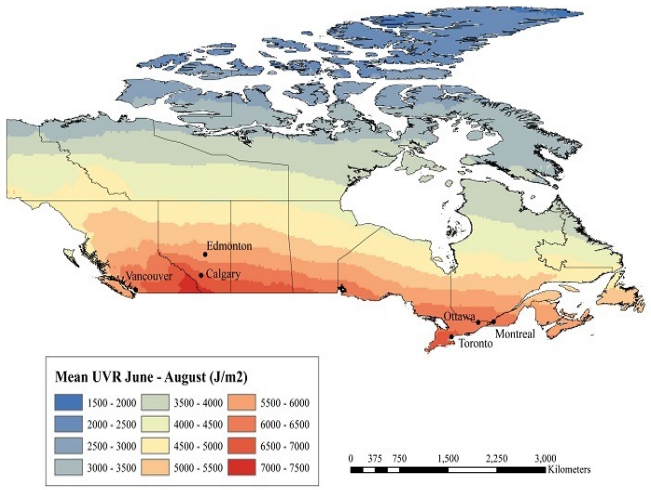
PEX System Standards and Code Compliance

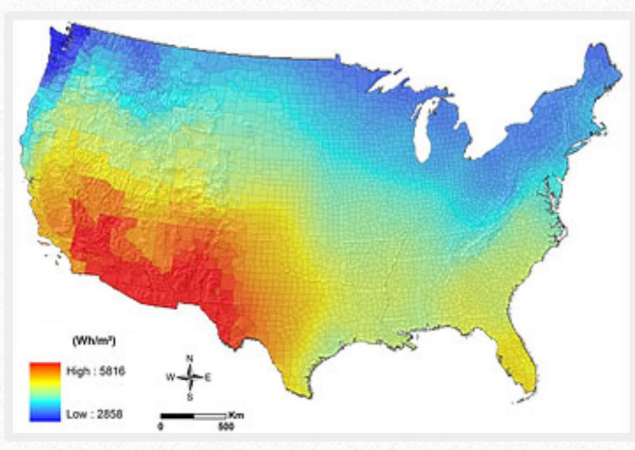
UV Resistance: Potential Threats

- 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 System Standards and 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

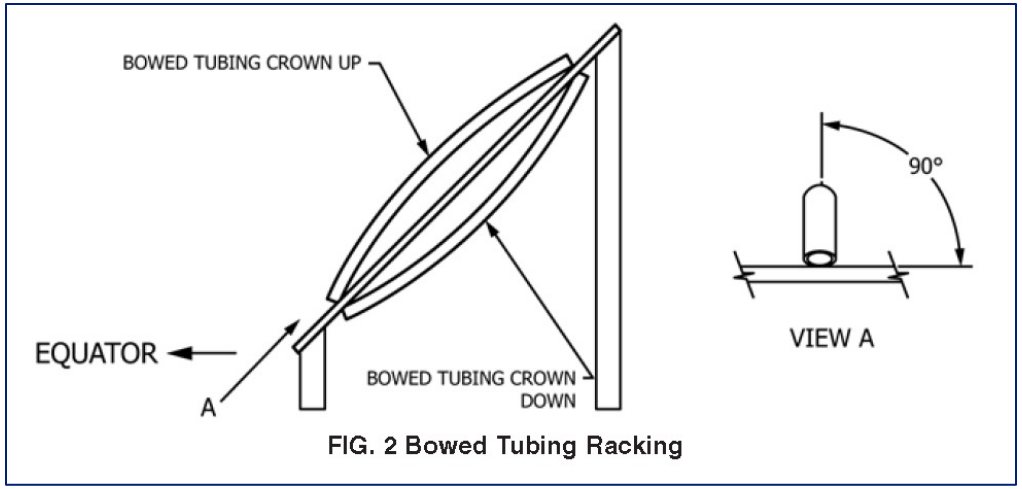


FIG. 2 Bowed Tubing Racking

Fig. 2 from ASTM F2657

PEX System Standards and 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 **'1'** is the **Minimum** requirement for PEX plumbing tubing according to ASTM F876

- 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 System Standards and Code Compliance

Sustained Pressure Ratings

Requirement from ASTM F876 for long-term hydrostatic strength (sustained pressure) ratings:

- **160 psig @ 73°F** (1,103 kPa @ 23°C)
- **100 psig @ 180°F** (690 kPa @ 82°C)
- 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 System Standards and Code Compliance

Design Factor (DF)

Requirement from ASTM F876:

- The Design Factor for PEX tubing 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 ASTM F876

Details:

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

PEX System Standards and Code Compliance

PEX Tubing Standards: Flame and Smoke Ratings in the UMC

- The 2021 UMC requires that if PEX tubing is to be installed within a return air plenum that requires “non-combustible materials”, then the tubing must demonstrate a flame spread rating ≤ 25 and a smoke spread rating ≤ 50 when tested according to **ASTM E84** or **UL 723**
- In Canada, flame and smoke spread testing is in accordance with **CAN/ULC S102.2**
- These values are generated using the “Steiner Tunnel” test
- Codes are subject to change, so check with local codes for specific requirements!

Image of Steiner Tunnel at UL LLC

PEX System Standards and Code Compliance

PEX Tubing Standards: Flame and Smoke Ratings in the IMC

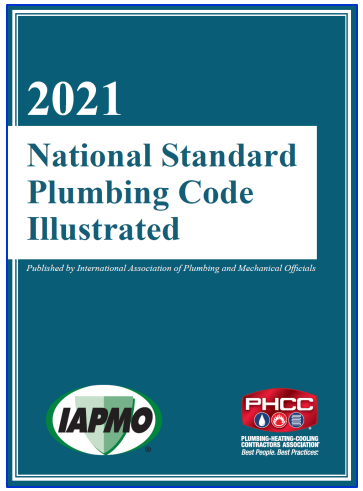
- The 2021 IMC requires testing according **ASTM E84** or **UL 723** or **UL 2846**
- IMC Section 602.2.1.7 allows that plastic water distribution piping and tubing listed and labeled in accordance with UL 2846 as having a peak optical density not greater than 0.50, an average optical density not greater than 0.15, and a flame spread distance not greater than 5 feet (1524 mm) and installed in accordance with its listing may be used
- Codes are subject to change, so check with local codes for specific requirements!

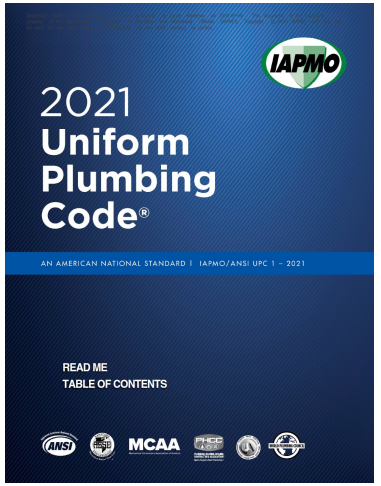
Image of Steiner Tunnel at UL LLC

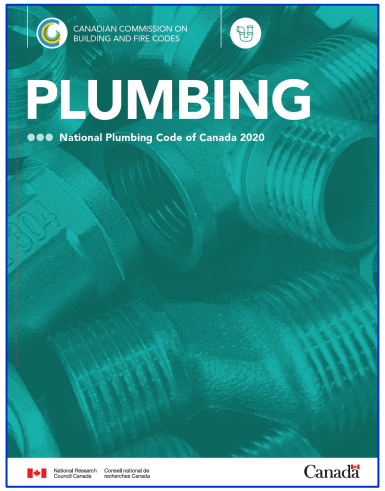
PEX System Standards and Code Compliance

Summary

- U.S. model plumbing codes **IPC**, **NSPC**, and **UPC** accept PEX systems when certified to ASTM F876 and ASTM F877
- The **NPC** of Canada accepts PEX systems when certified to CSA B137.5
- PEX tubing and fitting systems are fully accepted in all model plumbing codes







4. Plumbing Layouts Using PEX Tubing

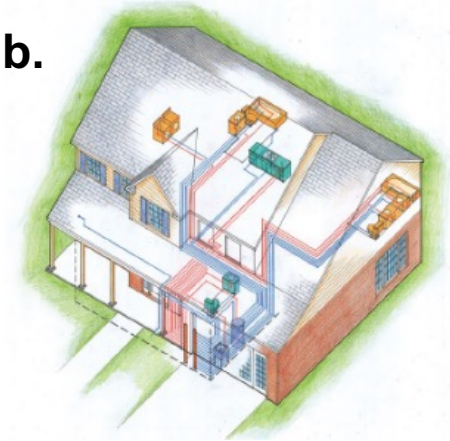
This Learning Objective describes three layout options:

a. **Trunk and Branch** (a.k.a. traditional)
b. **Parallel** pipe systems (a.k.a. home run)
c. **Zoned** systems (a.k.a. remote manifolds)

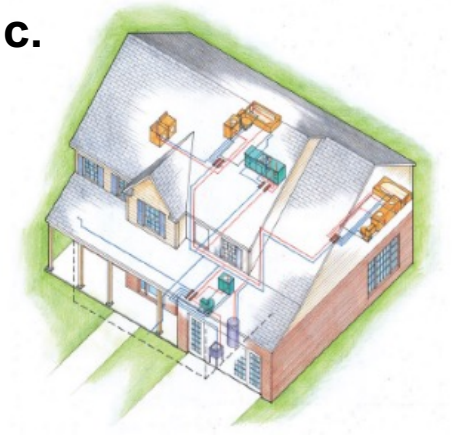
By carefully choosing the right system for the application, the plumbing designer can produce a home that balances safety, longevity, comfort, cost, installation time, environmental soundness and performance

a.

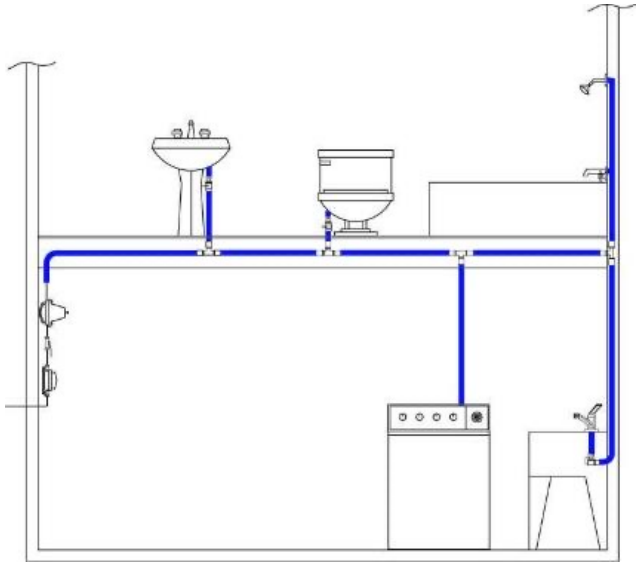
b.



c.



Plumbing Layouts Using PEX Tubing

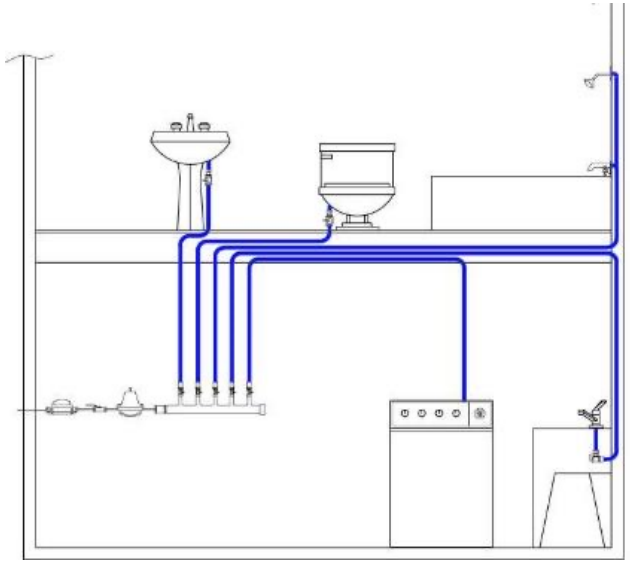


a. Trunk and Branch (a.k.a. traditional)

- **Trunk and Branch** is a familiar installation technique
- Employs normal use of reducing tees and elbows
    - Many elbows can be eliminated with pipe sweeps
- This traditional installation technique is faster with PEX due to tubing flexibility and faster joint assembly
- PEX tubing sizes up to 3” are available, drops are typically 3/8, 1/2, or 3/4 inch
- T&B is most appropriate when using larger diameter PEX (over 3/4”) where flexibility is not so relevant

- T&B is commonly used in multi-family and commercial plumbing design

Plumbing Layouts Using PEX

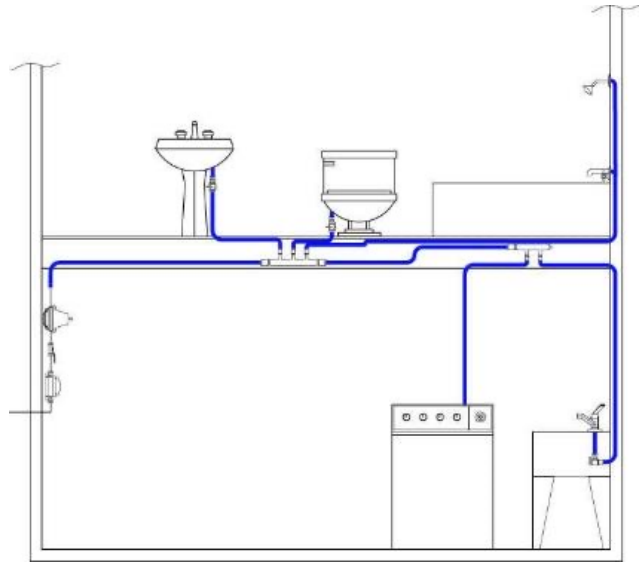


b. Parallel pipe systems (a.k.a. home run)

- **Parallel** technique employs 3/8 or 1/2 in. pipes "**home-run**" to each fixture
  - Small diameter tubing of one common size is easy to install
- Tubing is connected to central manifolds (hot and cold)
  - Manifolds (often valved) are located near the water source
- Sizing is simplified, systems are pressure-balanced
- Fewer fittings are required (none within walls) and tees are practically eliminated (still used for dishwasher)

