

Designing PEX Plumbing Systems to Optimize Performance and Efficiency

A presentation by The Plastics Pipe Institute



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The Plastics Pipe Institute

PPI Represents the Plastic Pipe Industry www.plasticpipe.org

- 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

- Improving quality of life today, and for generations to come, by championing the advancement, acceptance, and use of sustainable and resilient plastic pipe systems

PPI Members

- ~200 member firms involved with the North American plastic pipe industry

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, PEX, PEX/AL/PEX, PE-RT, PE-RT/AL/PE-RT, and PP (PP-R & PP-RCT)

BCD homepage: plasticpipe.org/BuildingConstruction



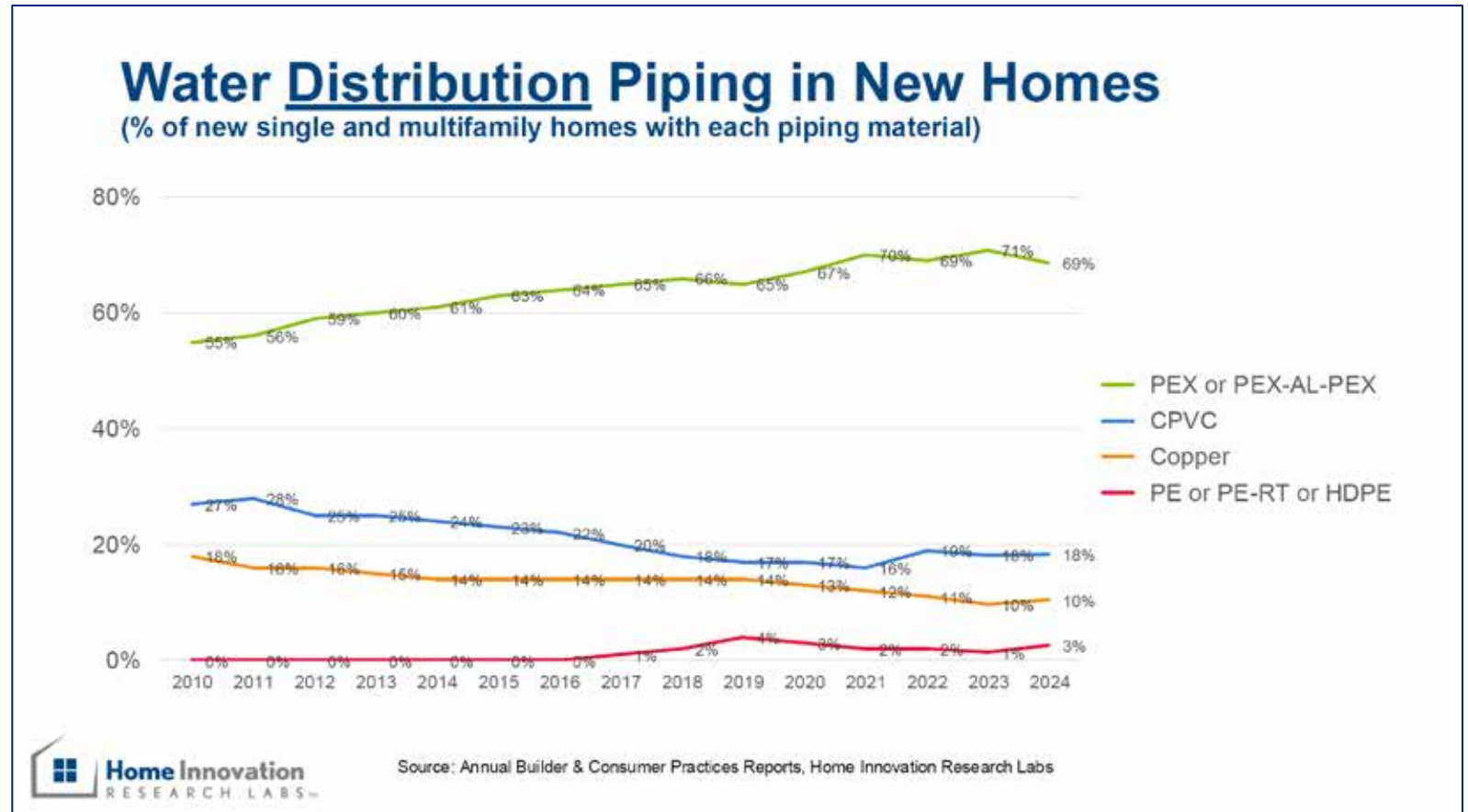
Course Introduction

- PEX tubing has been used for plumbing systems in North America for **over 30 years**, providing safe delivery of potable water and protecting the health of building occupants
- A result of modern polymer technology, PEX tubing performs in ways that provide superior reliability, durability, and safety
- 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

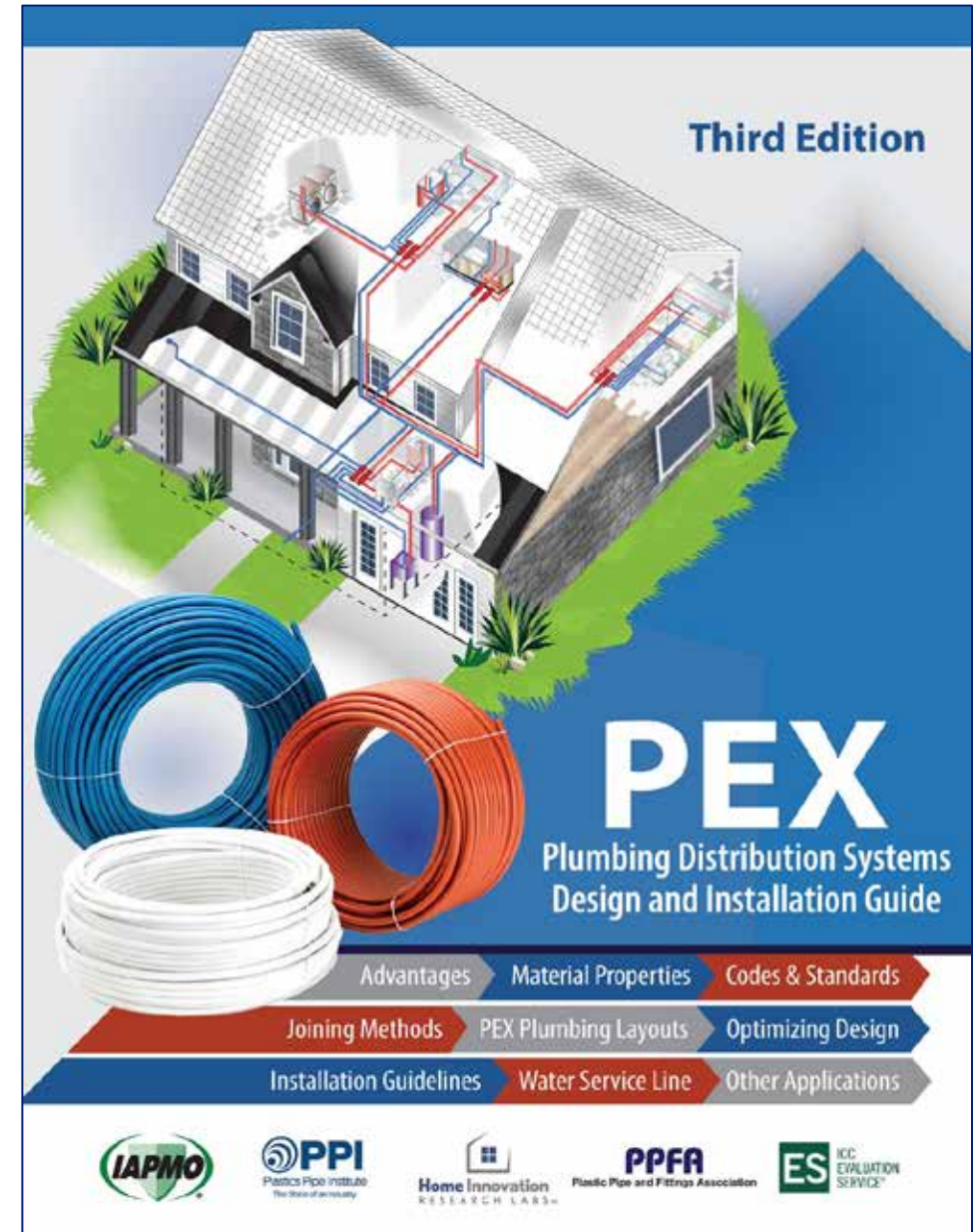
Proven Success

- Since 1997, the usage of PEX tubing in residential plumbing has increased from less than 10% to more than 66%
- Source: HIRL Builders Practices Report, Sept. 2025
- PEX plumbing systems are also making steady gains in commercial plumbing systems, often as part of hybrid systems



Course Background

- Much of the information in this course is taken from “PEX Plumbing Distribution Systems Design and Installation Guide” Third Edition
- PPI, PPFA, IAPMO, 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*
- PEX Plumbing 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

- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion
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- Static Water Column Pressure

[Read About BCD Calculator](#)

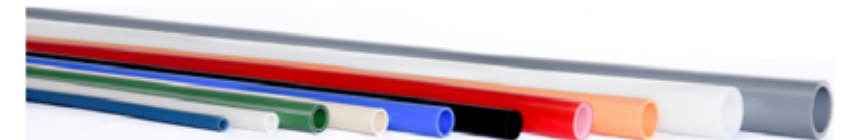


BCD Plastic Pipe Design Calculator Ver 3.2

The PPI Building & Construction Division's Plastic Pipe Design Calculator is a software tool that aids in designing plastic pressure pipe and tubing systems using the materials CPVC, HDPE, PEX, PE-RT, PP-R, and PP-RCT. It is intended to assist designers using these materials for applications such as plumbing, water service, fire protection, hydronic piping, radiant heating & cooling, snow & ice melting, geothermal ground loops, district heating, chilled water, and turf conditioning.

The Calculator includes six main functions accessed via blue buttons on the left:

- Pressure Drop/Head Loss
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Hydraulic Shock
- Expansion Arm/Loop
- Static Water Column Pressure



Plastic piping materials are the most reliable, resilient, and sustainable options for plumbing and mechanical applications. The Calculator utilizes dimensional data from ASTM and CSA standards for piping materials, as well as data extracted from PPI research projects and publications.



Note on Fittings: Characteristic pressure loss data on pipe fittings is often published by fitting suppliers as "equivalent feet of pipe length". This data is not built into the Calculator, due to the wide variety of fitting designs available in the market. When doing Pressure Drop/Head Loss calculations for piping systems with fittings, the user can manually enter this data for the selected fittings, if it is known, and the pressure loss through fittings will be added to the calculated pressure loss through piping.

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. 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*

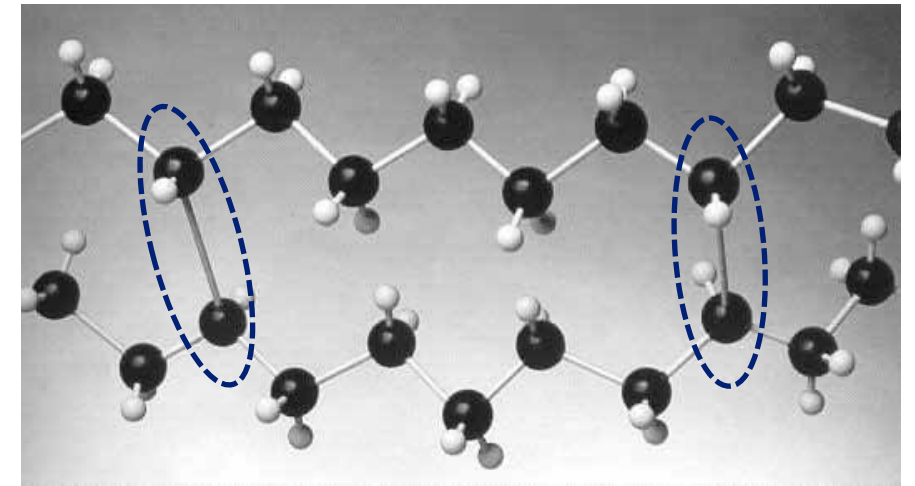


Illustration of a PEX “molecule”

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

Crosslinked Polyethylene (PEX) History & Overview

- See [PPI TN-17](#) for overview of PEX tubing & the source of the following information

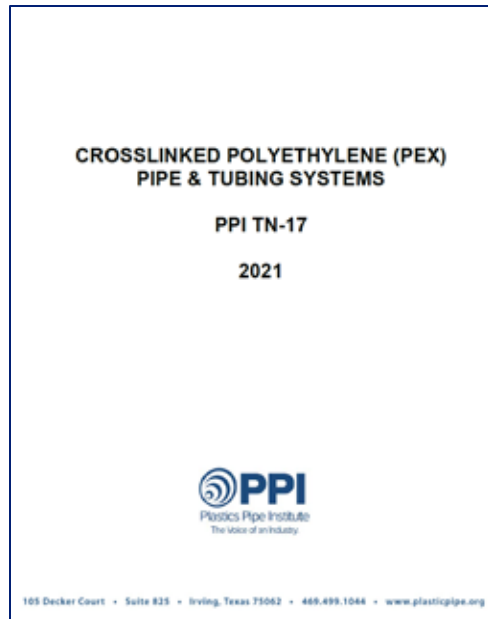


TABLE OF CONTENTS	
1.0	Introduction 1
2.0	PEX Definition 1
3.0	Crosslinking Improves the Properties from HDPE 2
4.0	Elevated Temperature Capabilities 3
5.0	Methods of Crosslinking HDPE into PEX 3
6.0	Typical Configurations of PEX Tubing or Piping Systems 4
7.0	Typical Applications for PEX Tubing and Pipe 5
8.0	The Advantages of PEX Systems 6
9.0	Sustainability 6
10.0	Code Acceptance of PEX Systems 7
11.0	PEX Material Designation Codes 7
12.0	Technical Qualification Requirements for PEX 8
13.0	PEX Fittings 14
14.0	Acknowledgements 15

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)	Typically Unchanged	PEX is suitable for both low- and elevated-temperature applications
Tensile Yield Strength @ 180°F (82°C)	Typically Increases	
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 Increased	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 History & Overview

- PEX is a high-temperature flexible pressure pipe material
- Crosslinking PE into PEX was pioneered and patented in **1960s**
- PEX was introduced for radiant heating in the early **1970s** in Europe
- Introduced to USA and Canada in **1980s*** for heating and plumbing
- Adopted into the *BOCA National Plumbing Code* in **1993**
- Today, PEX tubing systems are used for water service lines, hot- and cold-water distribution, residential fire protection, radiant heating & cooling, snow & ice melting, geothermal ground heat exchangers and other demanding applications



Courtesy Viega

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

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): 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



Courtesy REHAU

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** *Drinking Water System Components - 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 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.”