- Similar in concept to household wiring from a breaker panel

Plumbing Layouts Using PEX



c. Zoned systems (a.k.a. remote manifolds)

- **Zoned** technique uses trunk lines to supply **remote manifolds** at fixture group “zones”
  - Small manifolds replace many tees and joints
  - 3/8 or 1/2 in. diameter pipes are run to each fixture
- Manifolds are copper or polymer, usually not valved
  - Often embedded within walls
- Sizing is simplified, systems are pressure-balanced

- Fewer fittings are required and tees are practically eliminated (still used at dishwasher); less pipe than home-run

Plumbing Layouts Using PEX

Comments on Trunk and Branch

- Although PEX tubing works well in a traditional T&B layout and is very appropriate for commercial installations, it can be a slower installation technique for residential housing
- Experienced plumbers may reduce installation time and/or materials by using one of the other techniques

- **T&B systems** may be ideal for certain designs, especially large-diameter commercial plumbing

Plumbing Layouts Using PEX

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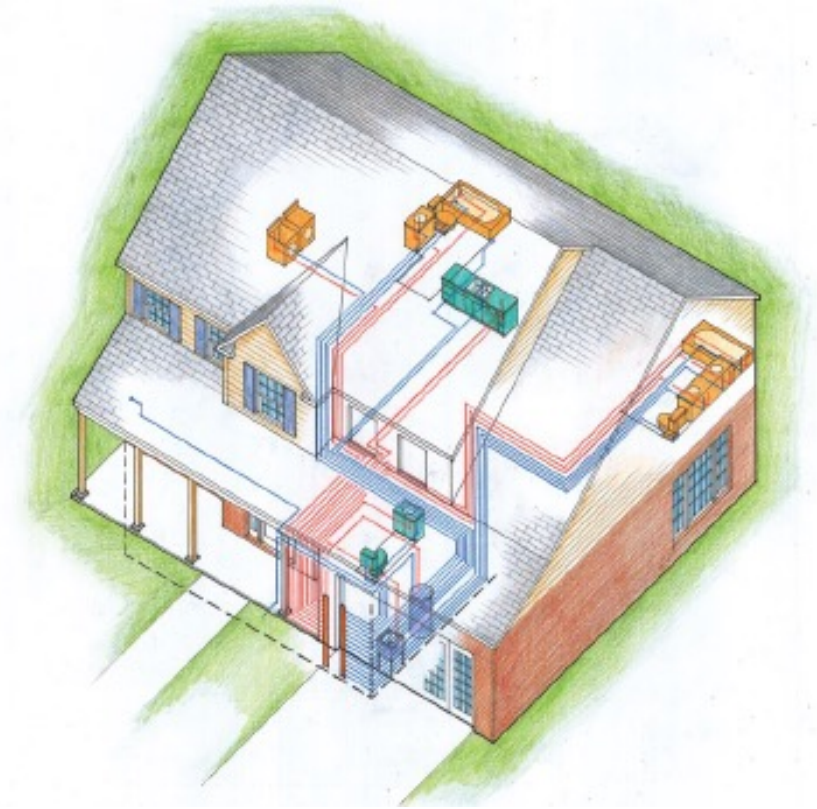
Example of a commercial PEX T&B plumbing system

Plumbing Layouts Using PEX

Comments on Parallel systems

- Although PEX tubing works well in a parallel home-run layout, in larger homes, this technique requires a lot of tubing, many holes in studs and plates, greater need for fasteners, and potentially longer installation time
- Faster delivery of hot water to fixtures is common
- Delivery time for *sequential hot-water* has no advantage over T&B

- **Parallel systems** may be ideal for certain designs, especially smaller residential systems with shorter pipe lengths



Plumbing Layouts Using PEX

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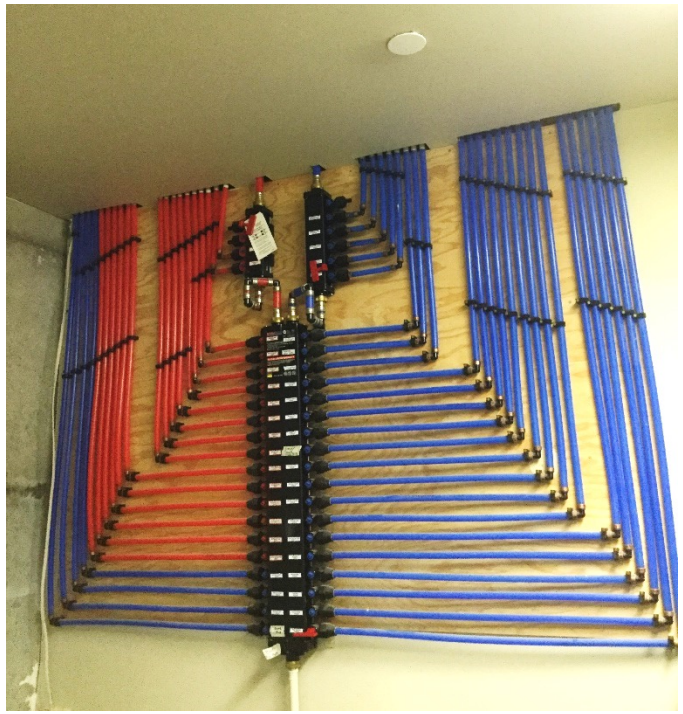

Example of a very large home-run plumbing system

Plumbing Layouts Using PEX

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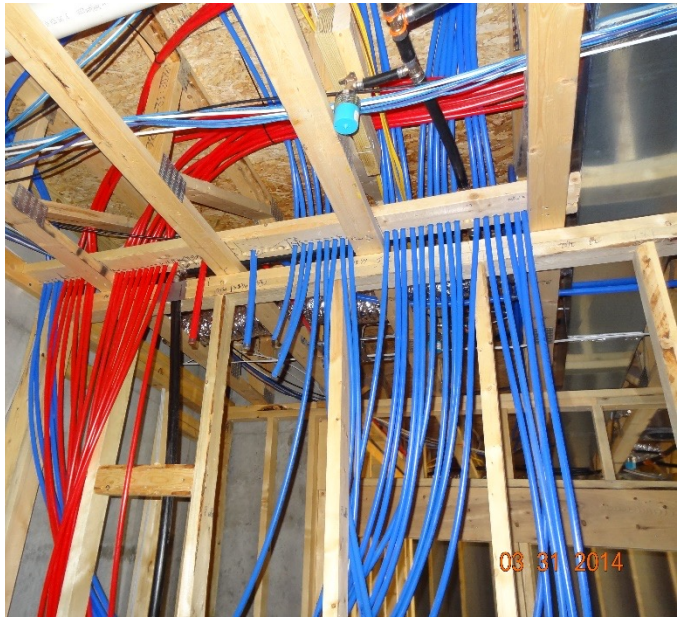


Example of a very large home-run plumbing system

Plumbing Layouts Using PEX

Comments on Zoned systems

- The Zoned technique reduces the total amount of tubing, reduces number of fittings and can reduce overall installation time
- Delivery time for *sequential hot-water* is reduced (i.e. faster delivery) over T&B and Parallel (home-run)

- **Zoned systems** may be ideal for certain designs, especially when hot-water recirculation is employed

Plumbing Layouts Using PEX

Quick Comparison from PEX Plumbing Design Guide

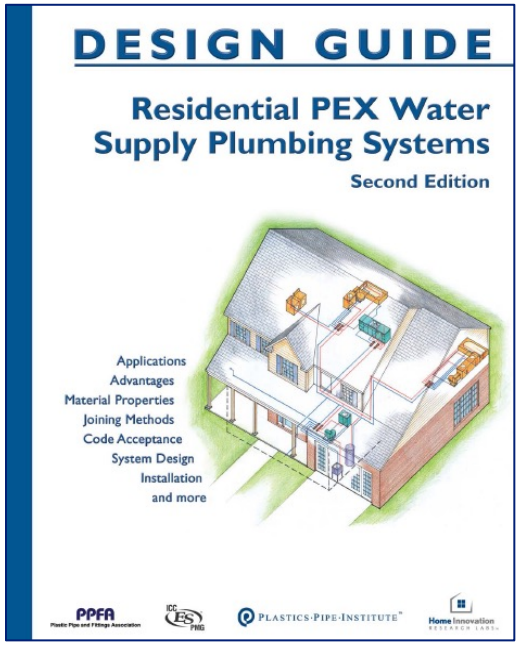
- The designer assigns priorities and can select the optimal layout using **Table 7.1**

* stars represent general rankings

Table 7.1 – General Rankings of the System Characteristics

Factor	* * *	* *	*
Minimize Pipe Used	Trunk and Branch	Zone	Parallel
Minimize Fittings and Joints	Parallel	Zone	Trunk and Branch
Sequential Flow Hot Water Delivery Time	Trunk and Branch Zone		Parallel
Minimize Hot Water Wait Time	Parallel	Zone	Trunk and Branch
Single Fixture Pressure	Trunk and Branch	Parallel Zone	
Pressure Stability with Use of Multiple Fixtures	Parallel	Zone	Trunk and Branch
Centralize Shut-off Valving	Parallel	Zone	Trunk and Branch
Joint Accessibility During Installation	Parallel	Zone	Trunk and Branch

* * * Indicates the highest level of performance for that factor
* Indicates typical performance



Plumbing Layouts Using PEX

Volume and Weights of PEX Tubing Sizes

- The volume of PEX tubing sizes should also be considered when designing layout of plumbing systems to minimize water waste/volume between fixtures and source

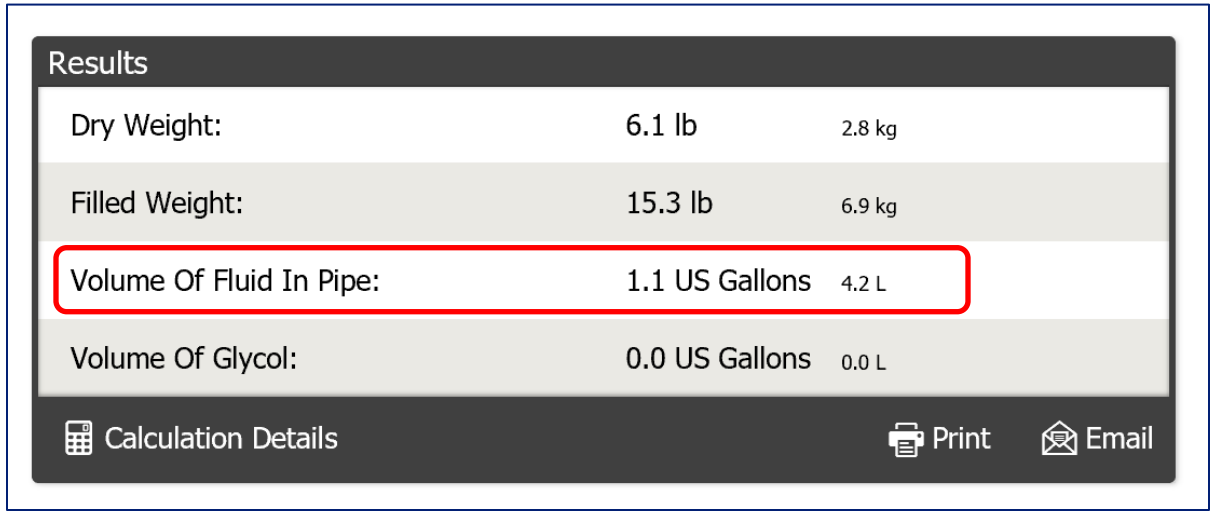
Tube Size (nominal)	Tube OD (average) in. *	Wall thickness (average) in. *	Tube ID (average) in. *	Weight of tube only, pounds per foot	Weight of tube & water, pounds per foot	Volume per ft. (gallon)	Volume per 100 ft. (gallon)
3/8	0.500	0.075	0.350	0.04	0.08	0.005	0.5
1/2	0.625	0.075	0.475	0.05	0.13	0.090	0.9
3/4	0.875	0.102	0.671	0.10	0.25	0.018	1.8
1	1.125	0.132	0.862	0.17	0.42	0.030	3.0
1 1/4	1.375	0.161	1.054	0.25	0.63	0.045	4.5
1 1/2	1.625	0.191	1.244	0.35	0.88	0.063	6.3
2	2.125	0.248	1.629	0.60	1.50	0.108	10.8
2 1/2	2.625	0.307	2.011	0.92	2.29	0.165	16.5
3	3.125	0.364	2.397	1.29	3.24	0.235	23.5

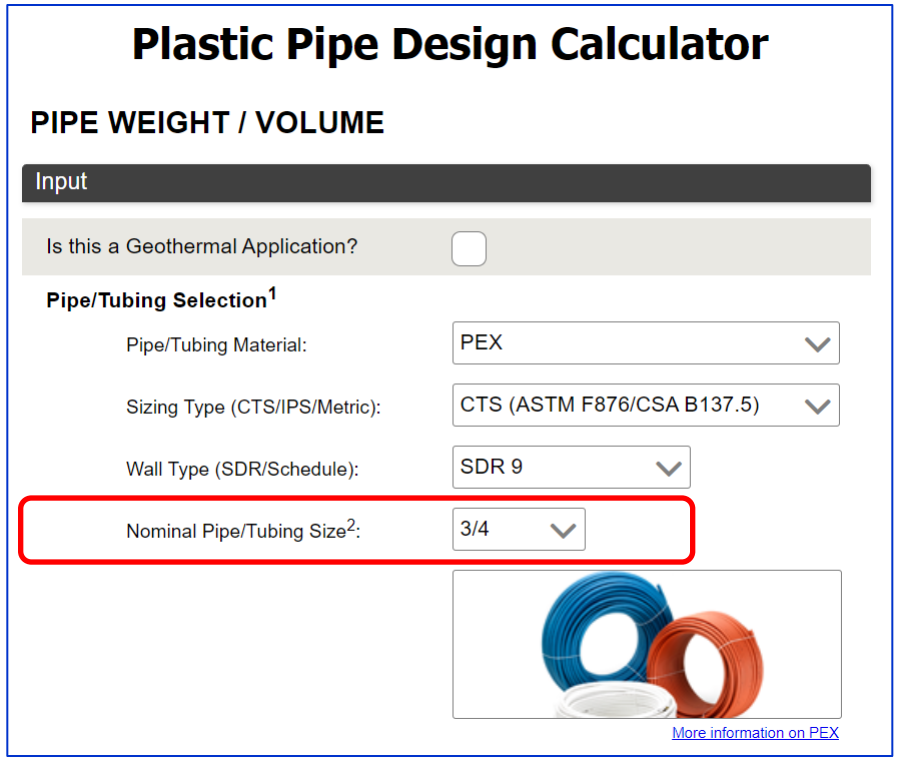
*Dimensions are b*ased on average OD and wall thickness dimensions as per ASTM F876 and CSA B137.5*