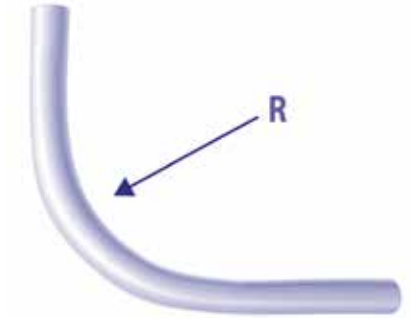
NSF/ANSI/CAN 372 is updated regularly with stringent requirements



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

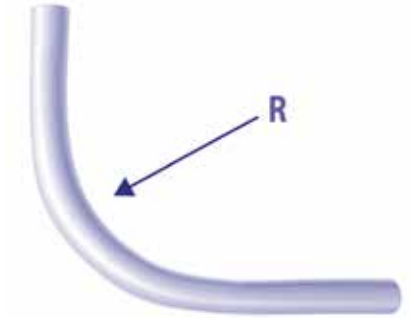


Example of tight bend radius possible with 3/4 PEX tubing



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
- Consult with tubing manufacturer for the minimum bend radius of their tubing

*Example of bundles of PEX tubing run together
No elbows needed*



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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

- 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:

- **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**

Example 2:

- **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



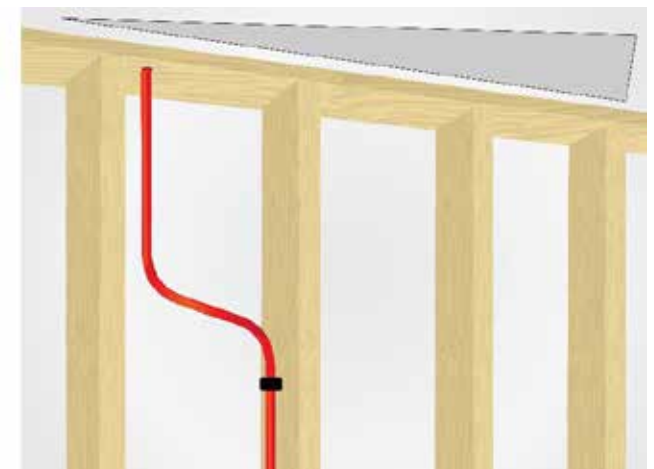
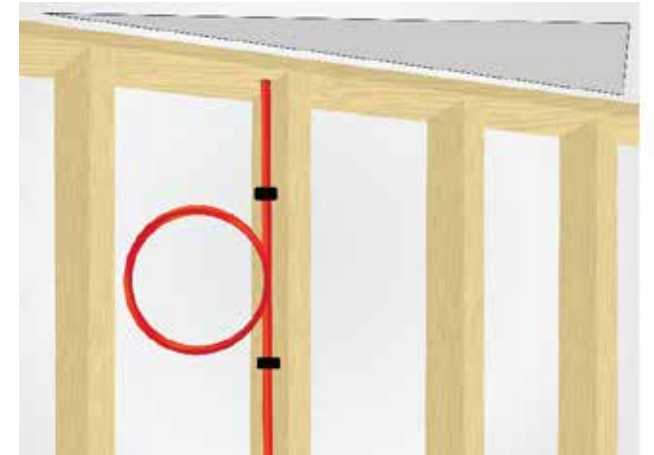
How the Properties of PEX Tubing and Fittings Can Improve Health, Safety, and Welfare

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
- 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:

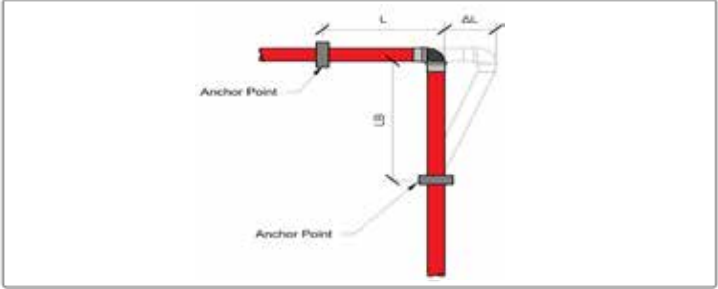
- Expansion loops or arms may be needed, depending on installation type, expected temperature changes, tubing size
- www.PlasticPipeCalculator.com helps with these calculations
- Example: **Expansion Arm** calculation shown

Plastic Pipe Design Calculator

EXPANSION ARM/LOOP

Input

Expansion Type: Arm Loop



Is this a Geothermal Application?

Pipe/Tubing Selection¹

Pipe/Tubing Material: PEX

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

Wall Type (SDR/Schedule): SDR 9

Nominal Pipe/Tubing Size²: 1 1/2

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**

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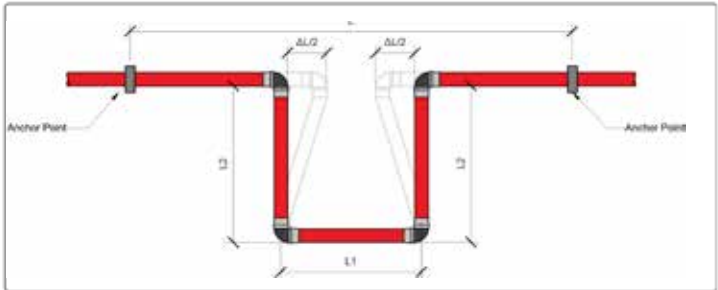
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Plastic Pipe Design Calculator

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Is this a Geothermal Application?

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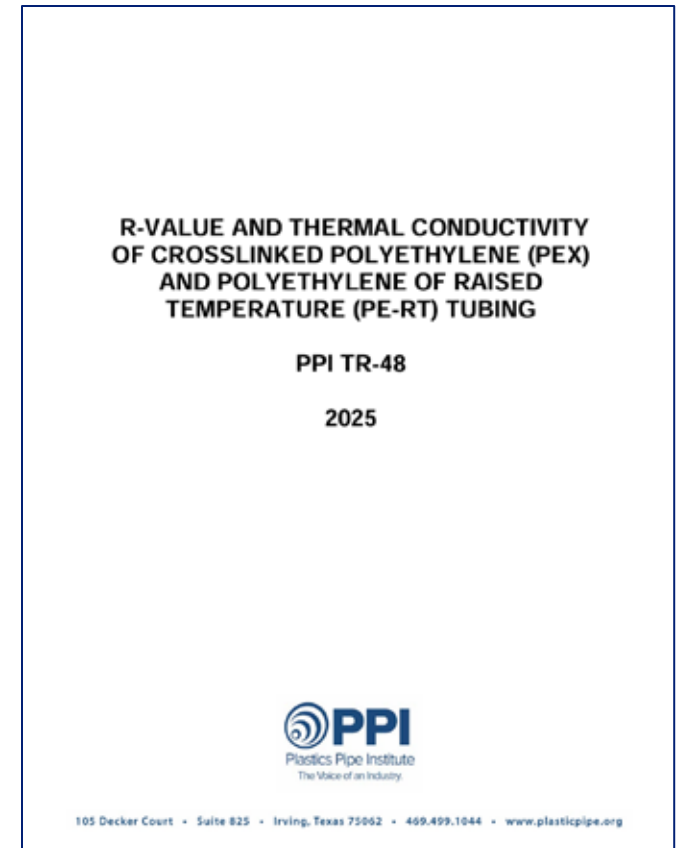
Nominal Pipe/Tubing Size²: 1 1/2

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)/(ft²·hr·°F) or **0.41** W/(m·°K)
- Copper k-value = **196** (BTU·in)/(ft²·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

- Insulating properties help PEX **prevent the freezing** of water
- PEX is **less susceptible** to the effects of cold temperatures, retaining flexibility even below freezing (i.e., does not become brittle)
- 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

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



Courtesy Viega LLC

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 – Crimp Ring



ASTM F1807 Crimp ring fitting
Available in brass or copper

ASTM F1807 copper crimp ring
(not to scale!)

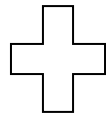
ASTM F2159 polymer crimp fitting
(black or white plastic)



Typical Crimp ring fitting assembly tool (not to scale)



PEX Fitting Systems - Clamp



OR



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

ASTM F2159 polymer fitting



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

PEX Fitting Systems – Cold Expansion with PEX Ring



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



PEX Fitting Systems – Cold Expansion with PEX Sleeve



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



PEX Fitting Systems – S/S Press Sleeve



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



PEX Fitting Systems – Push-fit



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



PEX Fitting Systems – Push-fit



*Courtesy Reliance
Worldwide Corp.*



ASSE 1061 Push-fit fittings

Available in polymer and lead-free brass



PEX Fitting Systems – Push-fit



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 - Selection

Wide range of PEX fitting types is available

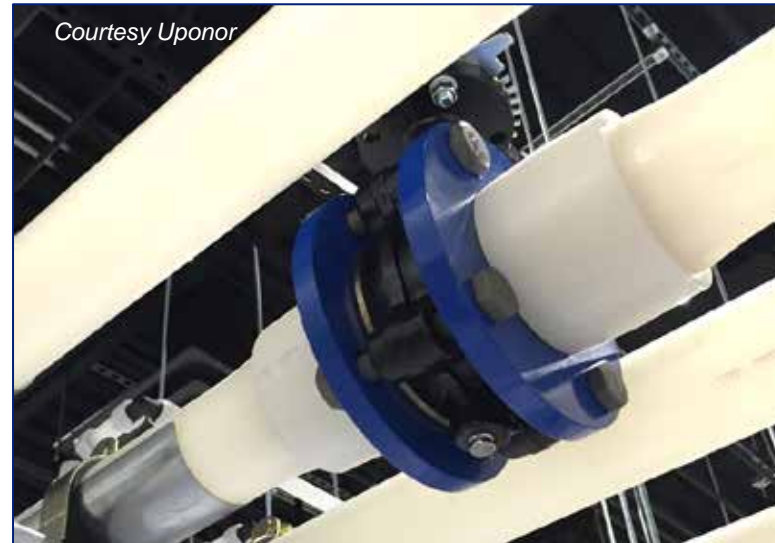
- Shapes such as tees, elbows, couplings, plugs, reducers available
- Various adapters: Copper sweat/street, MPT, FPT, drop-ear elbows, etc.



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

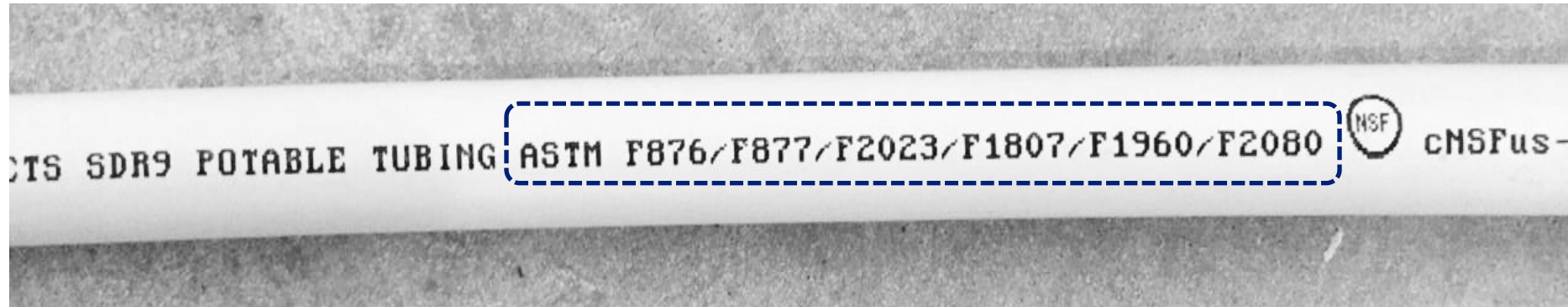
PEX Fittings Standards

- 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

- 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

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 & System 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 Water¹



Designation: F2657 – 25

Standard Test Method for
Outdoor Weathering Exposure of Crosslinked Polyethylene
(PEX) Tubing¹

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**



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 A1.1** “PEX Material Designation Codes”

Property	Test Method	0	1	2	3	4	5	6	7	8	9
Chlorine Resistance (minimum 50 years)	F2023	Not tested or rated	75 % at 73°F and 25 % at 140°F	...	50 % at 73 °F and 50 % at 140 °F	...	100 % at 140°F	...	...	...	...
Minimum UV Resistance	F2657	Not tested or rated	1 month	3 months	6 months	...	...	...	...	...	...
HDS for water at 73 °F	D2837	...	...	...	...	...	...	630	700	800	...

PEX System Standards and Code Compliance

Chlorine Resistance: Evaluation

- 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**
- Chlorine ratings (e.g., 1,3,5) are based on the end-use condition of **80 psig** and **140°F (60°C)**
- 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)

- 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

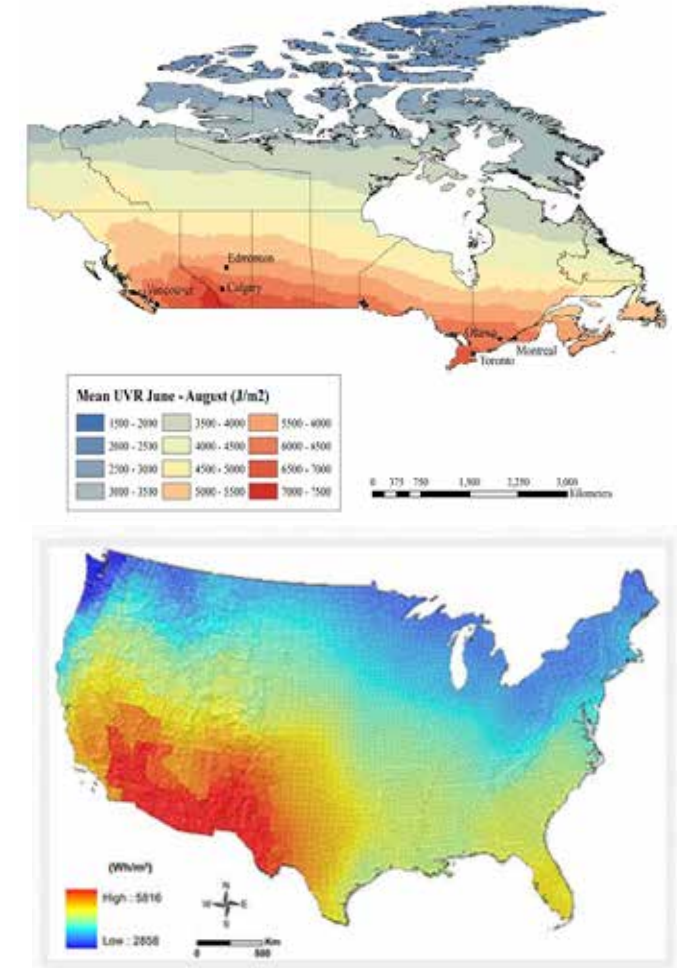
Storing PEX tubing outdoors is not permitted!



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**

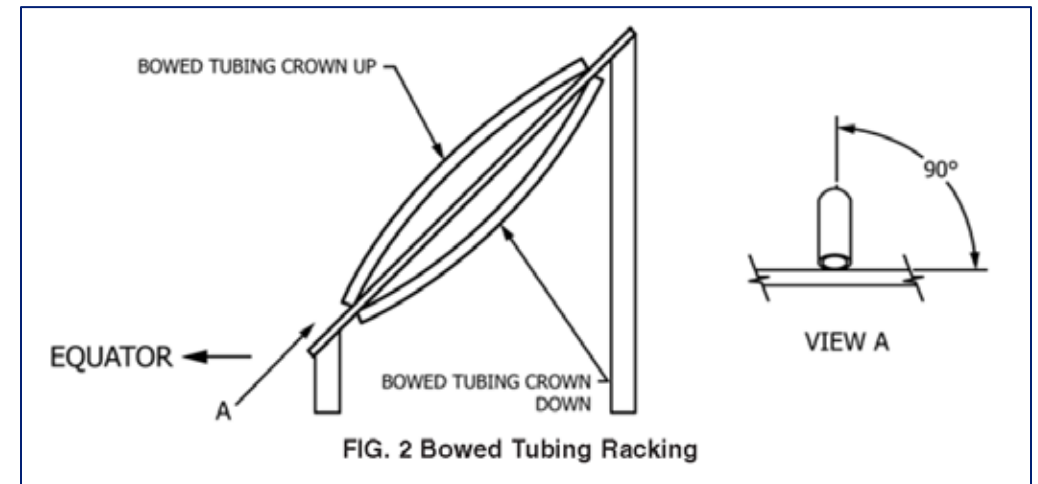


Fig. 2 from **ASTM F2657**

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

- Look for a label or packaging describing the maximum allowed UV exposure time
- Digit '1' is the **Minimum** requirement for PEX plumbing tubing according to **ASTM F876**

Suggested label text according to PPI TN-32

NOTICE

- Keep PEX stored indoors in the original packaging prior to installation for protection against UV/sunlight and other potential hazards.
- Do not store unprotected PEX outdoors.
- The long-term performance of PEX will be compromised by excessive UV radiation from sunlight.
- To prevent UV damage, ensure that exposure to sunlight during installation does not exceed the maximum allowable UV exposure time of **X**¹ days.
- UV damage is not visible to the naked eye and may degrade the material and reduce its service life.



PEX System Standards and Code Compliance

Sustained Pressure Ratings

Requirements 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 Material Designation Code, the minimum requirement in **ASTM F876**
- Some PEX products may be marked with “07” or “08”

Minimum PEX Material Code is “1106”

Details:

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

PEX System Standards and Code Compliance



Flame and Smoke Ratings in the 2024 UMC

- 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**
- **602.2 Exception (9):** “Plastic water distribution piping listed and labeled for use in plenums 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, shall be permitted.”
- In Canada, flame and smoke spread testing is in accordance with **CAN/ULC S102.2**
- Codes are subject to change, so check with local codes for specific requirements!

PEX System Standards and Code Compliance

Flame and Smoke Ratings in the 2024 IMC

- The 2024 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!

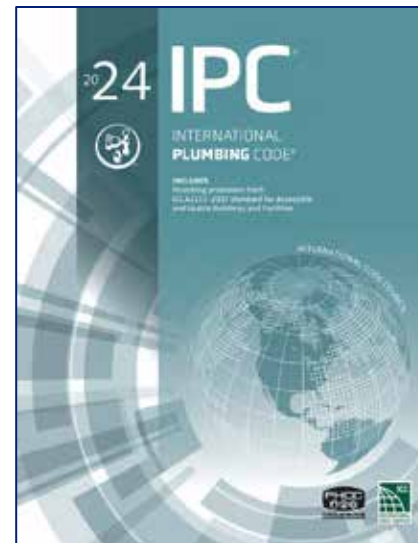
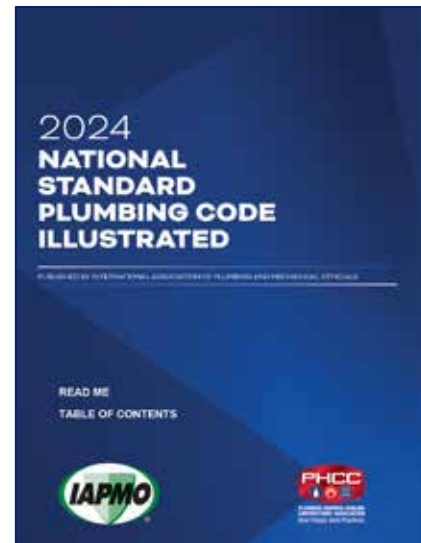
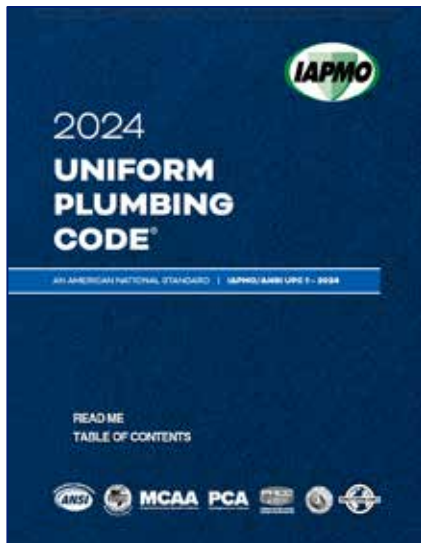


Image of Steiner Tunnel at UL LLC

PEX System Standards and Code Compliance

Summary

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



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)



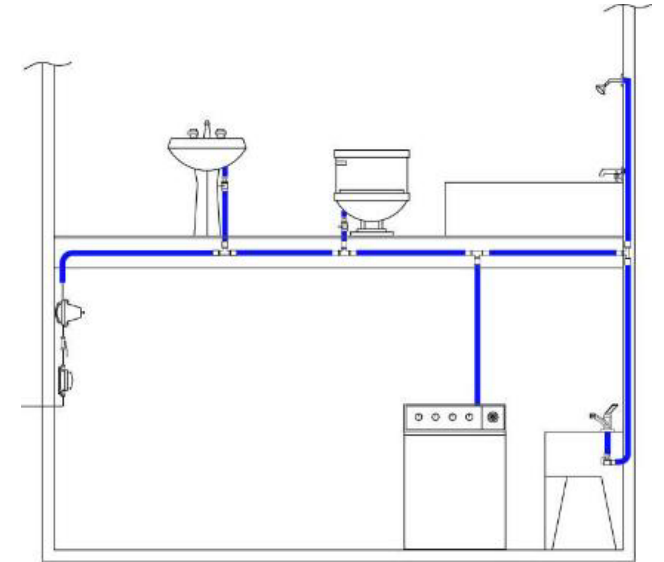
By carefully choosing the right system for the application, the plumbing designer can produce a home that balances safety, longevity, comfort, cost, installation time, environmental soundness and performance

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 NTS 3 are available, drops are typically 3/8, 1/2, or 3/4
- T&B is most appropriate when using larger diameter PEX (over 3/4) where flexibility is not so relevant

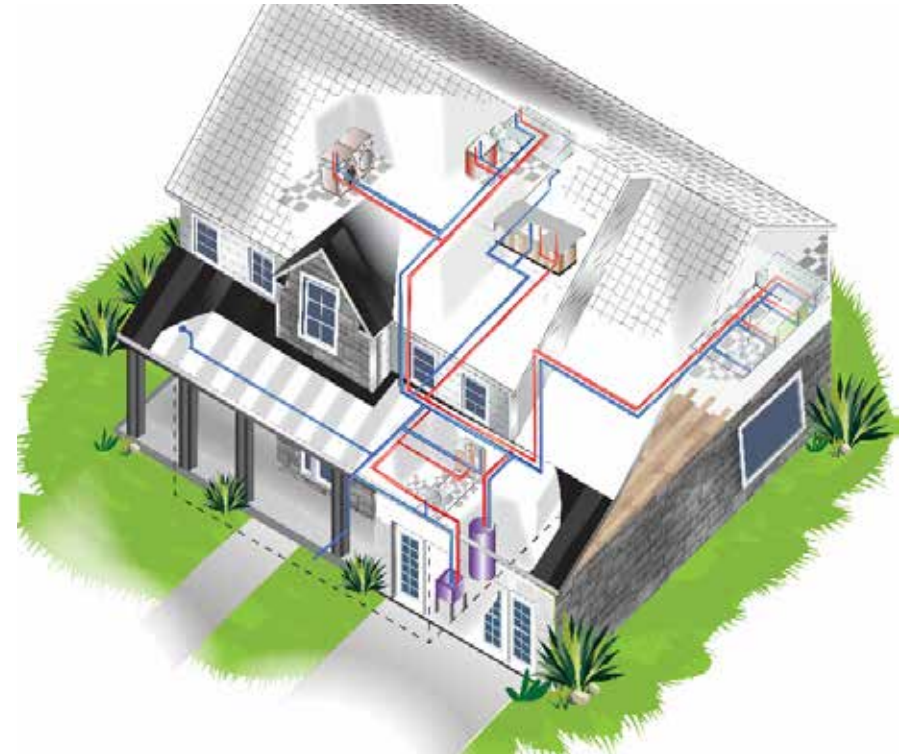
- T&B is commonly used in multi-family and commercial plumbing design



Plumbing Layouts Using PEX

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

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
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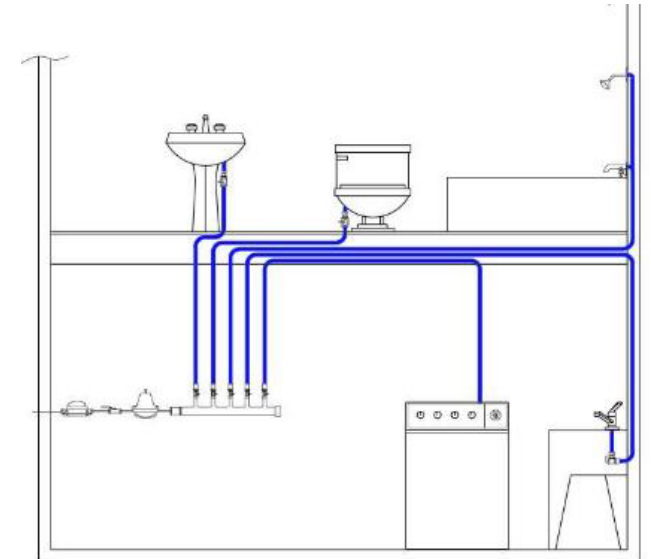


Example of a commercial PEX T&B plumbing system

Plumbing Layouts Using PEX

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

- **Parallel** technique employs 3/8 or 1/2 tubing “**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 and tees are practically eliminated
- Similar in concept to household wiring from a breaker panel

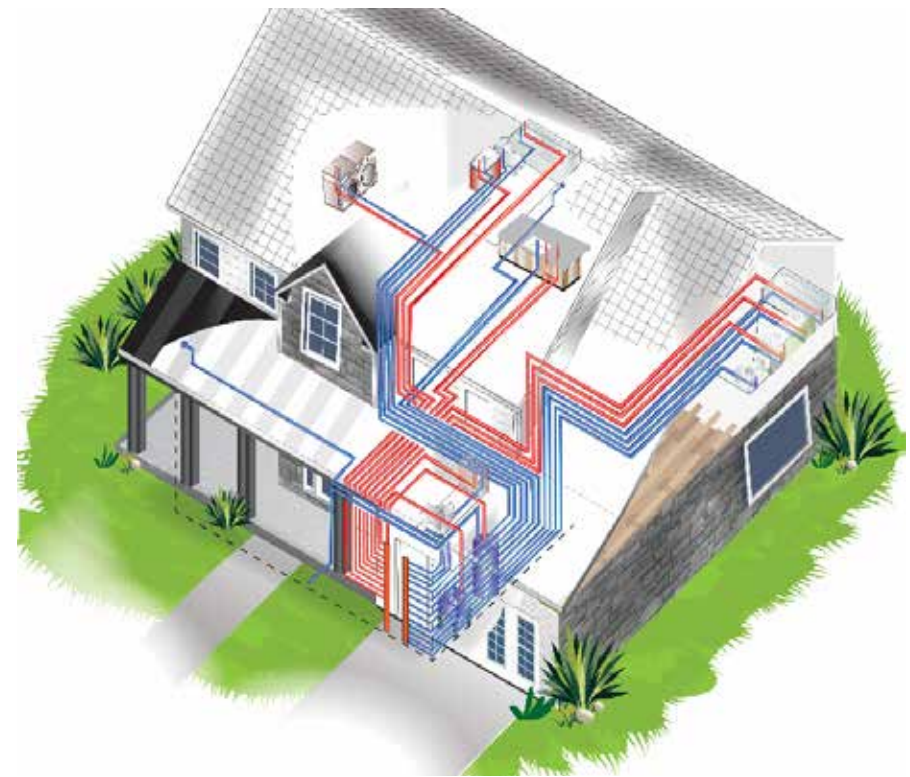


Courtesy Viega

Plumbing Layouts Using PEX

Comments on Parallel systems

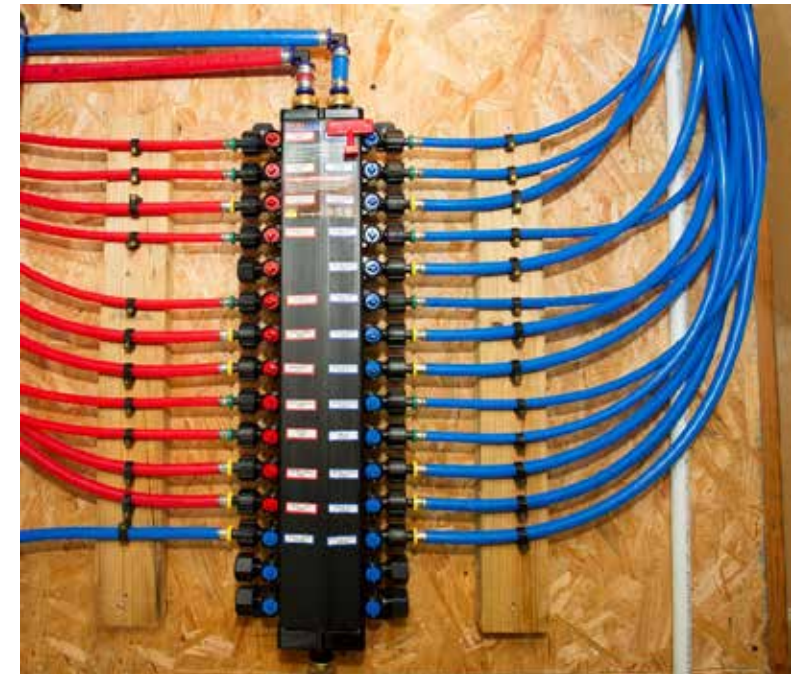
- Although PEX tubing works well in a parallel home-run layout, in larger homes, this technique requires a lot of tubing, many holes in studs and plates, greater need for fasteners, and potentially longer installation time
- Faster delivery of hot water to fixtures is common
- Delivery time for *sequential 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