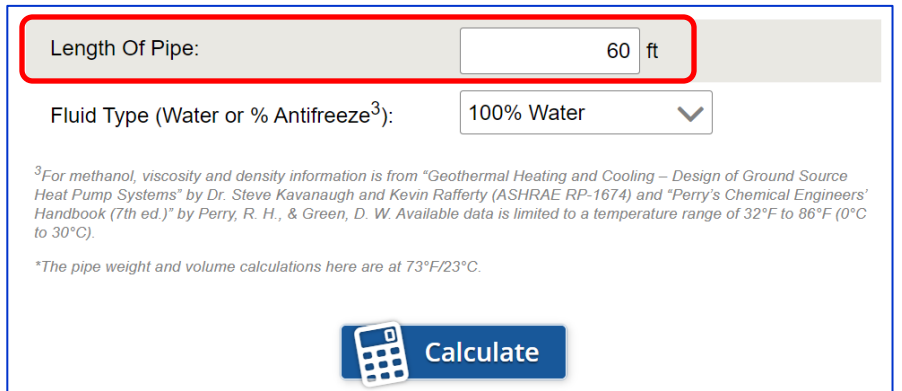
Plumbing Layouts Using PEX

Volume and Weights of PEX Tubing Sizes

- **Plastic Pipe Design Calculator** calculates volume of pipes
- Example: ¾ nominal PEX, 60 feet length = 1.1 US Gallons
- Images from www.plasticpipecalculator.com





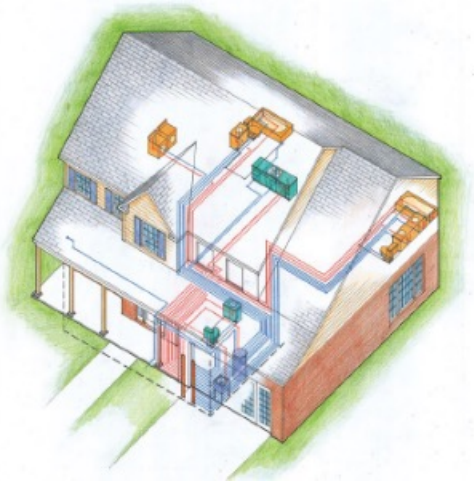


Plumbing Layouts Using PEX

Summary: This Learning Objective described 3 layout options

a. Trunk and Branch (a.k.a. traditional)
b. Parallel pipe systems (a.k.a. home run)
c. Zoned systems (a.k.a. remote manifolds)

Next, we'll see how to optimize designs



5. Optimizing Piping Design for PEX Systems

This Learning Objective discusses performance of the three layout options for four types of residences:

i. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths
ii. Ranch: 1,300 square feet, one story, 2 full baths
iii. Townhouse: 1,000 square, three levels, 1 full bath, 1 half bath
iv. Condo: 1,200 square feet, one level, 2 full baths

- The opportunity for the plumbing designer is to select the system that balances the needs of the installer, the builder, and the owner/occupant for an **optimized system**
- Water quality and water conservation are important responsibilities

Optimizing Piping Design for PEX Systems

The primary goals of hot-water plumbing design

1. Deliver hot water quickly for customer happiness
2. Waste the least amount of water while getting hot water to outlets (water is energy, water is life)
3. Ensure the water is safe and free from harmful pathogens
4. Don’t waste energy in transporting the hot water
5. Don’t waste costs on unnecessary materials

Methods to help achieve these goals:

- Route hot water piping closer to outlets to minimize distance
- Smaller diameter pipes hold less water (less water, less stagnation)
- Faster water velocity “pushes out” the cold water faster
- Plastic pipe has lower thermal conductivity, less heat loss through pipe wall
- PEX plumbing systems save costs on material and labor

Optimizing Piping Design for PEX Systems

Plumbing design tips

- Group fixtures together in a common location, stacking bathrooms when possible
- Route hot water piping close to fixtures, using recirculation at proper times to pre-charge the pipes
- For Parallel piping, group pipes together (hot-with-hot, cold-with-cold)
- Insulate pipes* where necessary (e.g., DHWR lines)

*Although PEX tubing is an insulator as compared with copper, code requirements and common sense still apply

See **PPI TN-65** *Insulation Recommendations for Plastic Pressure Piping Materials in Residential Applications*

Examples of bundled pipes:
- *Hot with hot*
- *Cold with cold*

Optimizing Piping Design for PEX Systems

Dimensional Comparisons: Copper vs. PEX Insider diameters

Inside Diameters (typical), Comparisons with Copper			
Nominal Tubing Size	**Cu Tubing (Type L) Insider Diameter (in.)**	**PEX Tubing Insider Diameter (in.)**	**PEX Inside Diameter vs. Cu**
3/8	0.430	0.350	81%
1/2	0.545	0.475	87%
3/4	0.785	0.671	85%
1	1.025	0.862	84%
1 1/4	1.265	1.054	83%
1 1/2	1.505	1.244	83%
2	1.985	1.629	82%

Optimizing Piping Design for PEX Systems

Volumetric Comparisons: Copper vs. PEX *Volume = Pi x r^2 x length*

Tubing capacity (volume), Comparisons with Copper			
Nominal Tubing Size	**Copper Tubing Volume: US Gallon per 100 ft**	**PEX Tubing Volume: US Gallon per 100 ft**	**PEX Volume vs. Cu**
3/8	0.754	0.500	66%
1/2	1.212	0.921	76%
3/4	2.514	1.837	73%
1	4.286	3.032	71%
1 1/4	6.529	4.532	69%
1 1/2	9.241	6.314	68%
2	16.076	10.827	67%

PEX tubing has less volume than copper

Example: 10 ft of ¾ tubing:

- ¾ PEX has 27% less water
- 0.2514 (Cu) x 0.1837 (PEX) Gallons
- Savings = 0.07 gallons (9 fluid ounces) each time 10 ft pipe length is flushed

PEX plumbing systems can help to reduce wait time for hot water and water waste

Optimizing Piping Design for PEX Systems

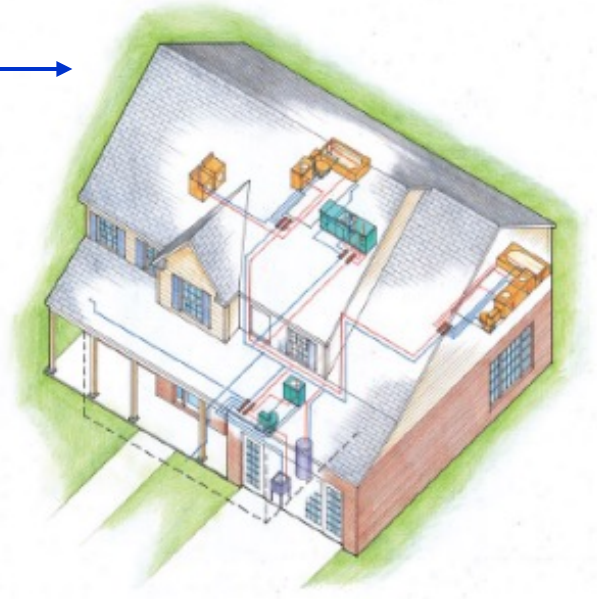
The next slides show how the DESIGN GUIDE compares three layout options for four types of residences, both graphically and quantitatively:

i. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths

ii. Ranch: 1,300 square feet, one story, 2 full baths

iii. Townhouse: 1,000 square, three levels, 1 full bath, 1 half bath

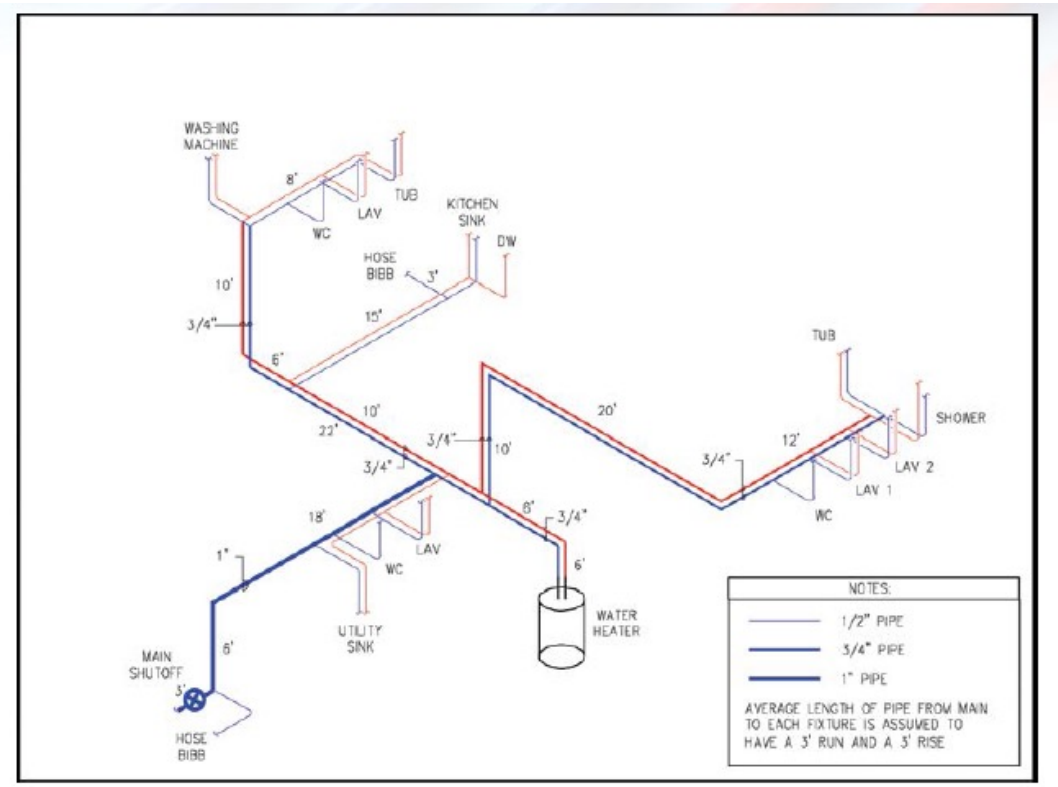
iv. Condo: 1,200 square feet, one level, 2 full baths



Optimizing Piping Design for PEX Systems

i. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths

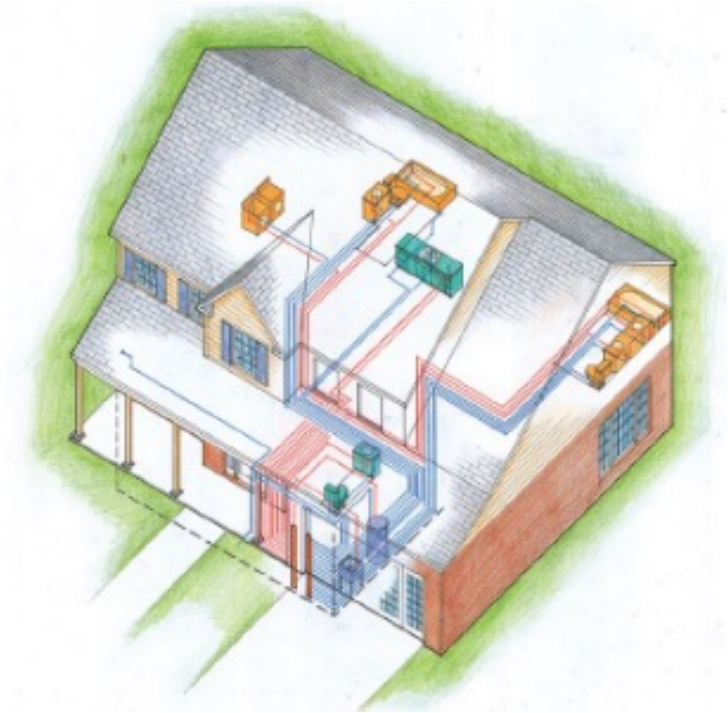
- Trunk and Branch Design

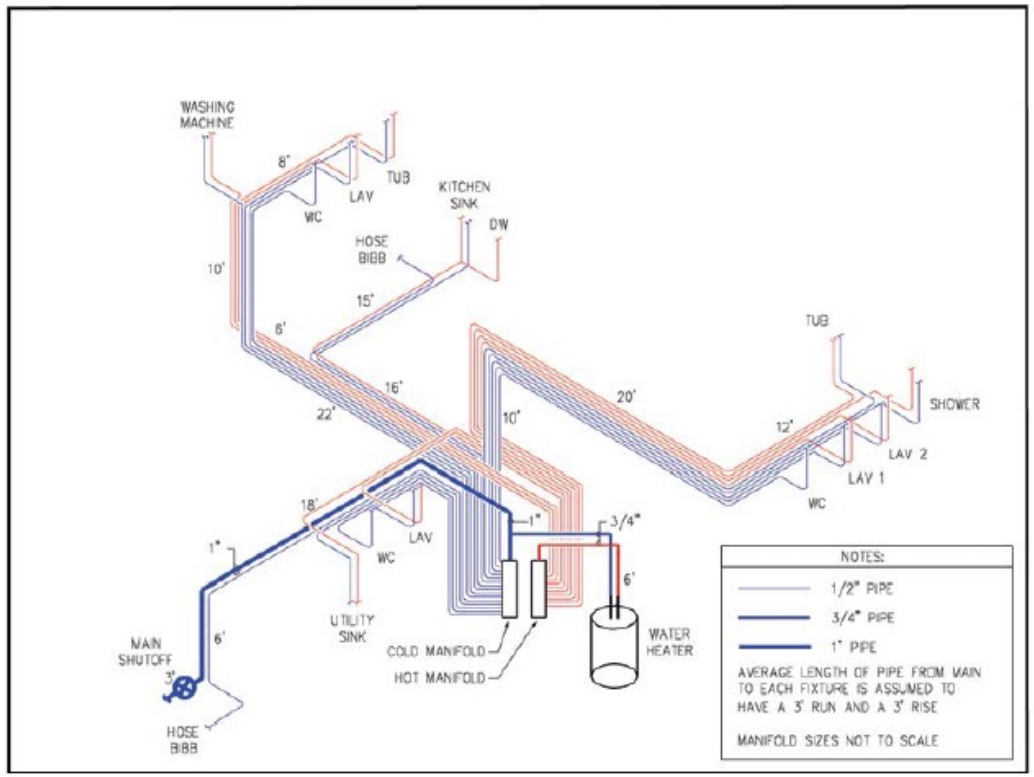


Optimizing Piping Design for PEX Systems

i. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths

- Parallel Design (home run)