Comments on Parallel systems

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Example of a large home-run plumbing system

Plumbing Layouts Using PEX

Comments on Parallel systems

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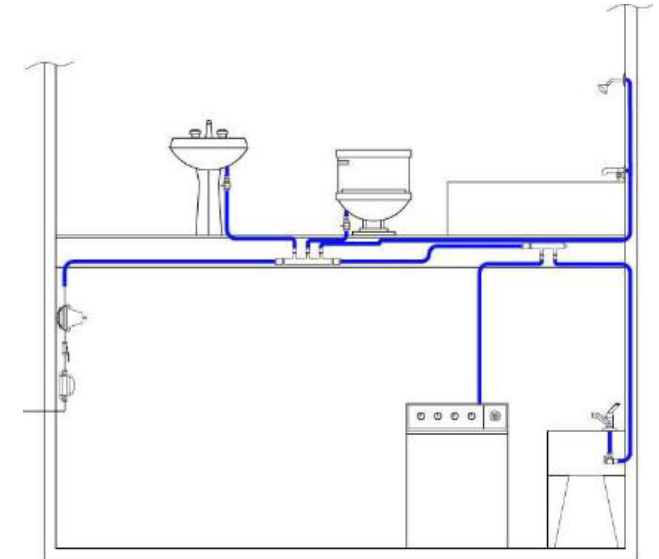


Example of a very large home-run plumbing system

Plumbing Layouts Using PEX

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

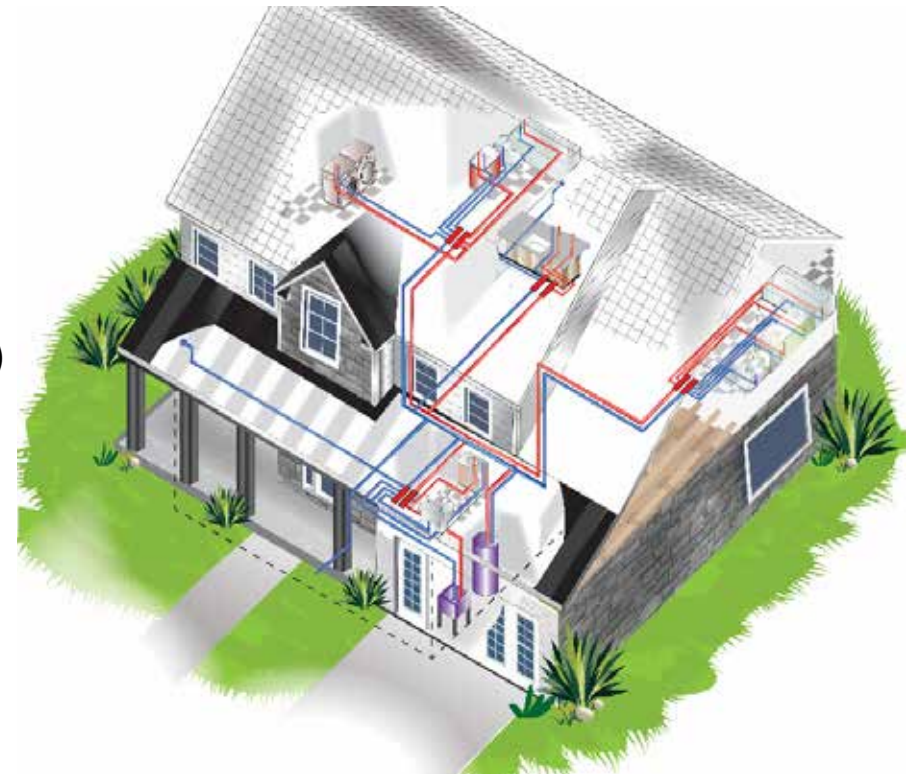
- **Zoned** technique uses trunk lines to supply **remote manifolds** at fixture group “zones”
 - Small manifolds replace many tees and joints
 - 3/8 or 1/2 tubing is run to each fixture
- Manifolds are copper or polymer, usually not valved
 - Often embedded within walls
- Sizing is simplified, systems are pressure-balanced
- Fewer fittings are required and tees are practically eliminated
- Less tubing than home-run



Plumbing Layouts Using PEX

Comments on Zoned systems

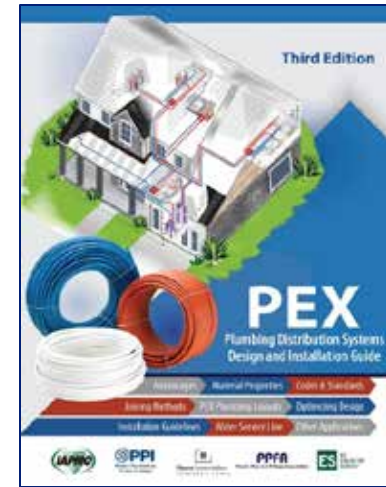
- The Zoned technique reduces the total amount of tubing, reduces number of fittings and can reduce overall installation time
- Delivery time for *sequential hot-water* is reduced (i.e., faster delivery) over T&B and Parallel (home-run)
- **Zoned systems** may be ideal for certain designs, especially 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 6.1**



*Stars represent **General Rankings** of various system characteristics

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

Results		
Dry Weight:	6.1 lb	2.8 kg
Filled Weight:	15.3 lb	6.9 kg
Volume Of Fluid In Pipe:	1.1 US Gallons	4.2 L
Volume Of Glycol:	0.0 US Gallons	0.0 L

[Calculation Details](#)
[Print](#)
[Email](#)

Plastic Pipe Design Calculator

PIPE WEIGHT / VOLUME

Input

Is this a Geothermal Application?


Pipe/Tubing Selection¹

Pipe/Tubing Material: PEX

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

Wall Type (SDR/Schedule): SDR 9

Nominal Pipe/Tubing Size²: ¾



[More information on PEX](#)

Length Of Pipe: 60 ft

Fluid Type (Water or % Antifreeze³): 100% Water

³For methanol, viscosity and density information is from "Geothermal Heating and Cooling – Design of Ground Source Heat Pump Systems" by Dr. Steve Kavanaugh and Kevin Rafferty (ASHRAE RP-1674) and "Perry's Chemical Engineers' Handbook (7th ed.)" by Perry, R. H., & Green, D. W. Available data is limited to a temperature range of 32°F to 86°F (0°C to 30°C).

*The pipe weight and volume calculations here are at 73°F/23°C.

[Calculate](#)

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:

- Plastic pipe has lower thermal conductivity, less heat loss through pipe wall
- Smaller diameter pipes hold less water (less water, less stagnation)
- Faster water velocity in PEX “pushes out” the cold water faster
- Route hot water piping closer to outlets to minimize distance
- 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 inherent insulator, 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%



Courtesy REHAU

Optimizing Piping Design for PEX Systems

Volumetric Comparisons: Copper vs. PEX

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%

$$Volume = \pi \times r^2 \times length$$

PEX tubing has less volume than copper

Example: 10 ft of 3/4 tubing:

- 3/4 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

Volume of PEX tubing sizes

- Volume of tubing should be considered to minimize water volume between source and fixtures
- Reduced volume = reduced waste = reduced stagnation time
- **PPI Plastic Pipe Design Calculator** calculates volumes
- Images from www.PlasticPipeCalculator.com

Results		
Dry Weight:	10.1 lb	4.6 kg
Filled Weight:	25.4 lb	11.5 kg
Volume Of Fluid In Pipe:	1.8 US Gallons	7.0 L
Volume Of Mixture Fluid:	0.0 US Gallons	0.0 L

[Calculation Details](#)
 Print
 Email

BCD Plastic Pipe Design Calculator Ver 3.2

PIPE WEIGHT / VOLUME

Input

Is this a Geothermal Application?

Pipe/Tubing Selection¹

Pipe/Tubing Material:

Sizing Type (CTS/IPS/Metric):

Wall Type (SDR/Schedule):

Nominal Pipe/Tubing Size²:



[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, such as with copper tubing. These products are sometimes referred to as "nominal tubing size" (NTS) or "copper tube size" (CTS). *Pipe* refers to products with an actual OD matching that of iron or steel pipe of the same nominal size. Those products are sometimes referred to as "iron pipe size" (IPS) or "nominal pipe size" (NPS). *Pipe* may also refer to products where the actual OD matches the nominal size (e.g. DN-Metric). Pipe and tubing dimensions used for these calculations are based on dimensional tables found within the listed product standards from ASTM and/or CSA. The Calculator assumes that all pipes have the nominal (i.e., average) outside diameter and an average wall thickness, resulting in an average inside diameter.

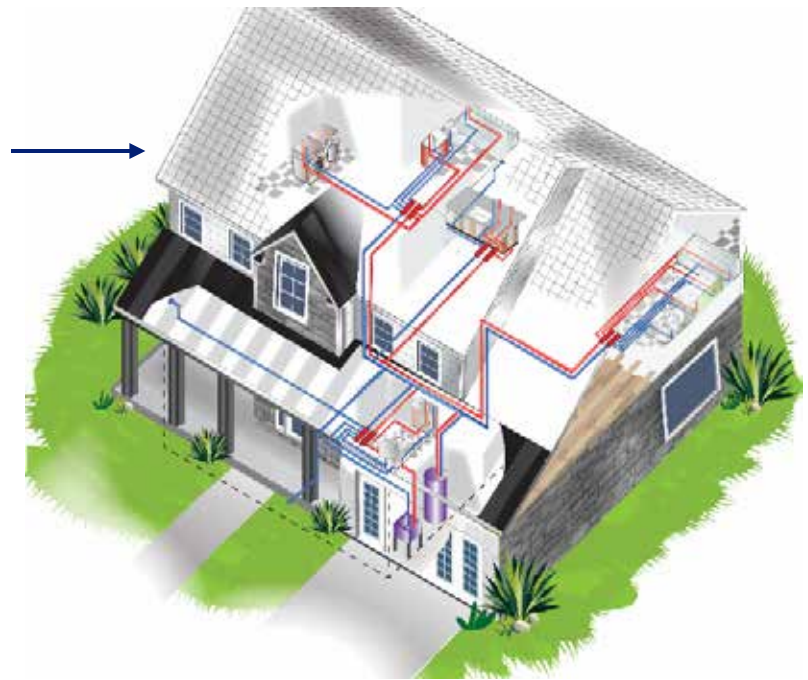
Length Of Pipe: ft

Fluid Type (Water or % Antifreeze³):

Optimizing Piping Design for PEX Systems

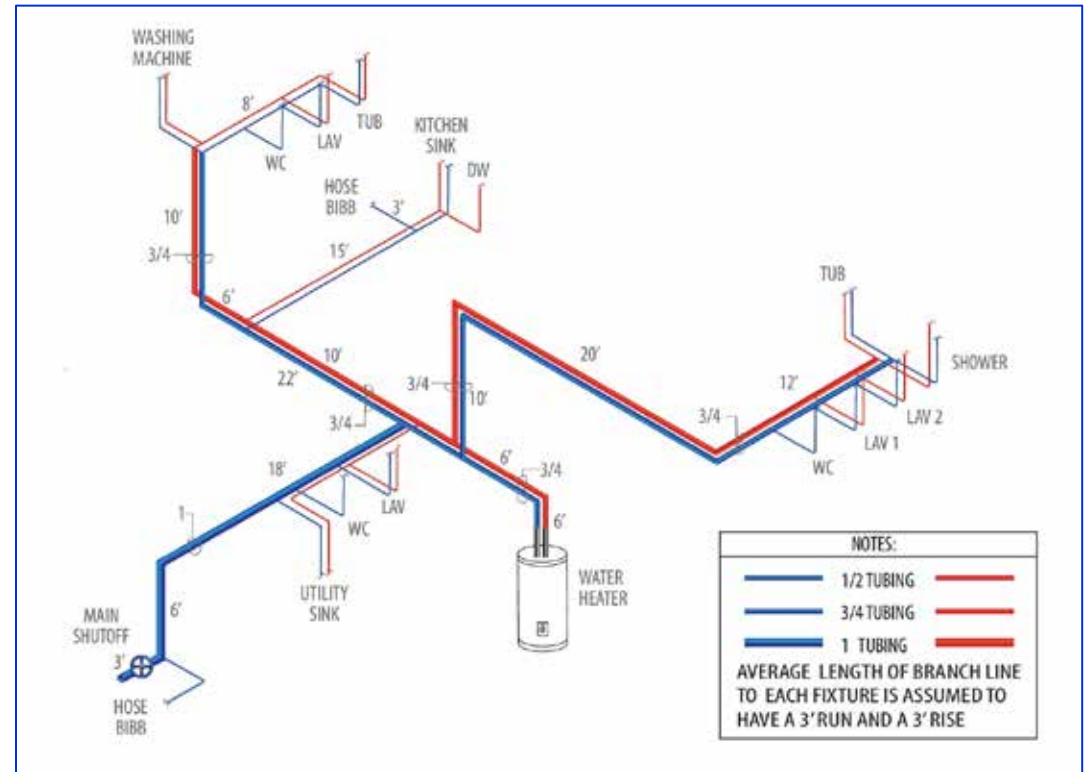
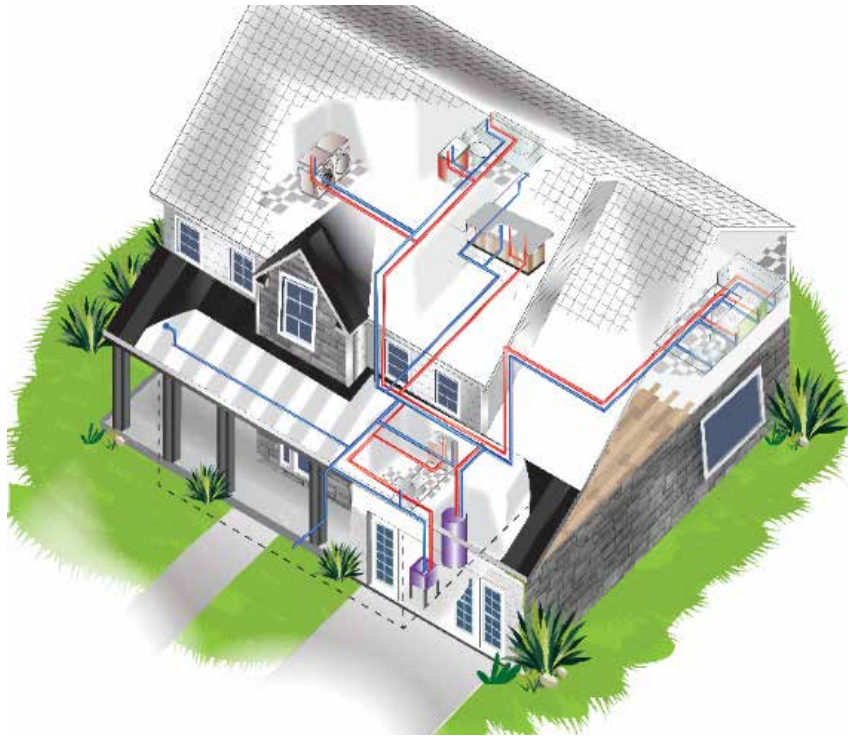
The next slides show how the PEX Plumbing Guide compares three layout options for four types of residences, both graphically and quantitatively:

- 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



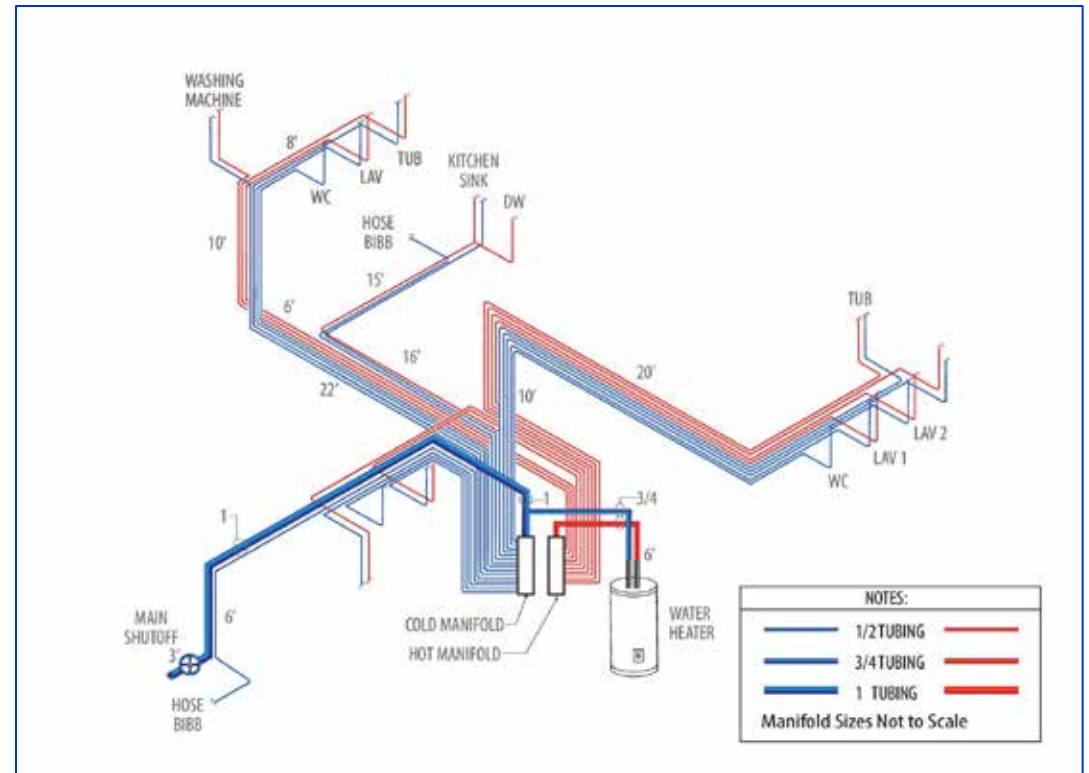
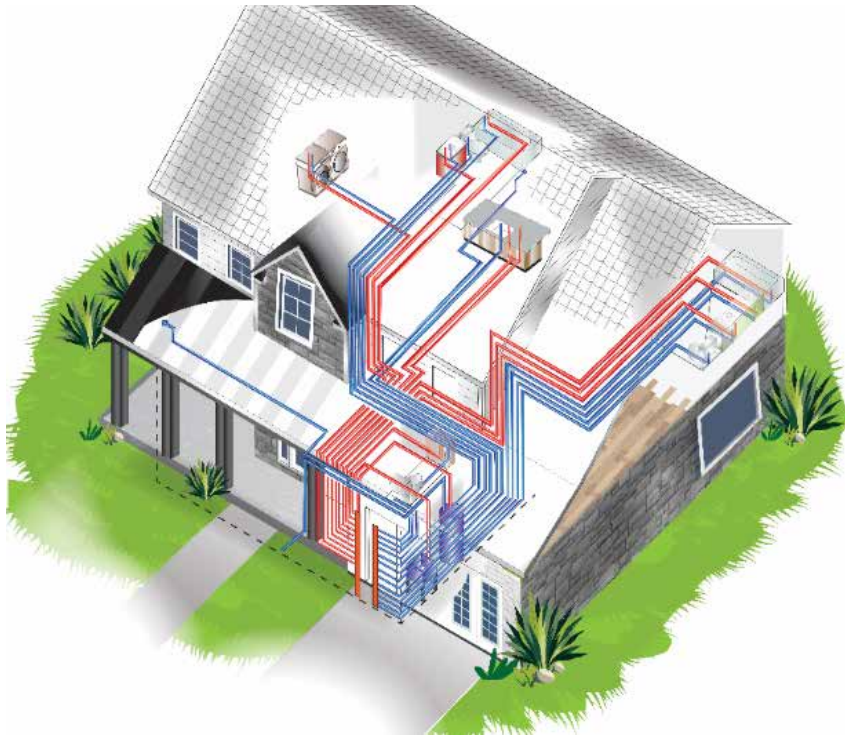
Optimizing Piping Design for PEX Systems

i. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths
- Trunk and Branch Design



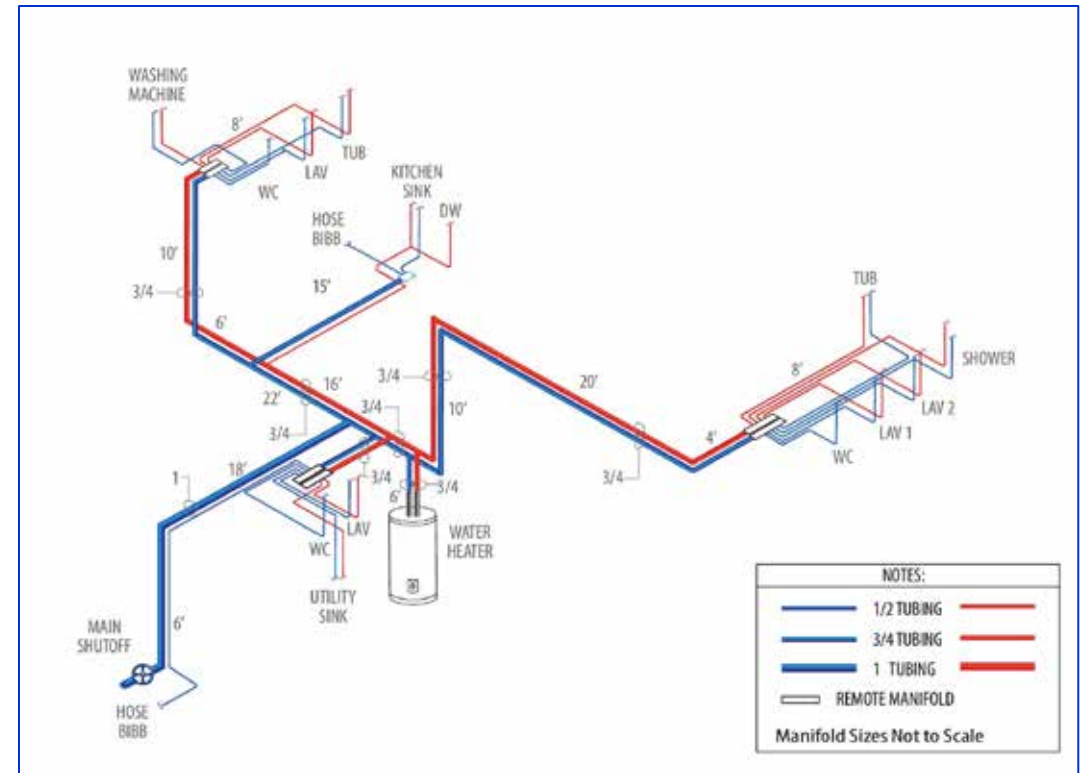
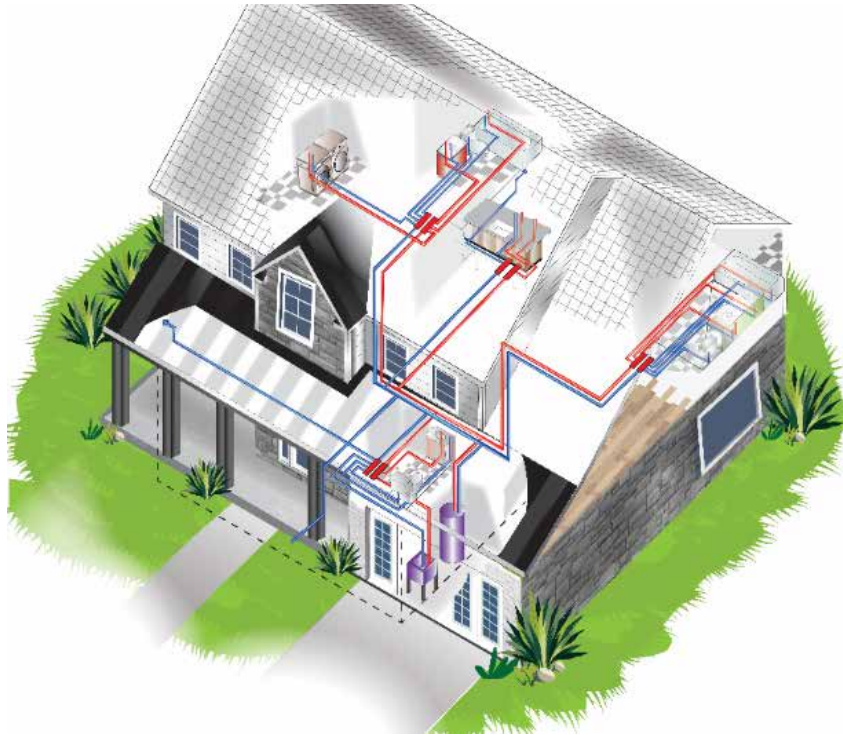
Optimizing Piping Design for PEX Systems