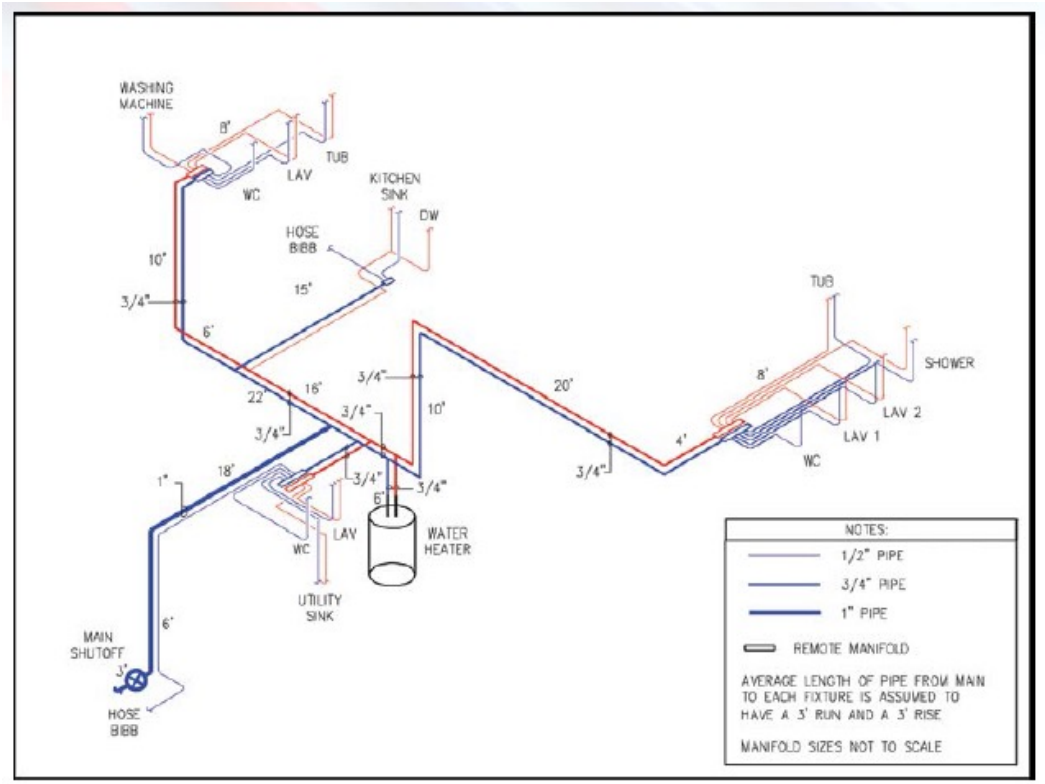




Optimizing Piping Design for PEX Systems

i. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths

- Zoned Design (remote manifolds)



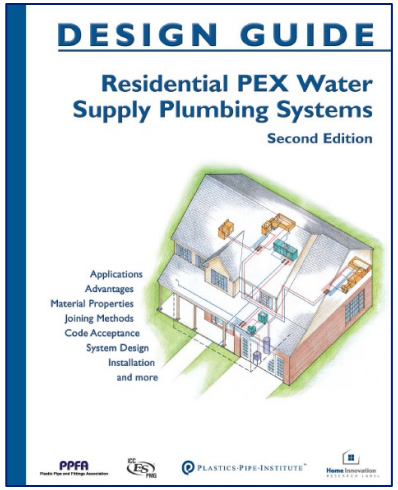
Optimizing Piping Design for PEX Systems

i. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths

- Material Summary in **Table 7.4**

Table 7.4 – Material Summary for the Colonial House

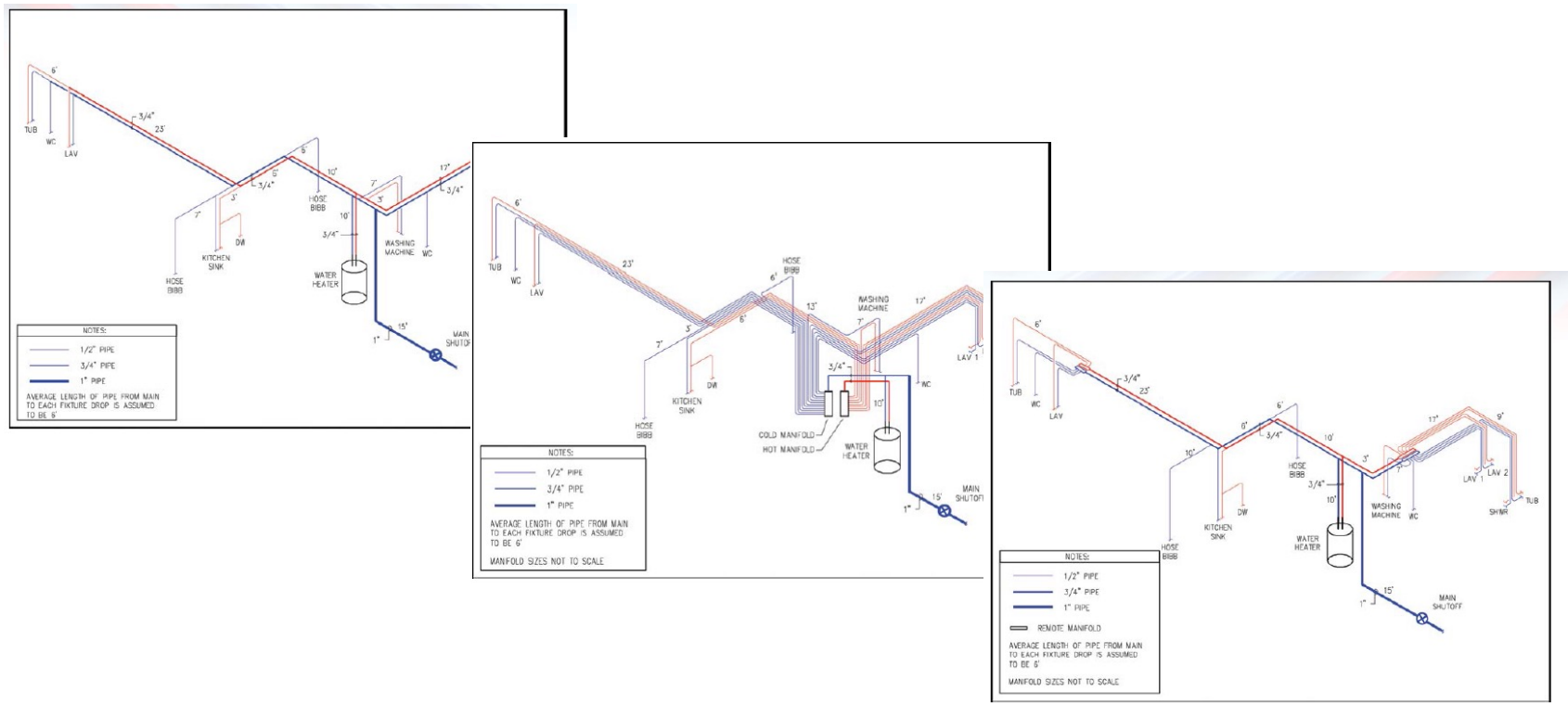
System	Length of Cold Pipe			Length of Hot Pipe			Fittings		Manifolds/ Multi-port Tees		Joints	
	1"	3/4"	1/2"	1"	3/4"	1/2"	Tees	Elbows	Main	Remote	Fixtures	Piping
Trunk and Branch	27'	80'	110'	0'	80'	98'	25	10	0	0	26	97
Parallel	33'	12'	602'	0'	12'	428'	2	7	2	0	26	49
Zone	27'	93'	152'	0'	93'	107'	8	13	0	7	26	83



Optimizing Piping Design for PEX Systems

ii. Ranch: 1,300 square feet, one story, 2 full baths

- Three designs were compared



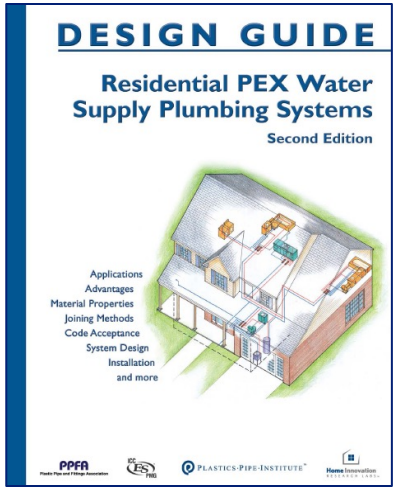
Optimizing Piping Design for PEX Systems

ii. Ranch: 1,300 square feet, one story, 2 full baths

- Material Summary in **Table 7.6**

Table 7.6 – Material Summary for the Ranch House

System	Length of Cold Pipe			Length of Hot Pipe			Fittings		Manifolds/ Multi-port Tees		Joints	
	1"	3/4"	1/2"	1"	3/4"	1/2"	Tees	Elbows	Main	Remote	Fixtures	Piping
Trunk and Branch	25'	75'	112'	0'	72'	81'	20	5	0	0	21	71
Parallel	25'	10'	413'	0'	10'	294'	2	5	2	0	21	39
Zone	25'	59'	196'	0'	59'	159'	8	4	0	4	21	53



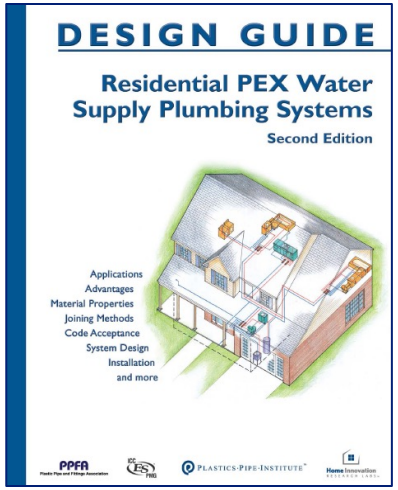
Optimizing Piping Design for PEX Systems

iii. Townhouse: 1,000 square, three levels, 1 full bath, 1 half bath

- Material Summary in **Table 7.8**

Table 7.8 – Material Summary for the Townhouse

System	Length of Cold Pipe			Length of Hot Pipe			Fittings		Manifolds/ Multi-port Tees		Joints	
	1"	3/4"	1/2"	1"	3/4"	1/2"	Tees	Elbows	Main	Remote	Fixtures	Piping
Trunk and Branch	0'	66'	86'	0'	30'	44'	14	8	0	0	15	59
Parallel	0'	42'	247'	0'	11'	138'	2	8	2	0	15	39
Zone	0'	67'	100'	0'	30'	44'	5	7	0	2	15	42



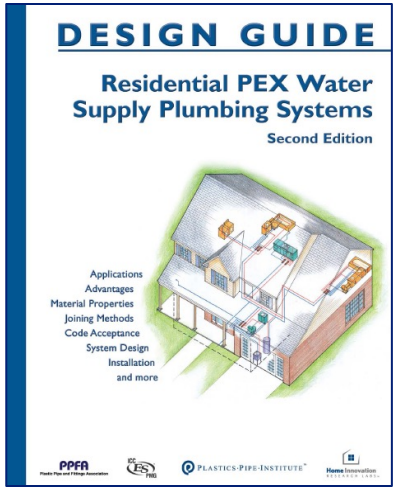
Optimizing Piping Design for PEX Systems

iv. Condo: 1,200 square feet, one level, 2 full baths

- Material Summary in **Table 7.10**

Table 7.10 – Material Summary for the Condominium

System	Length of Cold Pipe			Length of Hot Pipe			Fittings		Manifolds/ Multi-port Tees		Joints	
	1"	3/4"	1/2"	1"	3/4"	1/2"	Tees	Elbows	Main	Remote	Fixtures	Piping
Trunk and Branch	0'	45'	120'	0'	45'	104'	17	0	0	0	19	53
Parallel	0'	10'	295'	0'	10'	242'	1	2	2	0	19	29
Zone	0'	35'	132'	0'	35'	115'	5	0	0	4	19	37



PEX Plumbing System Performance Testing

Measuring System Performance

- NAHB Research Center (now *Home Innovations Research Lab/HIRL*) simulated a full house plumbing system in their plumbing lab,
- Performance results were measured
- Same simulated house was plumbed three ways:
  - Trunk & Branch
  - Parallel
  - Zoned

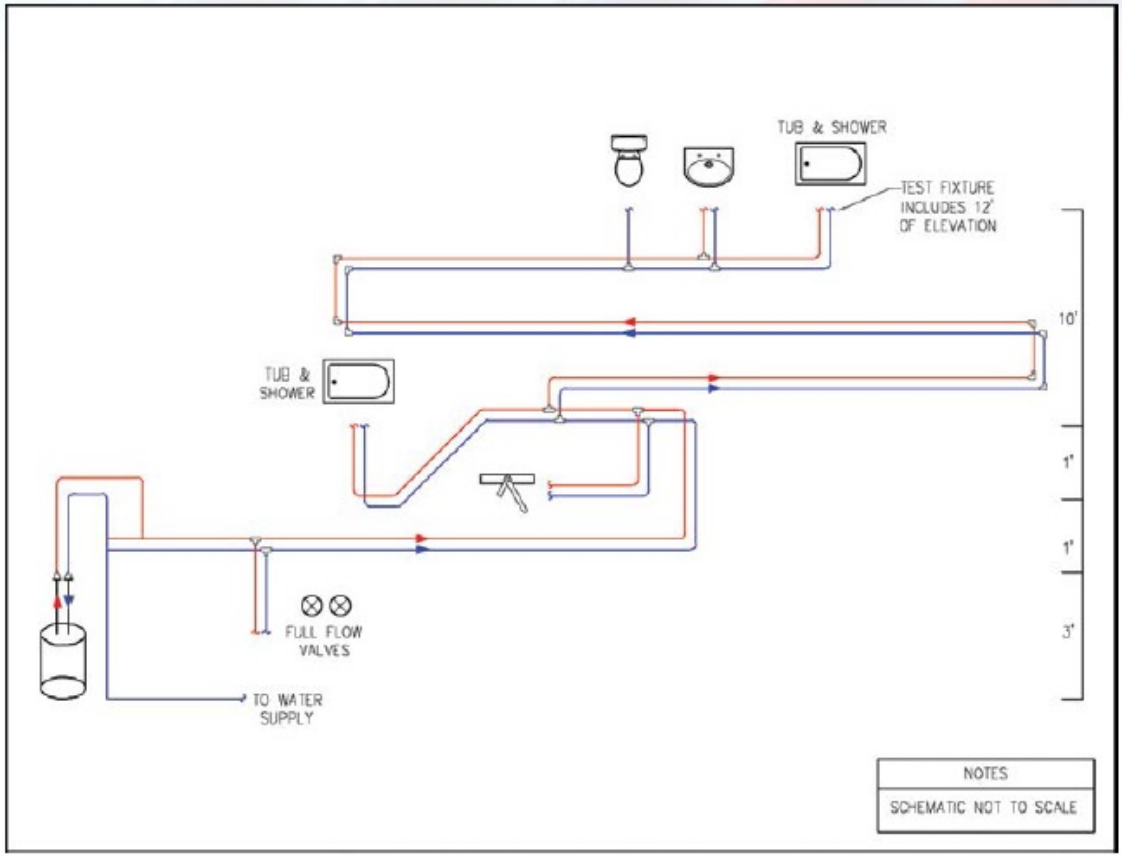


Figure 8.1 – Fixture Layout for Laboratory Testing

PEX Plumbing System Performance Testing

Measuring System Performance

- Simulated house built in plumbing lab, results measured
- Same simulated house, plumbed three ways:
  - Trunk & Branch
  - Parallel
  - Zoned

The following data is based on that lab testing:

- Pressure Loss
- Flow Rate/Sizing
- Surge Pressure

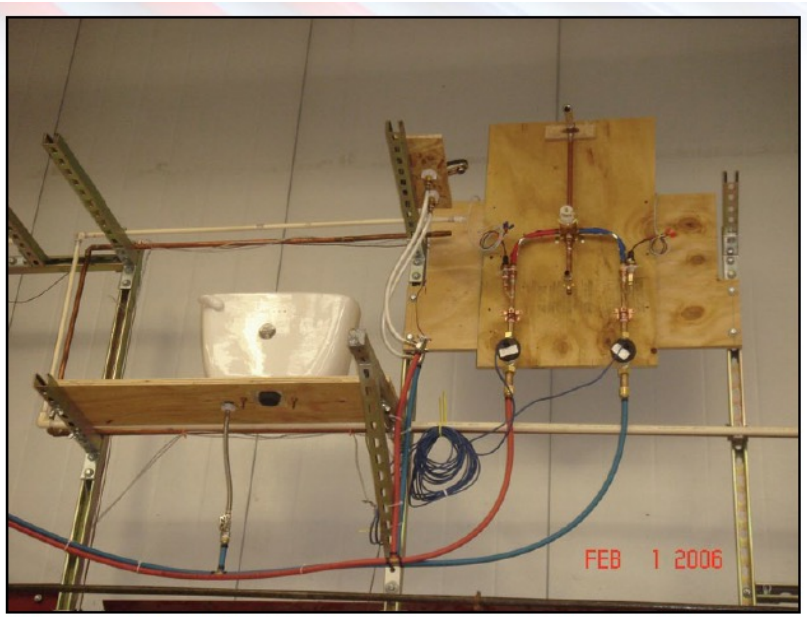


Figure 8.3 – The Test Fixture (Shower) with Flow and Pressure Sensors Installed

Figure 8.2 – Laboratory Test Set-up with Five Outlets, Hot Water Tank, and T&B System

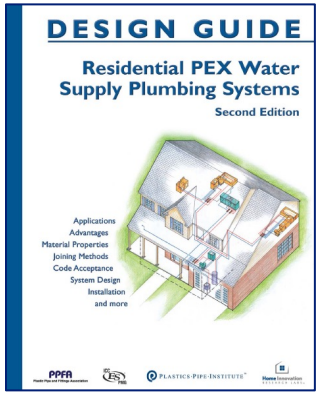
PEX Plumbing System Performance Testing

Pressure Loss

- See Chapter 7 “Design” (page 56)

Performance Verification Laboratory Testing

A set of laboratory tests using typical plumbing fixtures and plumbing pipe sizes, runs and fittings was performed to demonstrate the flow characteristics of the three different PEX systems. Results of this testing indicate that all three systems will supply adequate pressure and water delivery to a remote shower fixture located 100 feet from the base riser with an elevation head of 15 feet. Base source pressures of 40, 60, and 80 psi were used in each of the different system designs. Multiple tests were performed to add simultaneous flows from other fixtures including a shower, lavatory, kitchen and water closet. Test results are shown in Chapter 8.



PEX Plumbing System Performance Testing

Pressure Loss

- See Chapter 8 “Performance Data” (page 71)

- Pressure Drop to Fixtures with Simultaneous System Flows, plumbed in all three layouts

Legend:

TF = test show fixture
Lav = lavatory, both valves open
WC = water closet, tank type
Kit = Kitchen faucet
Sh2 = Second shower, full open valve

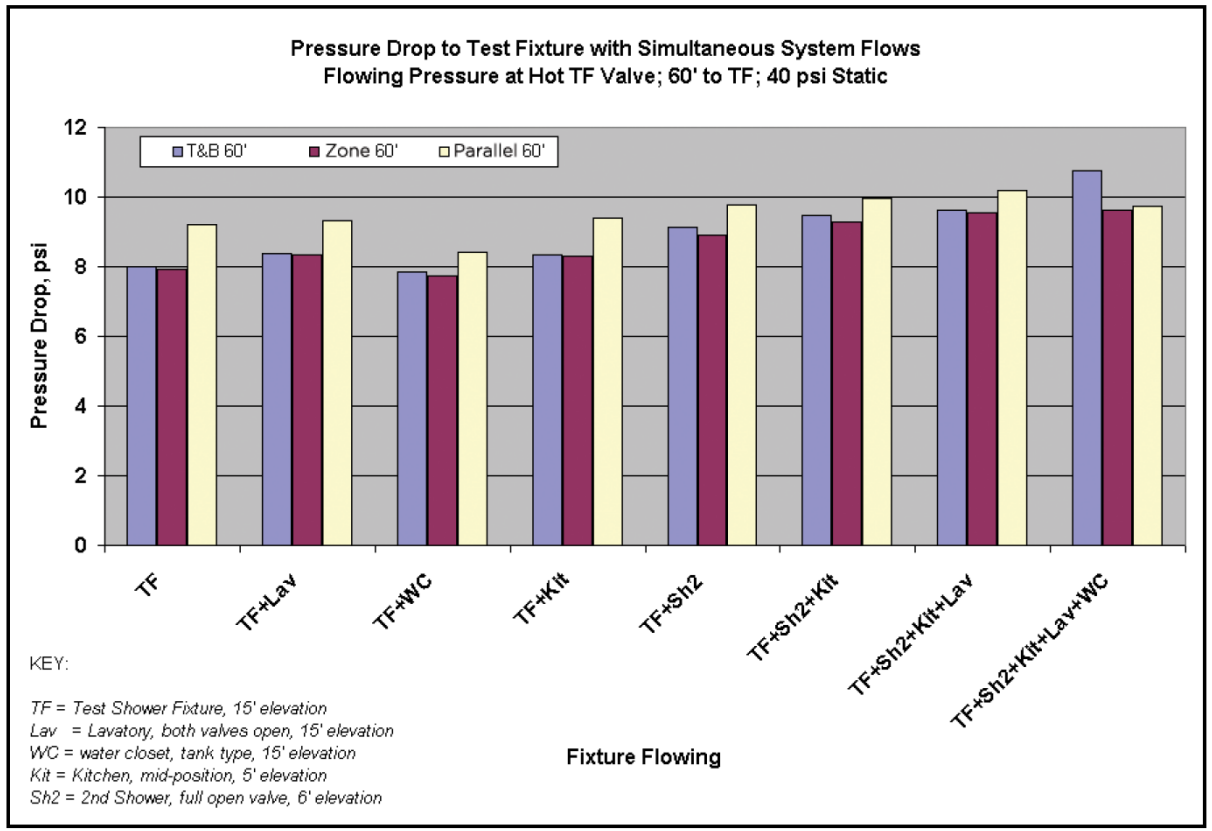


Figure 8.5 – Pressure Drop Comparison, 60’ Distance to TF

PEX Plumbing System Performance Testing

Pressure Loss

- See Chapter 8 “Performance Data” (page 71)

- Pressure Drop to Fixtures with Simultaneous System Flows:

Results:

- Pressure drop for one layout vs. another varied depending on the simultaneity of flows
- Pressure drop consistently below 10 psi with one exception (T&B, 5 demands at once)
- Parallel had the most consistent pressure drop

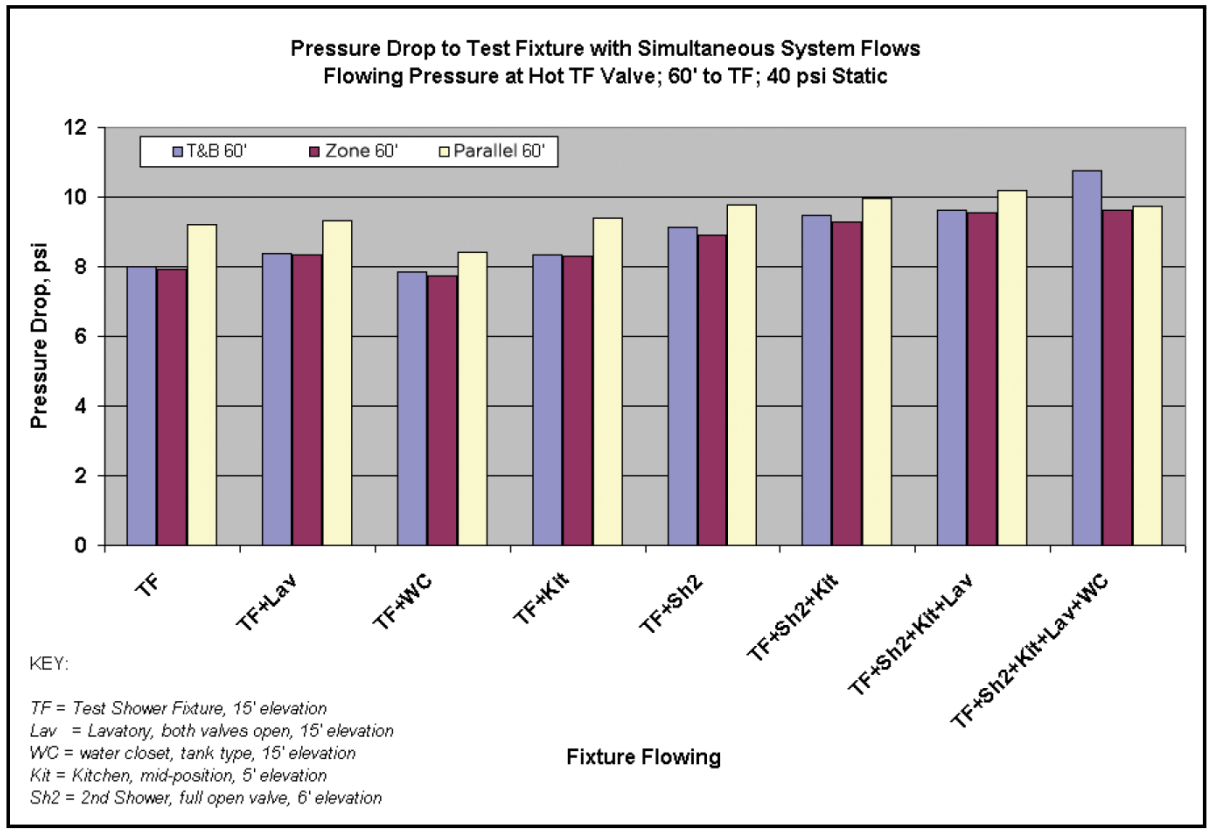


Figure 8.5 – Pressure Drop Comparison, 60’ Distance to TF

Testing performed at *Home Innovations*

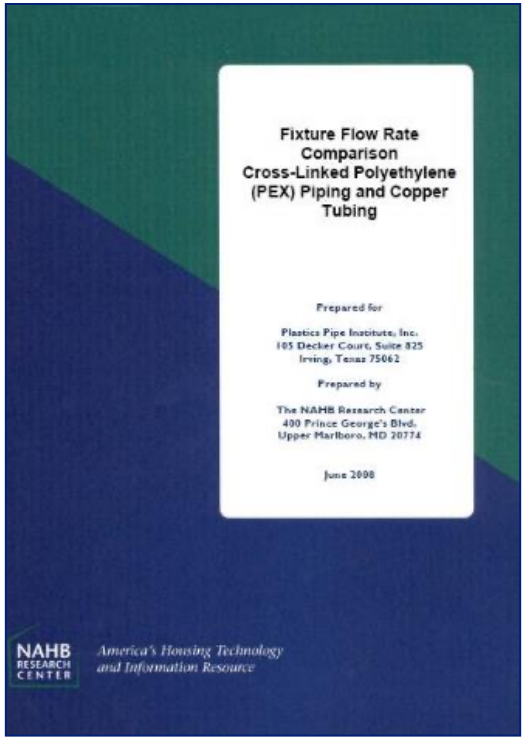
PEX Plumbing System Performance

Flow Rate & Tubing Sizing

- The ID of PEX tubing is *slightly* less than copper
  - Ex: ½ inch nominal PEX tubing has **96%** of the copper ID (0.480” vs. 0.500”)
- Thanks to its smooth wall and elimination of most elbows, codes allow for size-for-size replacement for PEX