- 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 7.3**

Table 7.3 Material Summary for the Colonial House

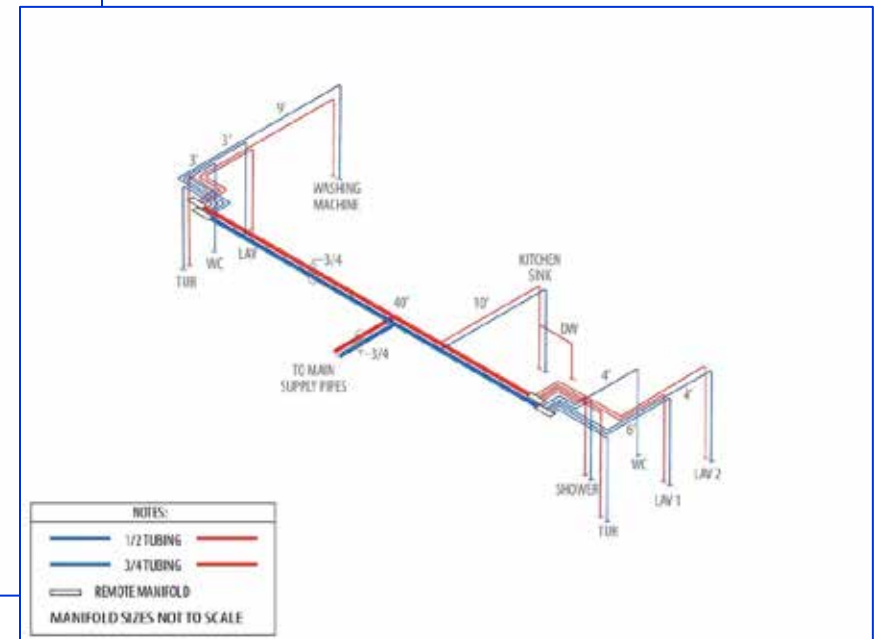
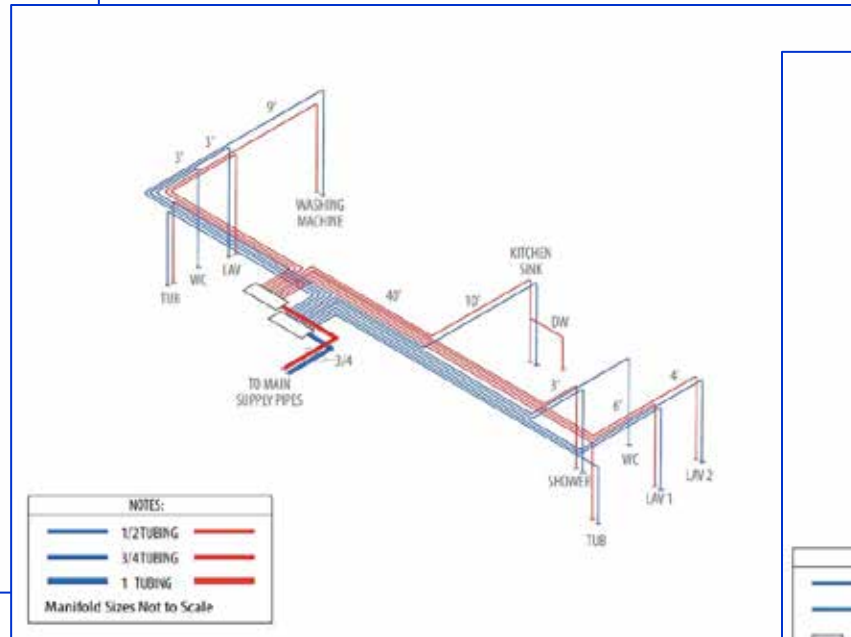
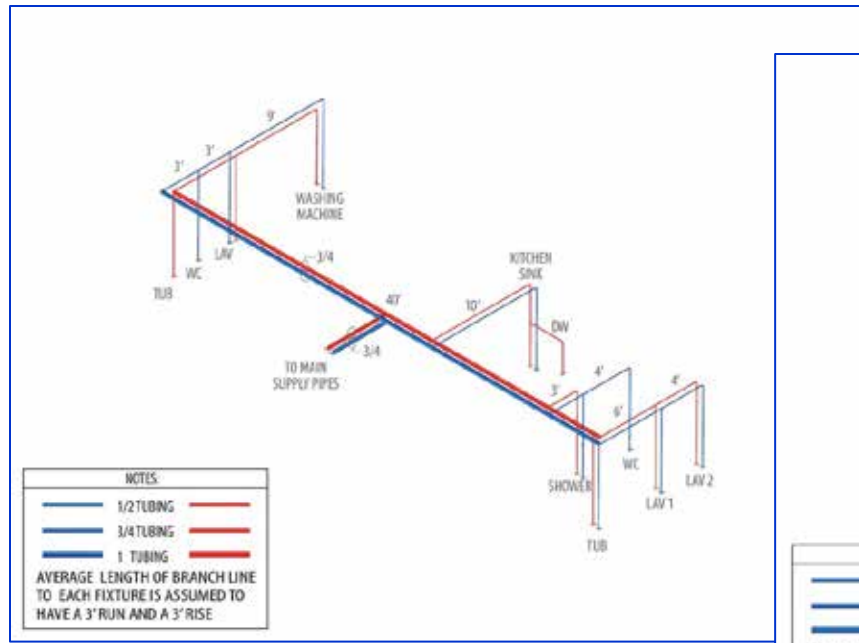
	Length of Cold Pipe			Length of Hot Pipe			Fittings		Manifolds/ Multi-port Tees		Joints	
	1	3/4	1/2	1	3/4	1/2	Tees	Elbows	Main	Remote	Fixtures	Piping
Trunk and Branch	27'	80'	110'	0'	80'	98'	25	10	0	0	26	97
Parallel	33'	12'	602'	0'	12'	428'	2	7	2	0	26	49
Zone	27'	93'	152'	0'	93'	107'	8	13	0	7	26	83



Optimizing Piping Design for PEX Systems

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

- Three designs were compared

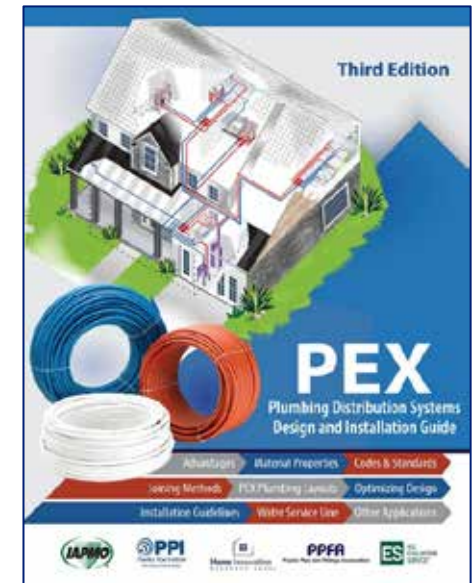


Optimizing Piping Design for PEX Systems

ii. Ranch: 1,300 square feet, one story, 2 full baths
 - Material Summary in Table 7.5

Table 7.5 Material Summary for the Ranch House

	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 7.7**

Table 7.7 Material Summary for the Townhouse

	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 7.9

Table 7.9 Material Summary for the Condominium

	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



Optimizing Piping Design for PEX Systems

Pipe Sizing

- Oversized piping can result in stagnant water in which disinfectants such as chlorine decay, creating the possibility of growth of opportunistic pathogens such as Legionella
- Oversized piping reduces the velocity of water within the pipes, with the potential to allow biofilm growth
- Finally, oversized piping wastes material and increases installation costs



AWWA Water Science



ORIGINAL RESEARCH

Impact of Premise Plumbing Design, Velocity, and Operational Factors on Microbial Activity During Stagnation in Pipes

Patrick L. Gurian¹ | Shahzaib Samuel¹ | Neha Yadav¹ | Michael Krieger¹ | Rajveer Singh¹ | Tim Bartrand²

¹Department of Civil, Architectural, and Environmental Engineering, Drexel University, Philadelphia, Pennsylvania, USA | ²ESPRI, Philadelphia, Pennsylvania, USA

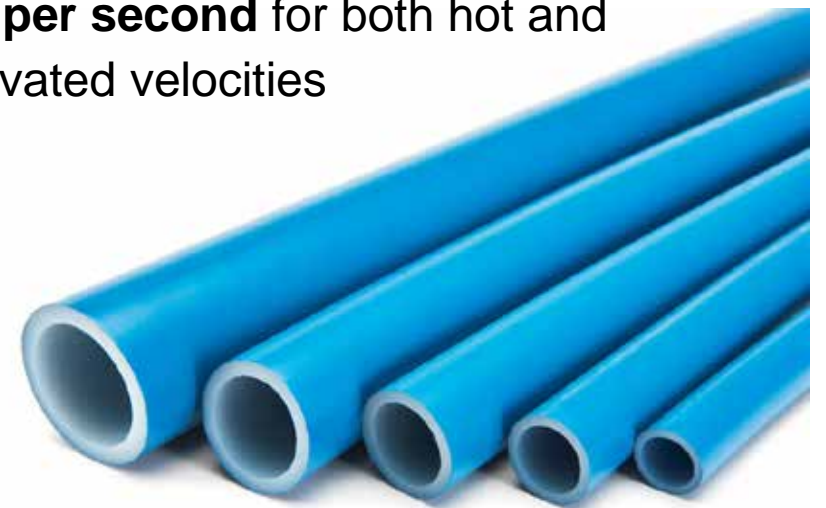
Correspondence: Patrick L. Gurian (pgurian@drexel.edu)

Optimizing Piping Design for PEX Systems

Flow Velocities

- The maximum recommended flow velocities through PEX tubing are **10 feet per second** (3.0 m/s) for cold water up to 80°F (26.5°C) and **8 feet per second** (2.4 m/s) for water temperatures above 80°F and up to 140°F (60°C)

Note: While PEX tubing can withstand flow velocities in **excess of 8 feet per second** for both hot and cold water without harm, the pressure drop through the tubing at such elevated velocities makes such flow rates impractical and inadvisable for most designs.



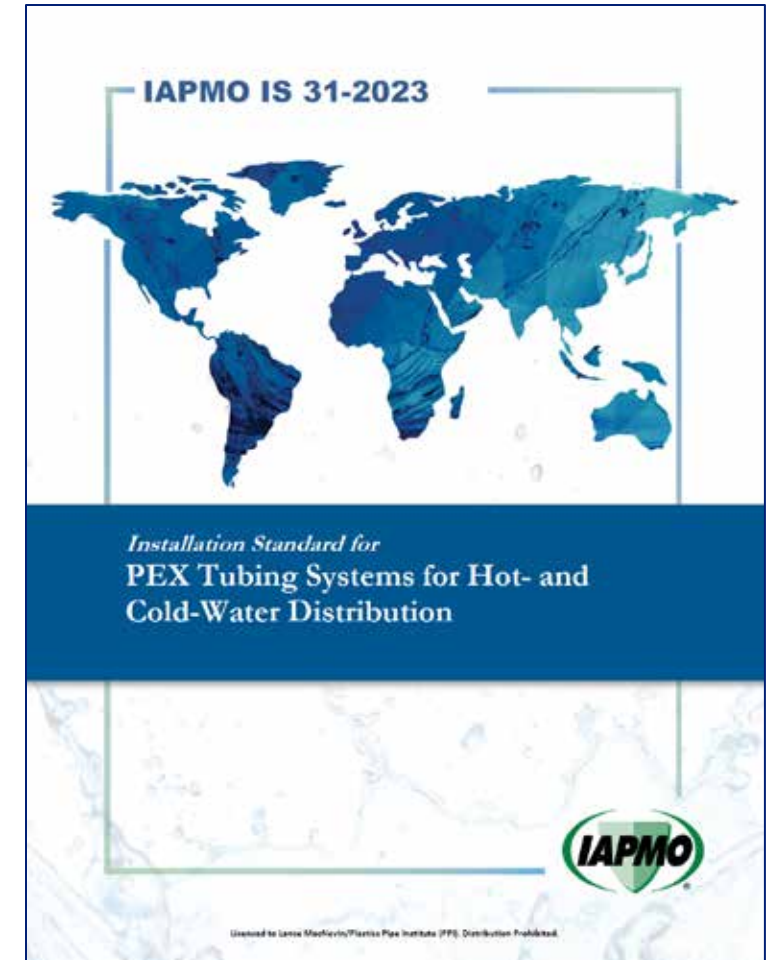
Optimizing Piping Design for PEX Systems

DHWR Velocities

- For the return piping of domestic hot water recirculation (DHWR) systems, according to **IAPMO IS 31-2023**, the return piping flow velocity for PEX tubing shall not exceed **2 feet per second** (0.6 m/s)
- See **Table 6.2** of PEX Plumbing Guide

Table 6.2 Flow Rate/Volume for PEX Tubing at 2 ft/sec Velocity

Nominal Tubing Size (NTS)	Flow Rate at 2 ft/sec GPM (L/min)
1/2	1.1 (4.2)
3/4	2.2 (8.3)
1	3.6 (13.6)
1 1/4	5.4 (20.4)
1 1/2	7.5 (28.4)
2	12.9 (48.8)
2 1/2	19.5 (74.0)
3	27.7 (105.0)
4	48.1 (182.0)



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,

Same simulated house was plumbed three ways:

- Trunk & Branch
- Parallel
- Zoned
- Performance results were measured

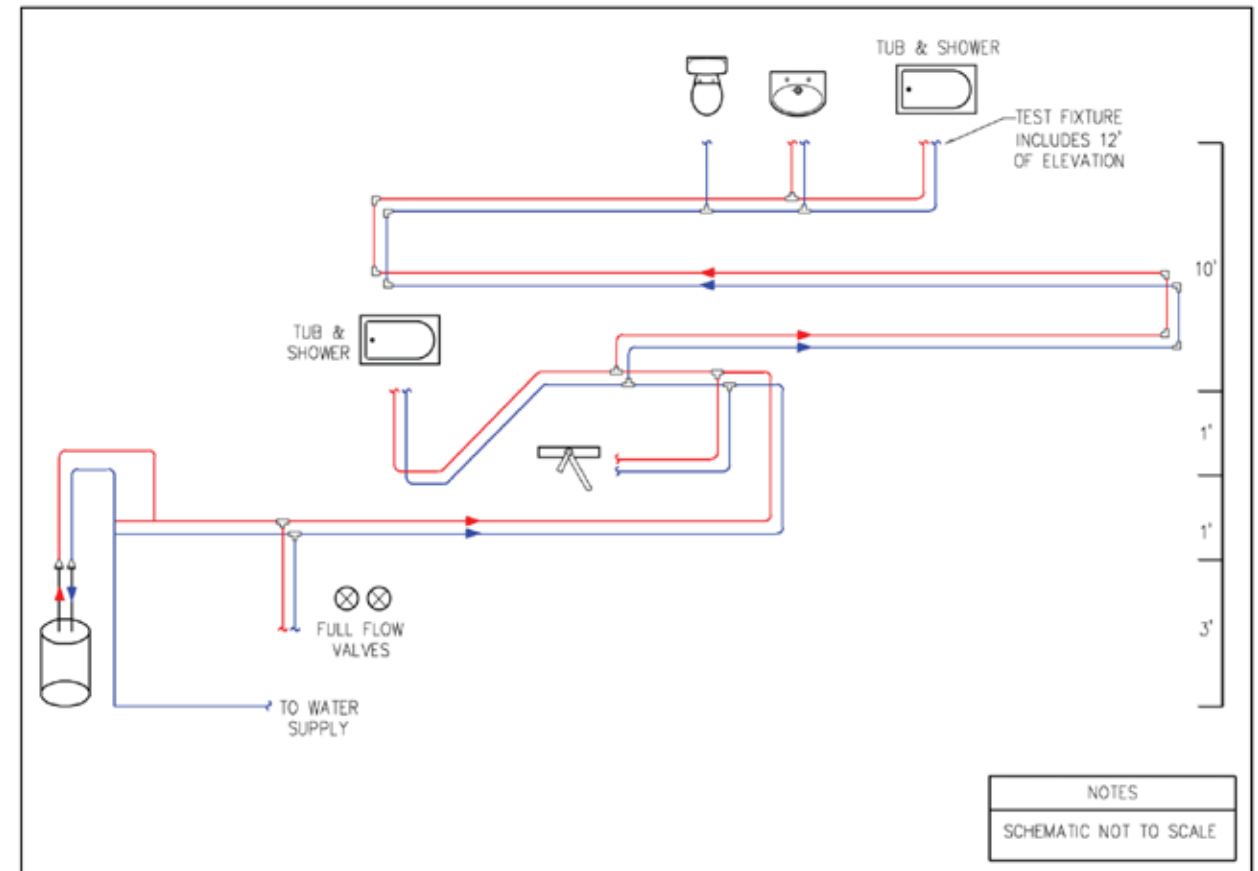


Figure 8.1 Fixture Layout for Laboratory Testing

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

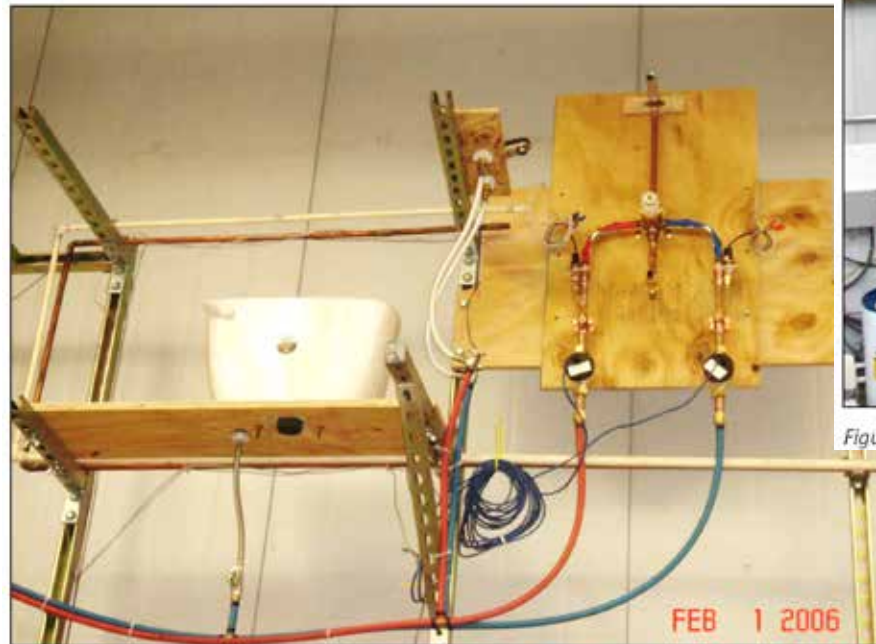


Figure 8.3 The Test Fixture (Shower) with Flow and Pressure Sensors Installed



Figure 8.2 Laboratory Test Set-up with Hot Water Tank for T&B System

PEX Plumbing System Performance Testing

Part IV: Comparison of Flow Rates through PEX and Copper Tubing in a Plumbing System

Based on the simultaneous flow performance data, all systems continued to supply adequate pressure and flow to the remote test fixture located 100 feet from the source. With the source pressure of just 40 psi, the maximum system flow rate was 8.0 GPM comprised of 5.0 GPM to the cold supply fixtures and 3.0 GPM to the hot supply fixtures. **Table 8.5** shows similar results with a system design of 60 feet to the TF.

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. Table 6.6 compares the two piping systems with a minimum source pressure of 40 psi and a maximum tubing length of 100 ft, the most demanding scenario in the test. Results of flow tests using higher pressures were consistent.

PEX Plumbing System Performance Testing

Pressure Drop

- See Chapter 8 “Performance Data” (page 91)
- Pressure Drop to Fixtures with Simultaneous System Flows, plumbed in all three layouts

Legend:

TF = Test (shower) Fixture

Lav = Lavatory, both valves open

WC = Water Closet, tank type

Kit = Kitchen faucet

Sh2 = Second shower, full open valve

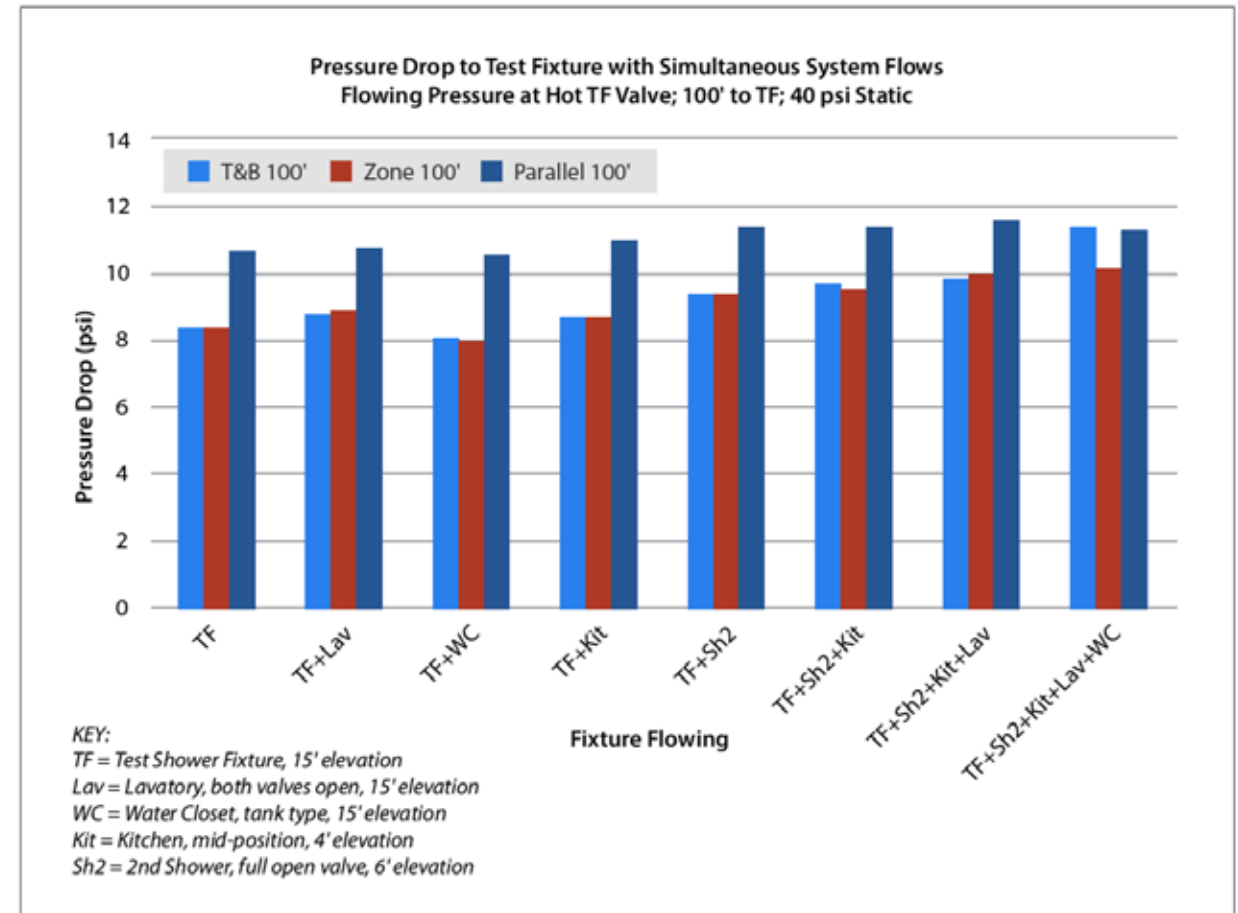


Figure 8.4 Pressure Drop Comparison, 100 ft. Distance to TF

PEX Plumbing System Performance Testing

Pressure Drop

- See Chapter 8 “Performance Data” (page 91)
- 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

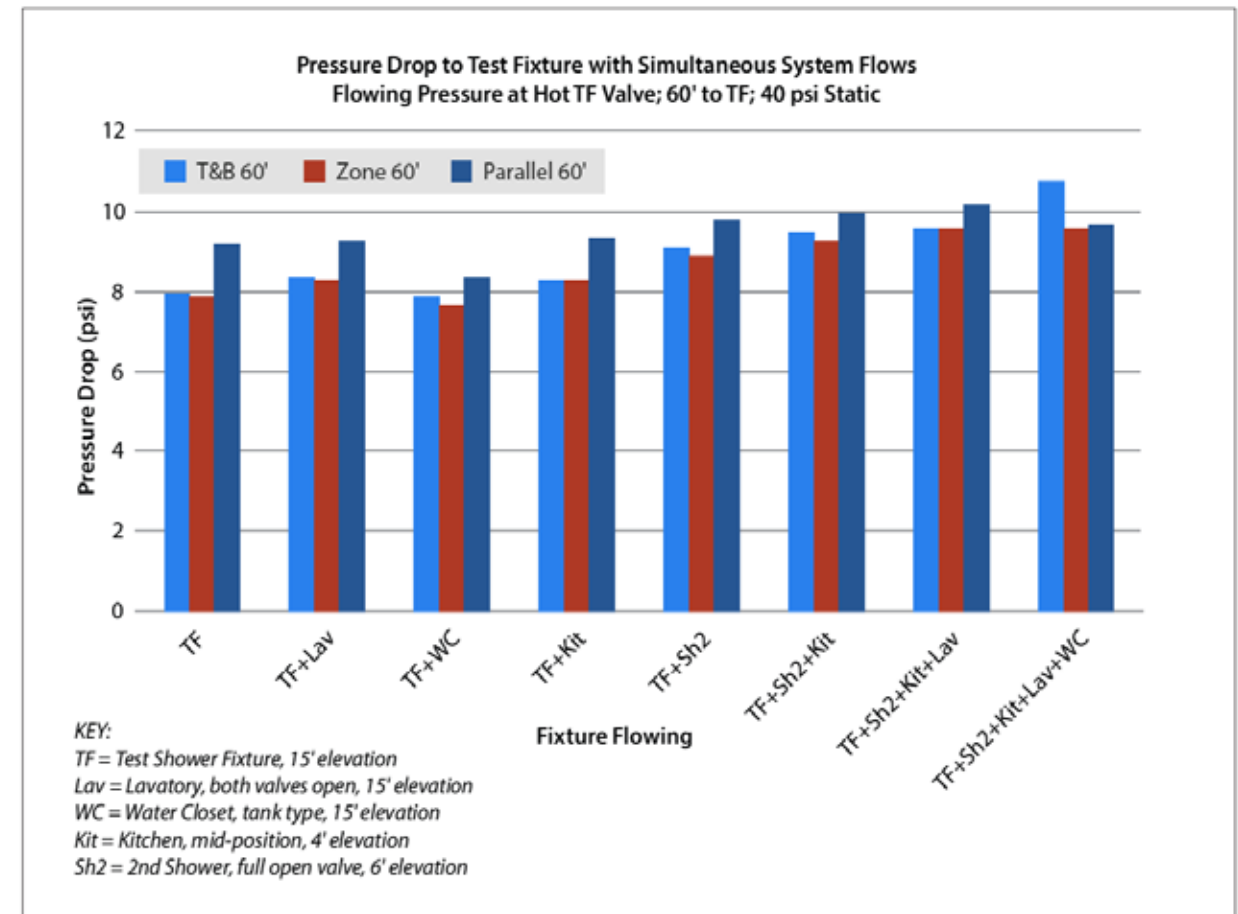


Figure 8.5 Pressure Drop Comparison, 60 ft. Distance to TF

PEX Plumbing System Performance Testing

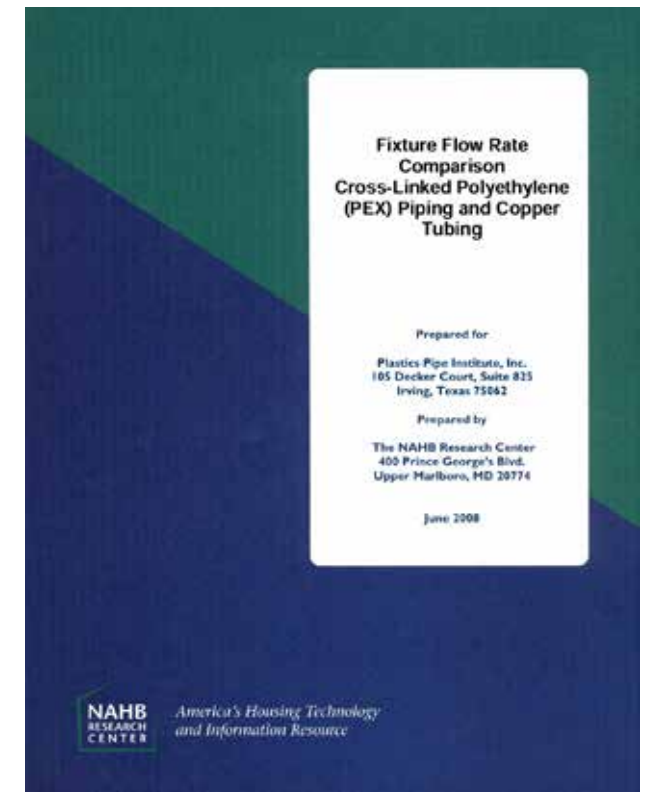
Flow Rate & Tubing Sizing

- The ID of PEX tubing is *slightly* less than copper
 - Ex: ½ inch nominal PEX tubing has **87%** of the copper ID (0.475" vs. 0.545")
- 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*

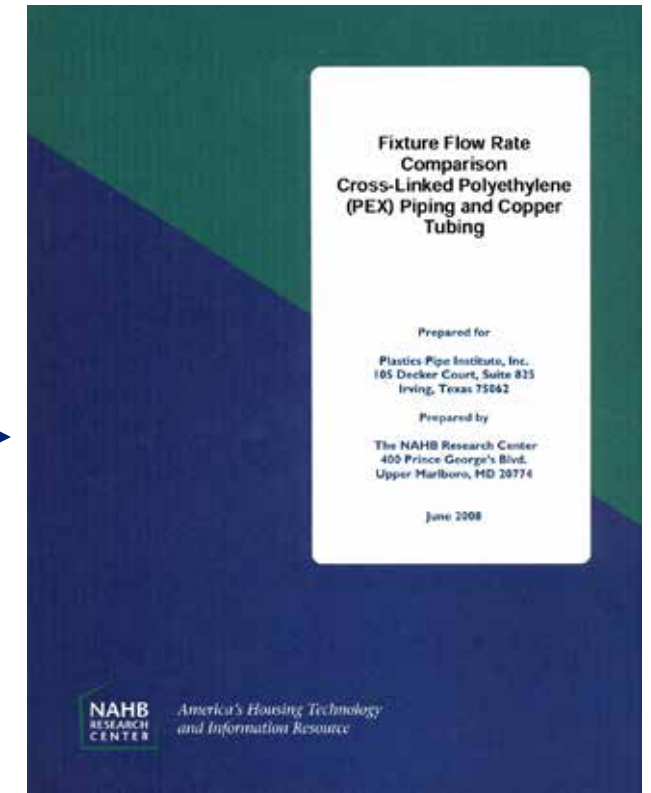


PEX Plumbing System Performance Testing

Flow Rate & Tubing Sizing

- See Chapter 8 “Performance Data” (page 69)

“This testing demonstrates 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. Details of this testing as well as additional test configurations are published in the NAHB-RC report “[Fixture Flow Rate Comparison – Crosslinked Polyethylene \(PEX\) Piping and Copper Tubing](#)” available on the PPI website.”