See report “Fixture Flow Rate Comparison: PEX and Copper Tubing” (2008)

- PEX tubing can typically be installed in place of copper tubing on a **size-for-size** basis, because Fixtures actually control the flow!
- Many code and piping designs are oversizing pipes*
- Details in DESIGN GUIDE



**Exception: Alternate system designs may actually reduce pipe diameter requirements*

Testing performed at *Home Innovations*

PEX Plumbing System Performance

Flow Rate & Tubing Sizing

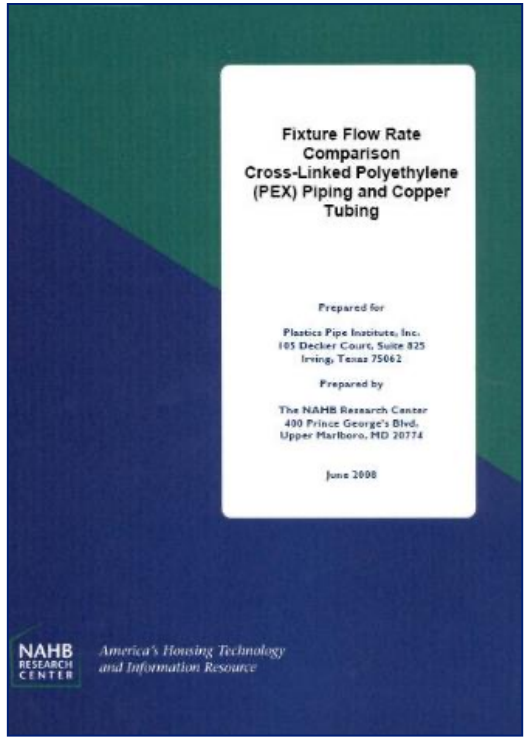
- See Chapter 8 “Performance Data” (page 75)

PEX and Copper Pipe Flow Rates

Laboratory testing was performed on identical configurations of PEX and copper trunk and branch (T&B) plumbing systems serving standard residential plumbing fixtures supplied at source pressures of 40, 60, and 80 psi, with lengths of 60 and 100-feet of pipe to the furthest fixture. The measured flow rate at each plumbing fixture was virtually identical for both piping systems, except for minor differences in the water closet fill rate.

Even though PEX tubing has a slightly smaller inside diameter than copper tubing of the same nominal dimension, both tubing systems satisfied the farthest fixture demand, even with multiple fixtures flowing. The following Table compares the two piping systems with a minimum source pressure of 40 psi, the most demanding scenario in the test Results of tests using higher pressures were consistent.

Results of this testing demonstrate that in a typical single-family residential plumbing system, both PEX and copper piping systems will deliver sufficient volumetric flow rates and pressures to the plumbing fixtures when using the same nominal size tubing.



PEX Plumbing System Performance

Surge Pressure/Water hammer

See NAHB-RC report "Surge Pressure in Plumbing Pipe Materials" (2009)

- Surge pressures in response to **fast-closing valves** were measured for Copper, CPVC, and PEX

- Hot and Cold water

- Various flow rates

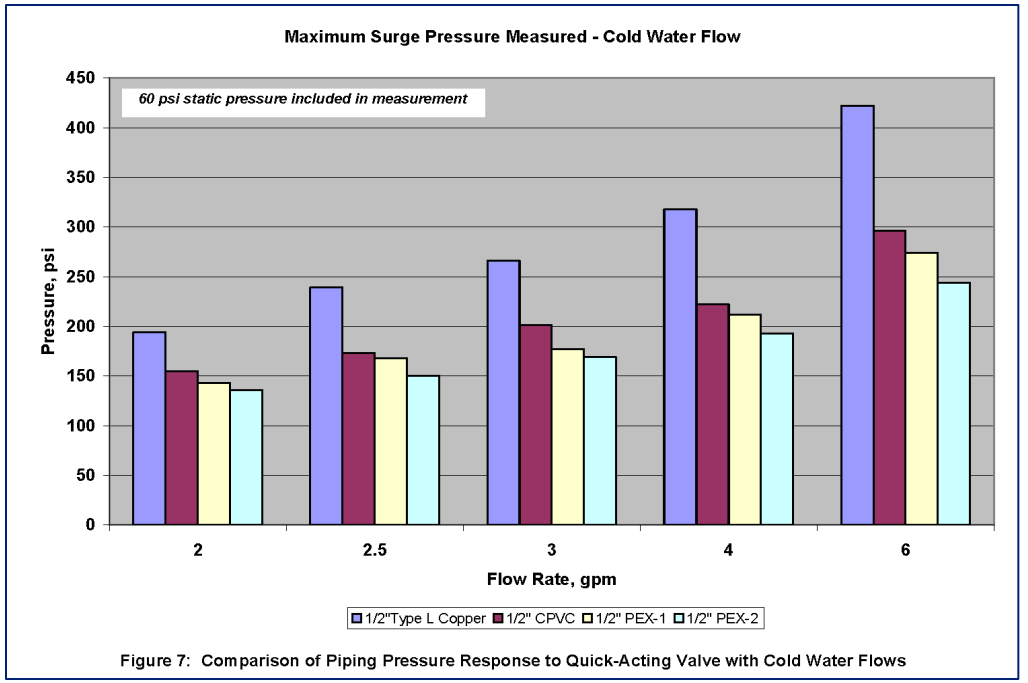
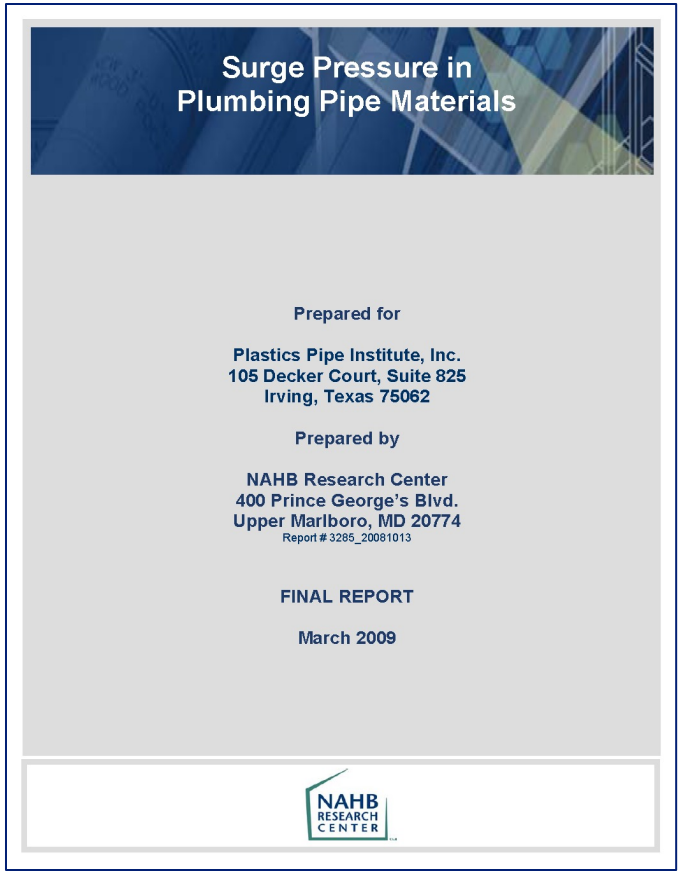


Figure 7: Comparison of Piping Pressure Response to Quick-Acting Valve with Cold Water Flows



Testing performed at *Home Innovations*

PEX Plumbing System Performance

Surge Pressure/Water hammer

See NAHB-RC report "Surge Pressure in Plumbing Pipe Materials" (2009)

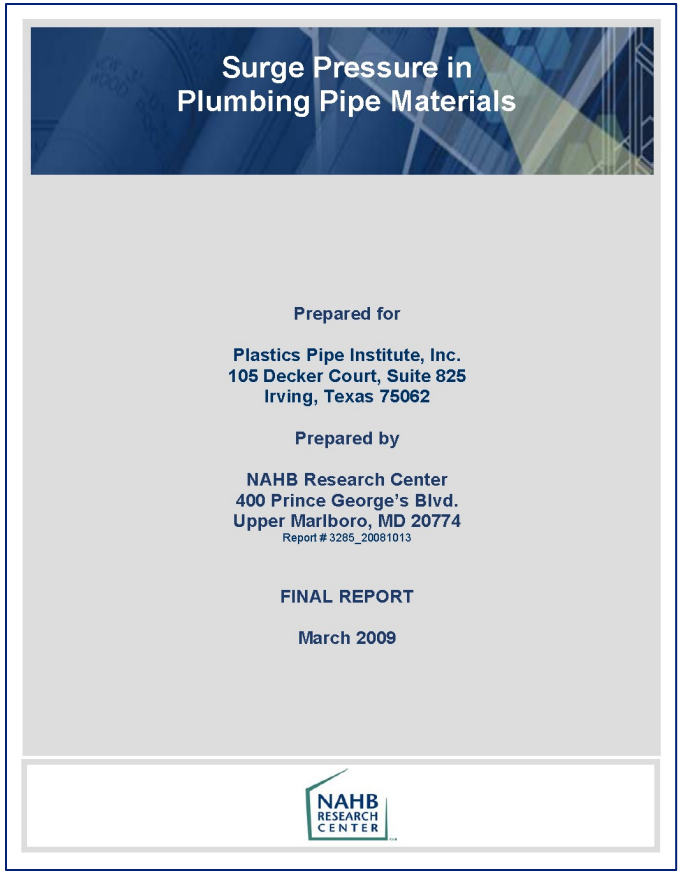
- PEX tubing absorbed surge pressures and reduced peak pressures by **30% (cold)** to **40% (hot)** as compared with copper

Table 3: Peak Pressure Comparison – 2.5 GPM Cold Water Flow, 54°F Water (See Figure 4b)

	Pipe Peak 1 (psig)	% Difference
½" Type L Copper	239	0
½" CPVC	173	28
½" PEX-1	168	30
½" PEX-2	150	37

Table 4: Peak Pressure Comparison – 2.5 GPM Hot Water Flow, 130°F Water (see Figure 5b)

	Pipe Peak 1 (psig)	% Difference
½" Type L Copper	181	0
½" CPVC	149	18
½" PEX-1	113	38
½" PEX-2	109	40



Testing performed at *Home Innovations*

PEX Plumbing System Performance

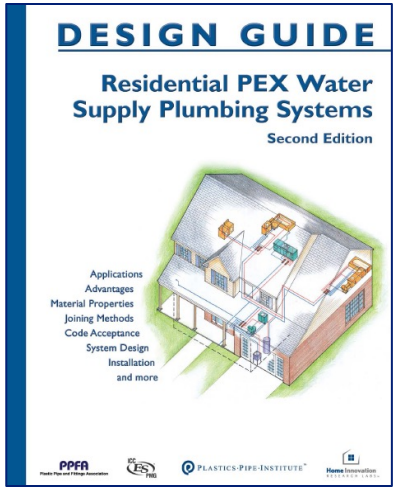
Surge Pressure/Water hammer

- See Chapter 8 “Performance Data” (page 74)

PEX Pipe Response to Surge Pressure (Water Hammer)

A benefit of flexible piping systems is the ability to mitigate or absorb pressure surges in plumbing systems, such as what can occur when flowing water is stopped by a fast-acting valve. To quantify this benefit, a test apparatus was constructed and operated such that pressurized flowing water in a 20-foot straight length of pipe was abruptly interrupted by a fast-acting solenoid valve. Several rigid and flexible, metal and plastic, nominal one-half inch diameter pipe materials were subjected to a test regime that included flow rates as high as 6 gallons per minute, using cold and hot water supplies.

For example, test results using nominal half-inch pipes with “cold” water at a typical flow rate of 2.5 GPM showed that peak pressures were reduced by up to 37% for PEX pipes as compared with copper pipes. Test results using nominal half-inch pipes with “hot” water at a typical flow rate of 2.5 GPM showed that peak pressures were reduced by up to 33% for PEX pipes as compared with copper pipes. Results are shown in Tables 8.7 and 8.8. At higher flow rates, the percentage of the surge pressure reduction increases.



PEX Plumbing System Performance Testing

Wait Time for Hot Water, from 53°F to 110°F: Figure 8.6

- Piping distance of 60 ft.
- T&B: 53 sec
- Parallel: 37 sec
- Zoned: 53 sec

- Parallel is faster by **30%**

- Piping distance of 100 ft.
- T&B: 92 sec
- Parallel: 56 sec
- Zoned: 89 sec

- Parallel is faster by **38%**

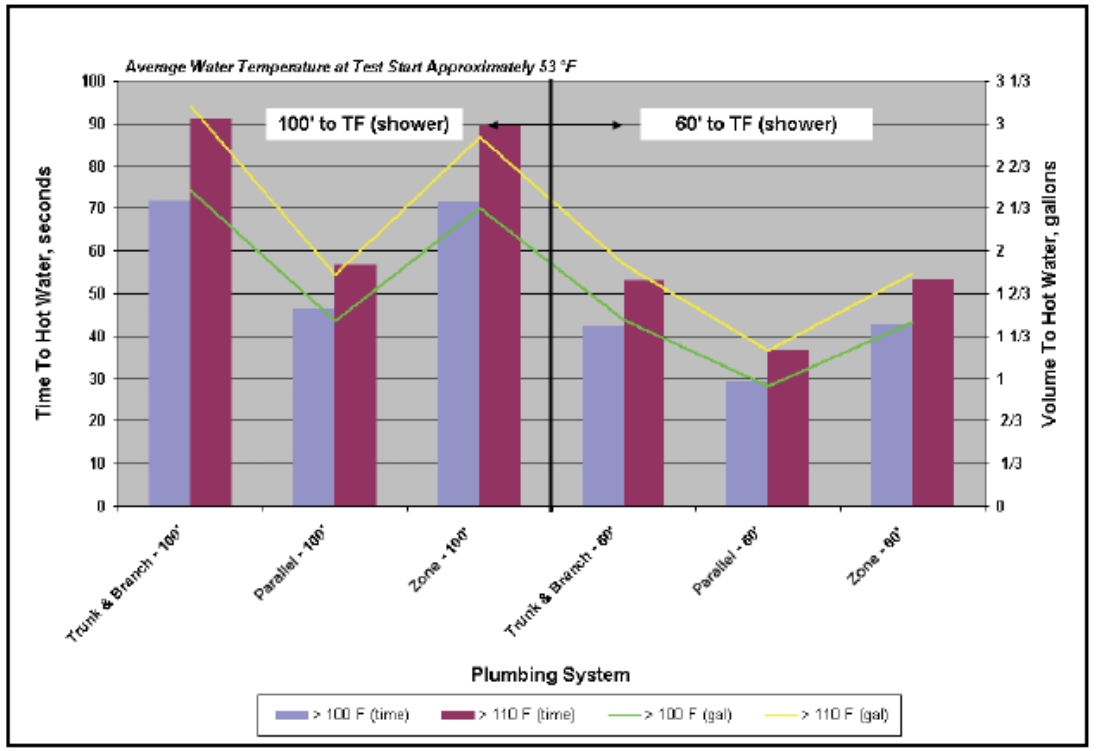


Figure 8.6 – Comparison of Hot Water Delivery Time

- Smaller diameter pipes, such as those used in **Parallel** layouts, flush faster
- Faster delivery of hot water (happy people)
- Less water waste

- **Zoned** plumbing layout performed very similar to **T&B**

Testing performed at *Home Innovations*

PEX Plumbing System Performance Testing

Summary of PEX Plumbing Performance Testing

- **T&B** will supply one fixture at a higher pressure, but **Parallel** will supply a more stable pressure to each fixture when operating simultaneous fixtures

- **Parallel** layout delivers hot water faster, especially when starting from cold

- **T&B** and **Zoned** systems deliver hot water faster during sequential flows

- **All three designs** delivered sufficient flow and pressure even with base pressure of just 40 psi, and a length to farthest outlet of 100 ft. No indication that pipes should be upsized.

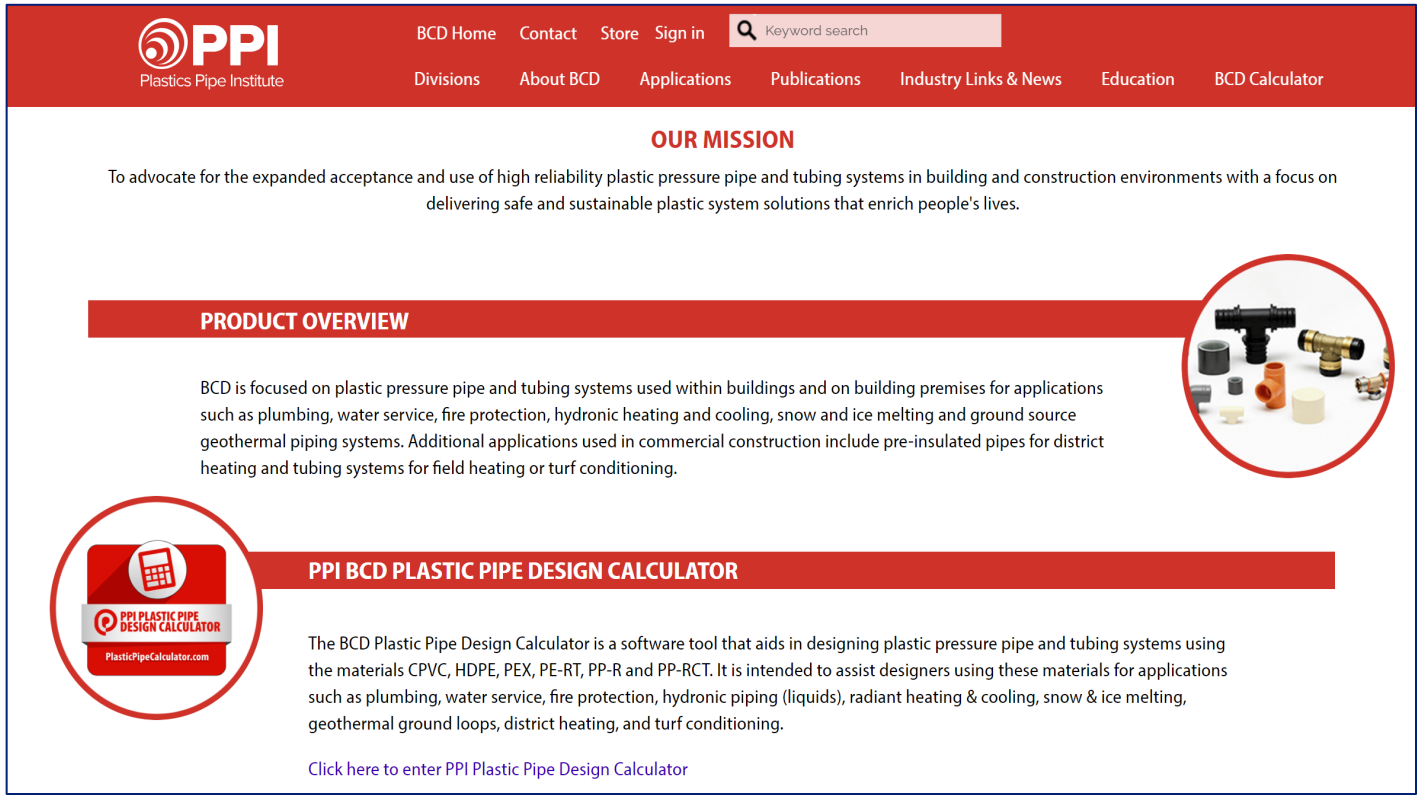
DESIGN GUIDE includes the reported test data

6. Accessing Industry Resources

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

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

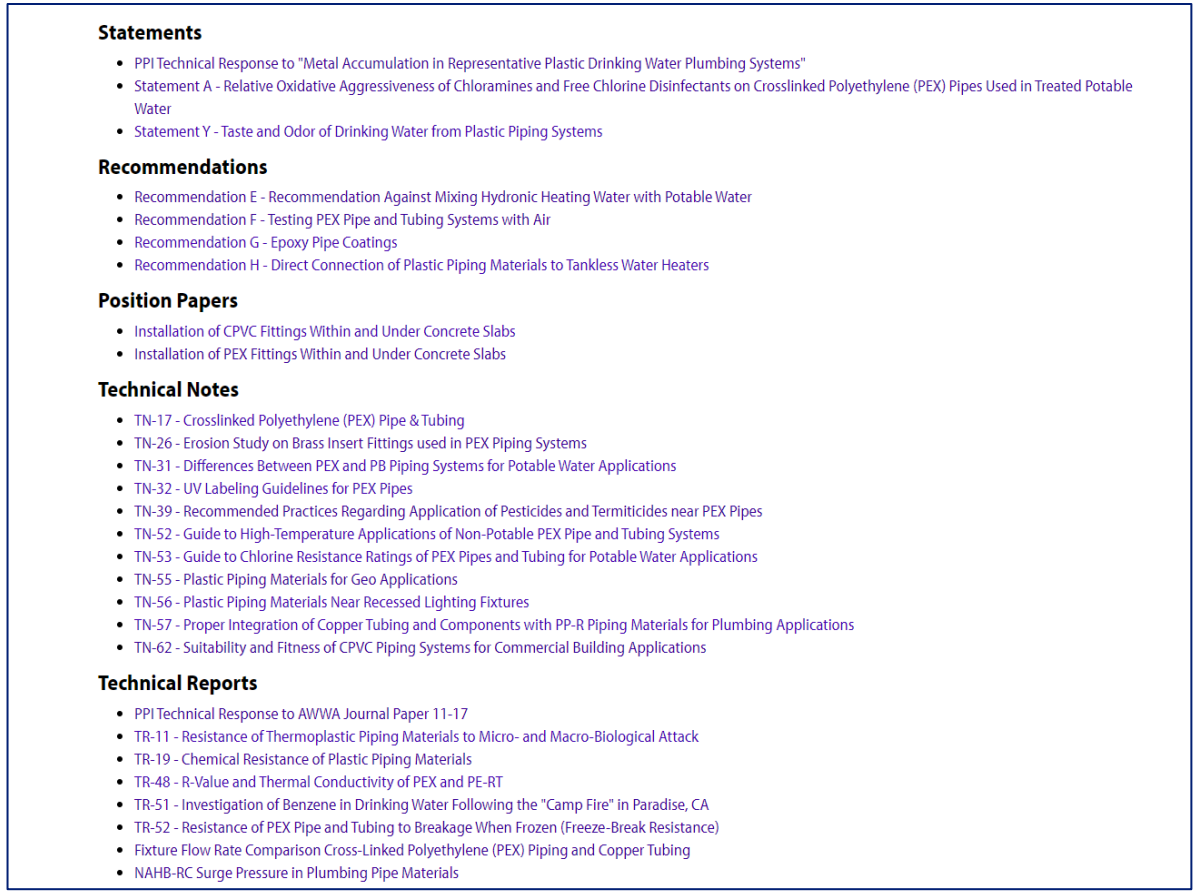
- www.plasticpipe.org/buildingconstruction



Accessing Industry Resources

PPI's Building & Construction Division (BCD)

- **Technical Publications**
- Pipe Material webpages
- Plastic Pipe Design Calculator
- Presentations and recorded webinars
- Educational videos
- Case studies



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

Accessing Industry Resources

PPI's Building & Construction Division (BCD)

- Technical Publications
- **Pipe Material webpages**
- Plastic Pipe Design Calculator
- Presentations and recorded webinars
- Educational videos
- Case studies

PPI CROSSLINKED POLYETHYLENE (PEX)

PEX tubing comes in nominal sizes ranging from 1/4 to 3 in. copper tube size (CTS), and pipe sizes in both inch and metric sizes. PEX tubing is SDR9 with standard hydrostatic pressure ratings of 160 psi at 73°F (1105 kPa at 23°C) and 100 psi at 180°F (690 kPa at 82°C). Consult the specific PEX manufacturer's literature and listings for appropriate pressure ratings. PEX tubing and pipe are sold in coils and straight lengths.

Definition

PEX is a polyethylene material which has undergone a change in molecular structure using a chemical or a physical process whereby the polymer chains are chemically linked. Crosslinking of polyethylene into PEX for pipes results in improved properties such as elevated temperature strength and performance, chemical resistance and resistance to slow crack growth.

PPI Members with PEX Systems

- Aurey
- Bow
- CB Supplies
- Golan
- Heatlink Group Inc.
- Interplast
- IPEX
- Legend
- Mr. PEX
- Mercury
- Reliance Worldwide
- REHAU
- Rifeng
- Uponor
- Viega LLC
- Watts
- Zurn PEX

Most Relevant PEX Standards

- ASTM F876 - Standard Specification for Crosslinked Polyethylene (PEX) Tubing
- ASTM F877 - Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems
- ASTM F2023 - Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Chlorinated Hot Water
- ASTM F2657 - Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing
- ASTM F2788 - Standard Specification for Metric and Inch-sized Crosslinked Polyethylene (PEX) Pipe
- ASTM F2829 - Standard Specification for Metric- and Inch-Sized Fittings for Crosslinked Polyethylene (PEX) Pipe
- ASTM F2929 - Standard Specification for Crosslinked Polyethylene (PEX) Tubing of 0.070 in. Wall and Fittings for Radiant Heating Systems up to 75 psig
- ASTM F3253 - Standard Specification for Crosslinked Polyethylene (PEX) Tubing with Oxygen Barrier for Hot- and Cold-Water Hydronic Distribution Systems
- AWWA C904 - Cross-Linked Polyethylene (PEX) Pressure Pipe, 1/2 inch (12 mm) Through 3 inch (76 mm), for Water Service
- CSA B137.5 - Crosslinked Polyethylene Tubing Systems for Pressure Applications

Accessing Industry Resources

PPI's Building & Construction Division (BCD)

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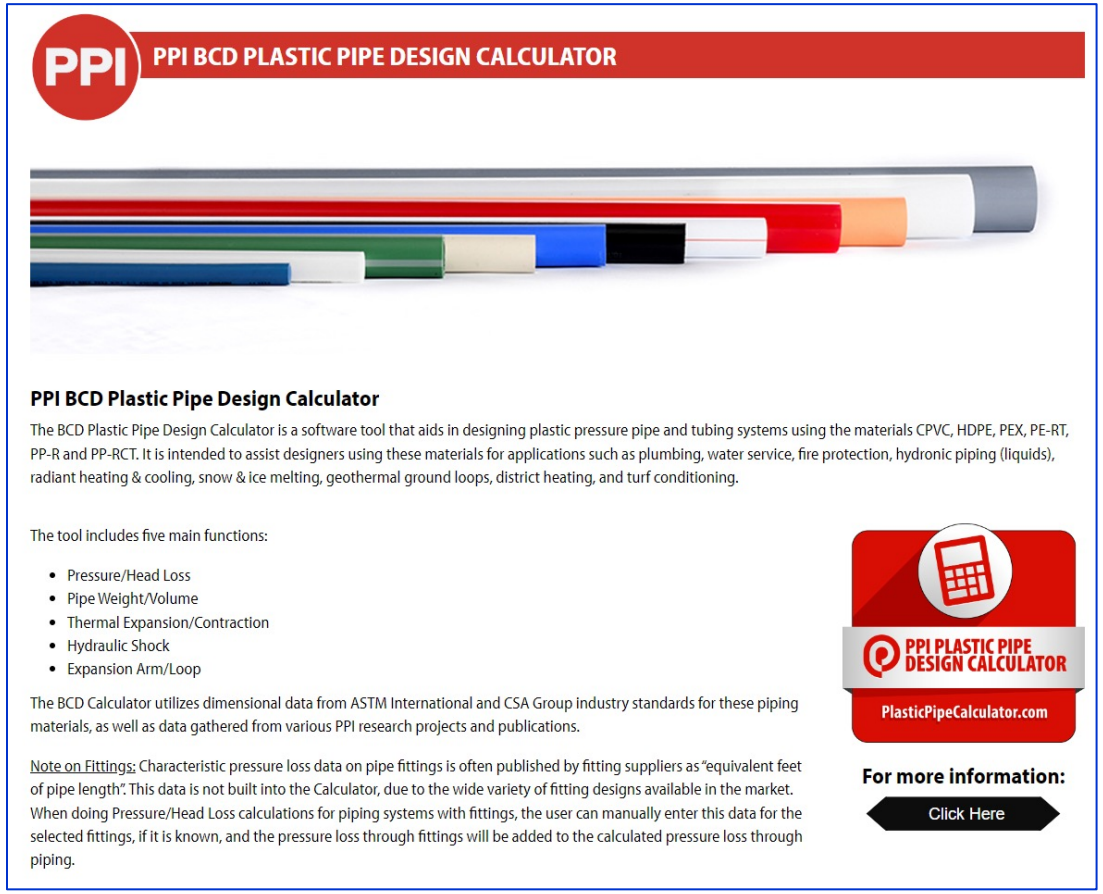

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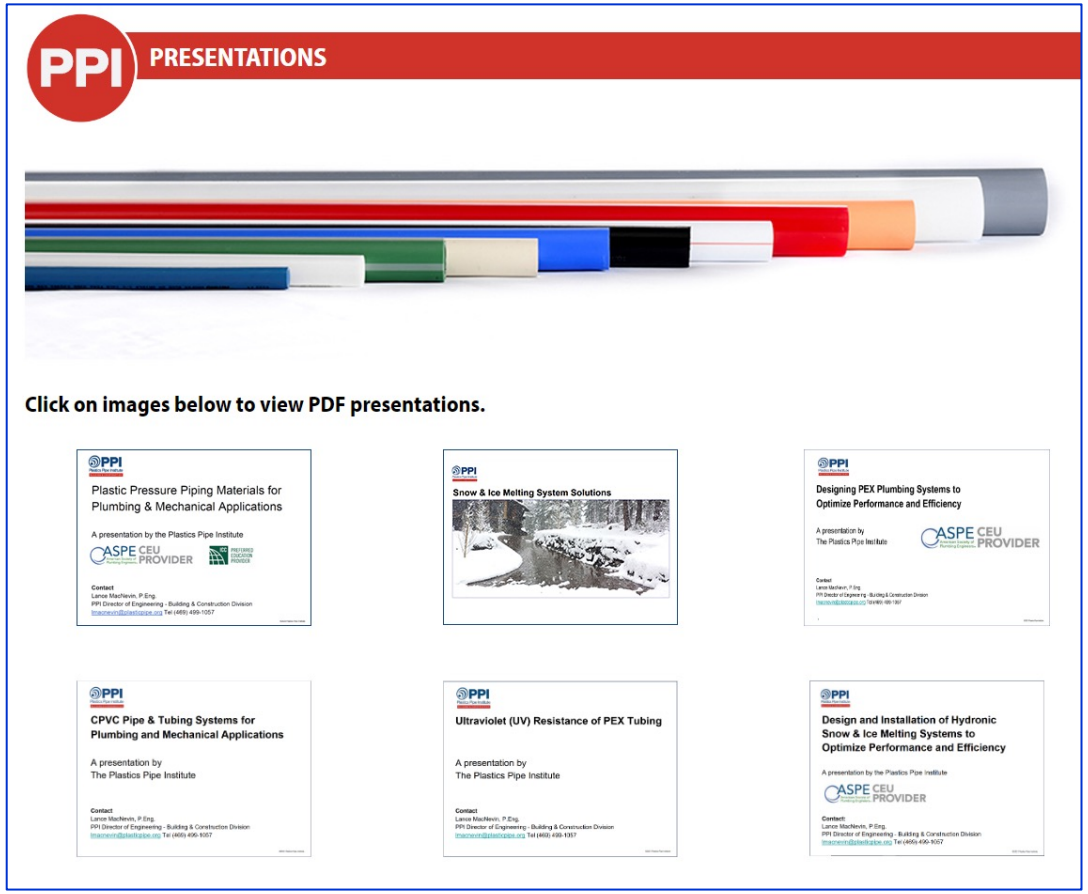

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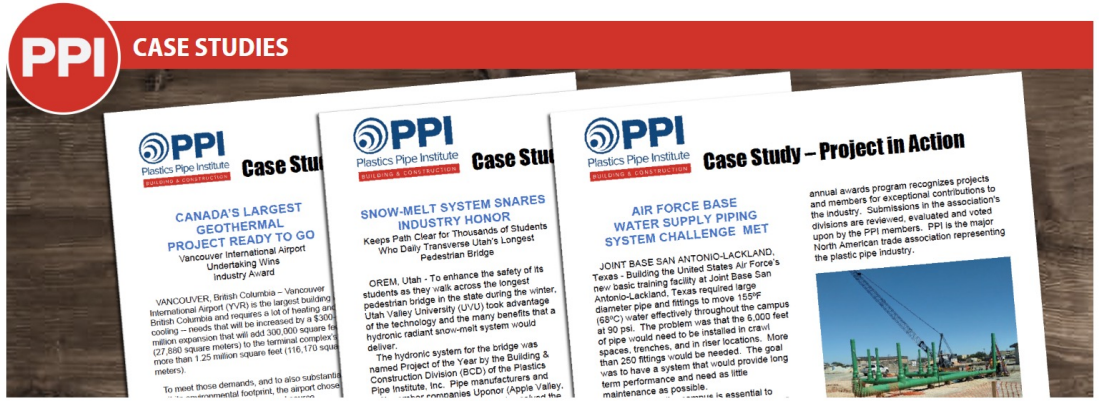


Plumbing

- Riyadh, Saudi Arabia: King Abdullah Financial District (KAFD) Development Chooses Plastic Pipes for Heating/Plumbing Needs
- Boston-Area "Quiet House" Offers Unique Selection of Noise-Reducing Features
- Prestigious Westgate Building in Austin Save Over $1 Million in Repiping Expenses as Result of Innovative Plumbing Design and Conversion to Flowguard Gold CPVC
- Psychiatric Hospital Preserves Patient Comfort and Safety While Replacing Failed Plumbing in Main Care Facility
- Dallas-Based G-H Plumbing Calculates Substantial Savings with Installation of Flowguard Gold CPVC Pipe and Fittings
- Award-Winning Custom Builder Solves Aggressive Water and Noise Problems with High-Performance CPVC Plumbing SystemAward Winning Building
- Homeowners, Frustrated by Pinhole Leaks in Copper Plumbing, Find Relief

Geothermal

- Canada's Largest Geothermal Project Ready to Go

Hydronic Piping

- Mechanical Joining System Benefits New Napa Valley Resort
- These Pipes Make HVAC Systems Run More Efficiently

Turf Conditioning

- Cleveland Browns Stadium - Turf Cooling System

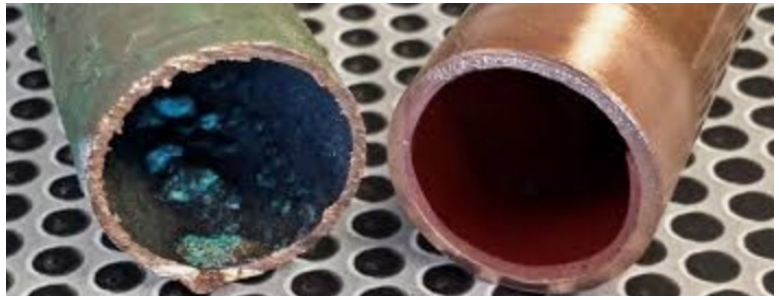
Snow & Ice Melting

- Upscale Senior Living Demands Snow & Ice Free Streets and Sidewalks
- Ski Resort's Massive Snow Melting System Takes Industry Group's Top Honors
- Fallsview Casino Resort - Snow and Ice Melt System
- Solaris in Vail CO - Radiant Heating & Snow & Ice Melting

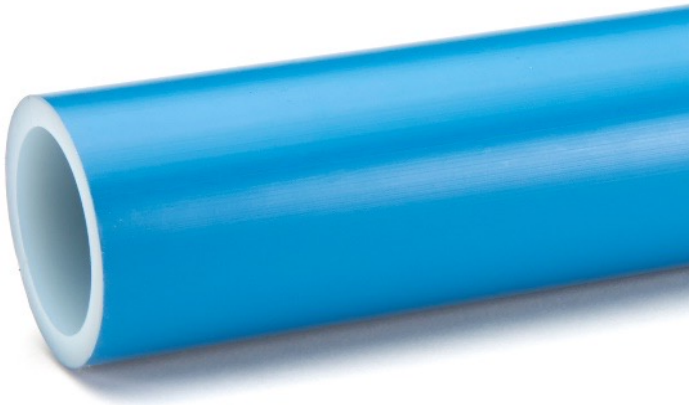
Annex 1: Sizing PEX Tubing Systems

PEX Tubing can be Sized the Same as Copper Tubing

- PEX tubing dimensions are very close to copper tubing (outside diameter is identical, wall is thicker)
- Ex: ½ inch nominal PEX tubing has **96%** of the copper ID (0.480” vs. 0.500”)
- Smooth interior surface of PEX provides superior flow through its entire life
- PEX resists scaling and deposits, no mineral build-up
- Flow calculations for PEX use **C factor** of **150**



Old and new copper tubing



Annex 1: Sizing PEX Tubing Systems

Calculating Pressure Drop

- Use **PPI Plastic Pipe Design Calculator**
- Free online tool www.plasticpipecalculator.com
- Example: **8 GPM** through 60 ft of 1 in. PEX = **2.5 psi** drop

Results		
Flow Regime:	Turbulent	
Pressure Drop:	2.5 Psi	17.6 kPa
Head Loss:	5.9 ft water	
Velocity*:	4.4 ft/s	1.3 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

Annex 2: Reasons to Select PEX Plumbing Systems

Advantages of PEX Plumbing Systems

- Safety of potable water and long-term reliability
- Resistance to scale and mineral buildup
- Smooth wall, excellent flow characteristics
- Resistance to corrosion, erosion, water disinfectants
- Quiet operation, absorbs pressure surges (water hammer)
- Flexibility to facilitate faster installations
- Potential for reduced installation costs
- Many fitting and joining options; no flame risk
- Better heat retention, less condensation
- Freeze-break resistance (see PPI TR-52)
- Water conservation is assisted with reduced heat loss
- Proven long life, rigorous certifications, highly tested

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Annex 2: Reasons to Select PEX Plumbing Systems

PEX Plumbing Systems are Sustainable

- No mining operations for the ore
- Lower cost to the environment for production
- Reduced water consumption for manufacturing
- Low energy cost to produce PEX as compared with copper
- Smooth wall, excellent flow characteristics reduce pumping costs
- Proven long life and durability provides value
- Light weight of PEX reduces transportation costs
- Flexibility can dampen water hammer, reducing pressure spikes
- PEX pipe does not add minerals to drinking water
- PEX systems protect health and safety

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Course Learning Objectives

By this time, participants should be able to:

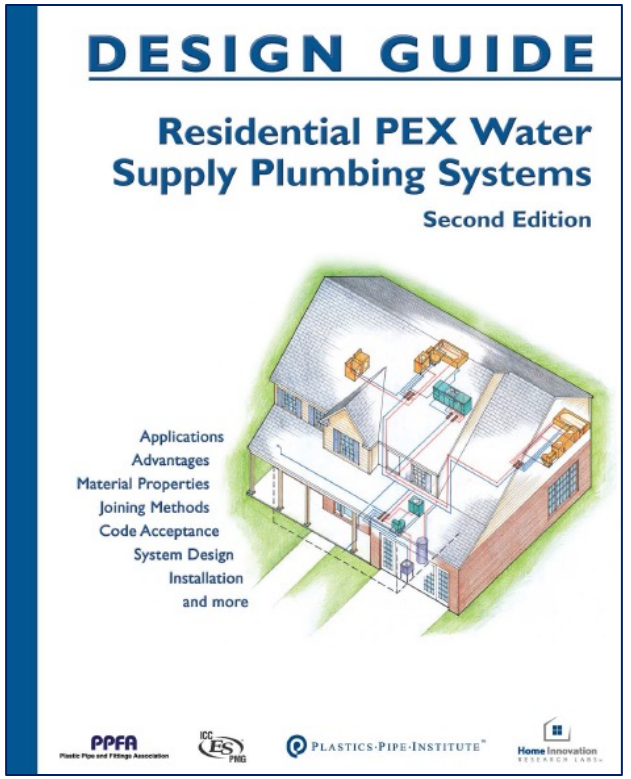
1. Explain how the properties of PEX tubing and fittings can protect health, safety, and welfare
2. Introduce several options of PEX fitting system designs
3. Discuss PEX system standards and code compliance
4. Describe three distinct plumbing layouts using PEX systems and compare the advantages and disadvantages of each
5. Apply test data from published research to demonstrate how design of the plumbing layout can improve system performance (e.g., flow) and provide faster delivery of hot-water with reduced water waste
6. Show how to access industry resources for additional material, design, and installation information

Conclusion

By applying proper design techniques, PEX plumbing systems can deliver the optimum combination of performance, efficiency, cost and longevity

Additional information about design and installation of PEX plumbing systems is found within the DESIGN GUIDE, so please refer to this document for details not covered in today's presentation at www.plasticpipe.org

Direct link to DESIGN GUIDE: PEX Design Guide (plasticpipe.org)



Designing PEX Plumbing Systems to Optimize Performance and Efficiency

Thank you!

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