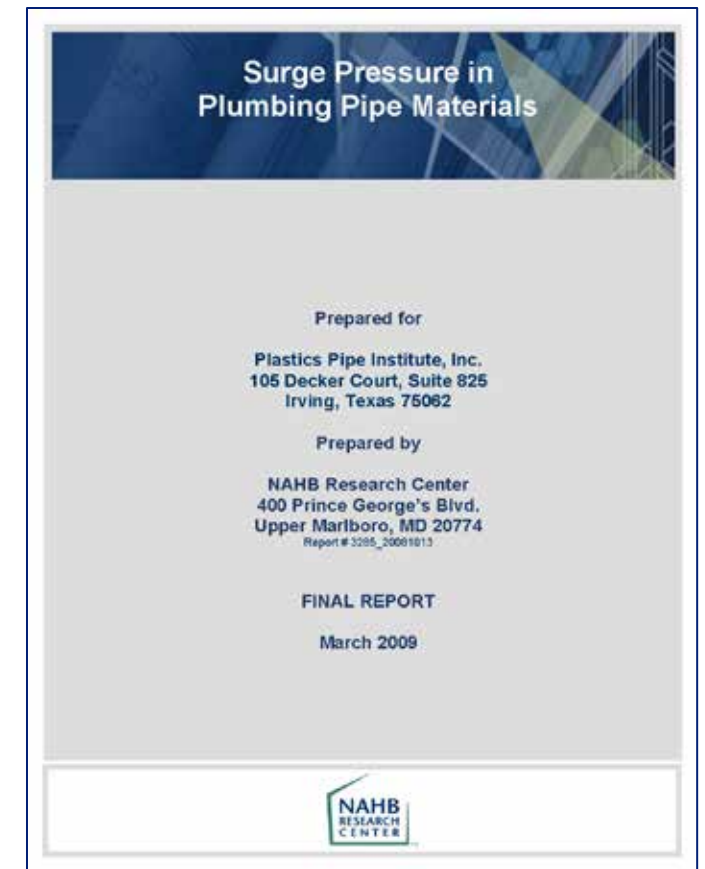
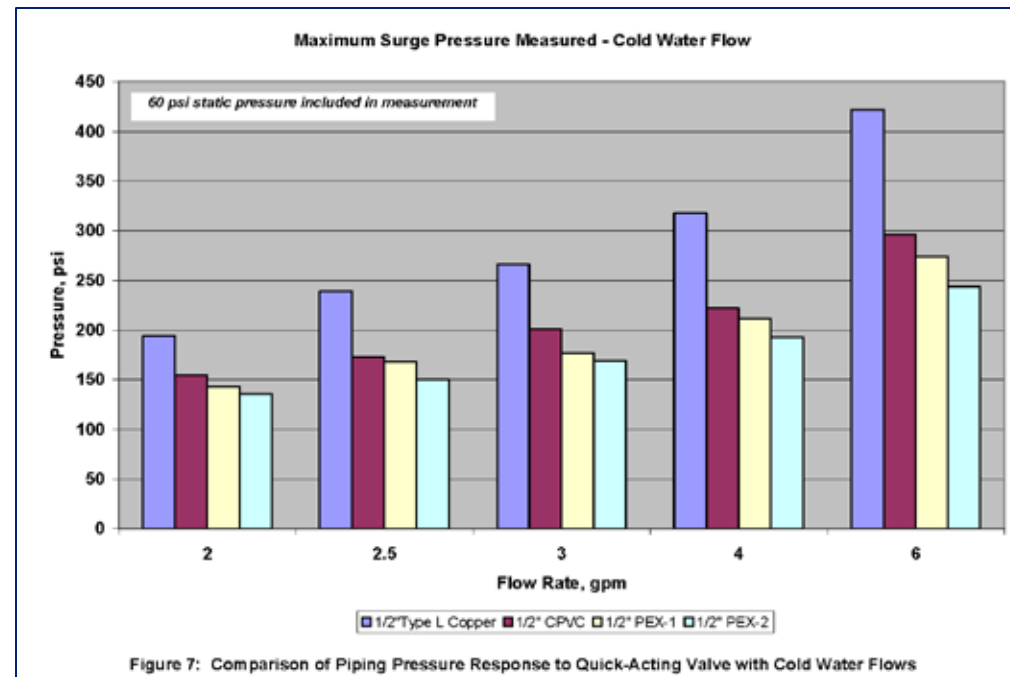


PEX Plumbing System Performance Testing

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



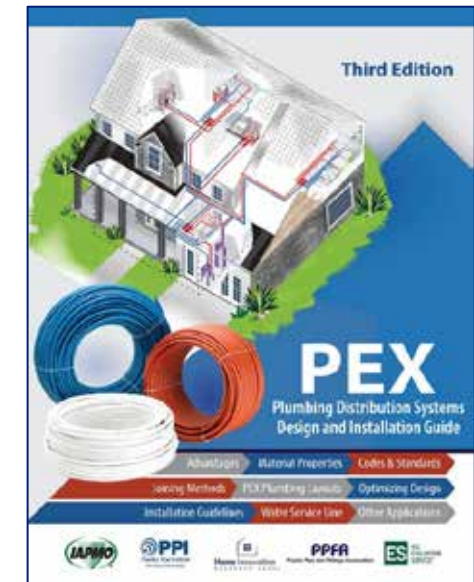
PEX Plumbing System Performance Testing

Surge Pressure/Water hammer

- PEX tubing absorbed surge pressures and reduced peak pressures by **30% (cold)** to **40% (hot)** as compared with copper (see Table 3.4 in GUIDE)

Table 3.4 Peak Pressure Comparison – 2.5 GPM

Pipe Material (NTS 1/2)	54°F Water		130°F Water	
	Pipe Peak 1 (psig)	% Difference	Pipe Peak 1 (psig)	% Difference
1/2 Type L Copper	239	0	181	0
1/2 CPVC	173	28	149	18
1/2 PEX-1	168	30	113	38
1/2 PEX-2	150	37	109	40



PEX Plumbing System Performance Testing

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

- Piping distance of 60 ft.

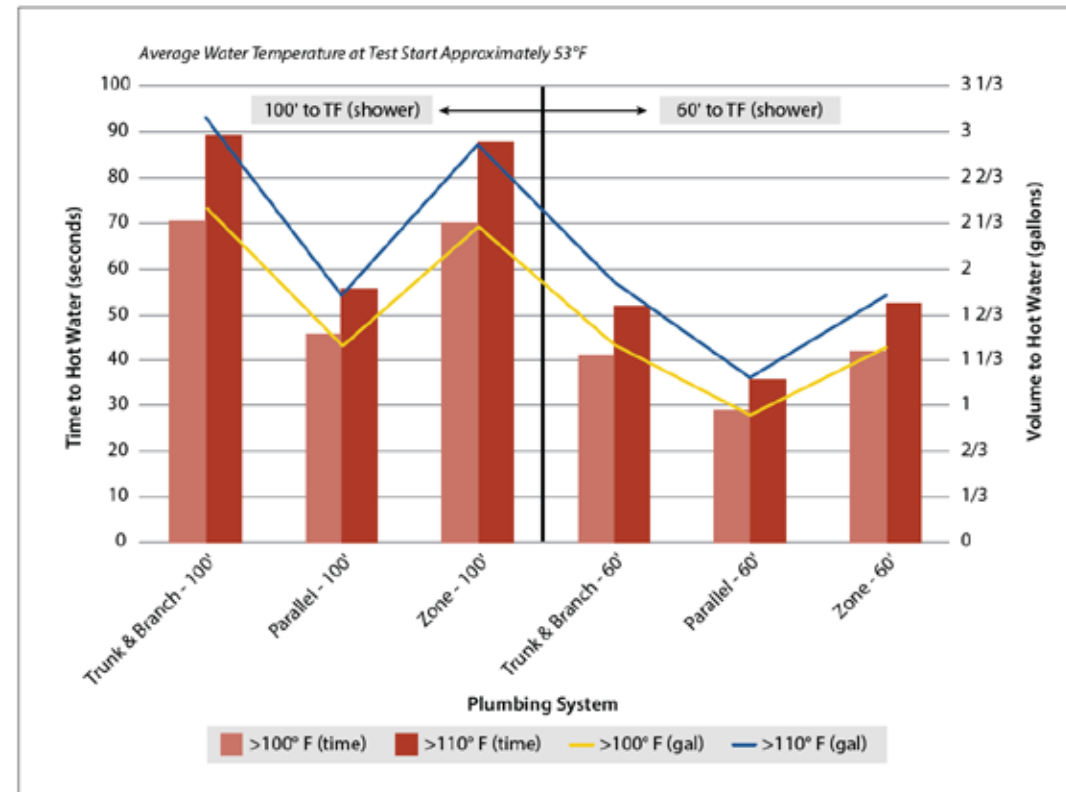
- T&B: 53 sec
- Parallel: 37 sec
- Zoned: 53 sec

- 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%**



- 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**

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.

PEX Plumbing Design and Installation 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

BCD Webpages

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

BCD TECHNICAL LITERATURE



PPI TN-55
2024



PPI MS-7
2023



PPI Statement Y

Model Specifications

- MS-7 Model Specification for Plastic Piping Materials for Ground Source Geothermal Applications
- MS-8 Model Specification for Polypropylene (PP-R & PP-RCT) Pressure Pipe Systems for Plumbing & Mechanical Applications

Statements

- PPI Statement A - Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants on Crosslinked Polyethylene (PEX) Pipes Used in Treated Potable Water
- PPI Statement Y - Taste and Odor of Drinking Water from Plastic Piping Systems
- PPI Statement AA - PFAS Chemicals and Plastic Piping for Potable Water Transport
- PPI Statement AB - Microplastics and Plastic Piping for Potable Water
- PFAS and Plastic Piping Frequently Asked Questions (FAQs)

Recommendations

- PPI Recommendation E - Recommendation Against Mixing Hydronic Heating Water with Potable Water in Combined Systems
- PPI Recommendation F - Testing PEX and PE-RT Tubing Systems with Compressed Air or Inert Gas
- PPI Recommendation G - Recommendation Against Using Epoxy Pipe Coatings Within Plumbing Distribution Systems Utilizing Plastic Components
- PPI Recommendation H - Direct Connection of Plastic Piping Materials to Tankless Water Heaters for Domestic Applications
- PPI Recommendation I - Guidance on Restoring Potable Water Piping Systems Post-Urban/Wildland Wildfires

Position Papers

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

Technical Notes

- TN-14 - Plastic Pipe in Solar Heating Systems
- TN-17 - Crosslinked Polyethylene (PEX) Pipe & Tubing Systems
- TN-26 - Erosion Study on Brass Insert Fittings Used in PEX Piping Systems
- TN-28 - Guide to Differences in Pressure Rating PE Water Pipe Using the ASTM/PPI and ISO Methods
- TN-31 - Differences Between PEX and PB Piping Systems for Potable Water Plumbing Applications
- TN-32 - UV Labeling Guidelines for Crosslinked PEX Tubing and Pipe
- TN-39 - Recommended Practices Regarding Application of Pesticides and Termiticides near PEX Pipes
- TN-46 - Guidance for Field Hydrostatic Testing of High Density Polyethylene Pressure Pipelines
- 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

Accessing Industry Resources

BCD Webpages

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


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 180 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

• Aury	• Mercury
• Bover	• Reliance Worldwide
• CB Supplies	• REHAU
• Golan	• Rifeng
• HeatLink Group Inc.	• Uponor
• Interplast	• Viega LLC
• IPEX	• Watts
• Legend	• Zurn PEX
• ML 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 Hydraulic 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

BCD Webpages

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



PPI BCD PLASTIC PIPE DESIGN CALCULATOR

PPI BCD Plastic Pipe Design Calculator

The BCD Plastic Pipe Design Calculator is a software tool that aids in designing plastic pressure pipe and tubing systems using the materials CPVC, HDPE, PEX, PE-RT, PP-R and PP-RCT. It is intended to assist designers using these materials for applications such as plumbing, water service, fire protection, hydronic piping (liquids), radiant heating & cooling, snow & ice melting, geothermal ground loops, district heating, and turf conditioning.

The tool includes five main functions:

- Pressure/Head Loss
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Hydraulic Shock
- Expansion Arm/Loop

The BCD Calculator utilizes dimensional data from ASTM International and CSA Group industry standards for these piping materials, as well as data gathered from various PPI research projects and publications.

Note on Fittings: Characteristic pressure loss data on pipe fittings is often published by fitting suppliers as "equivalent feet of pipe length". This data is not built into the Calculator, due to the wide variety of fitting designs available in the market. When doing Pressure/Head Loss calculations for piping systems with fittings, the user can manually enter this data for the selected fittings, if it is known, and the pressure loss through fittings will be added to the calculated pressure loss through piping.

PPI PLASTIC PIPE DESIGN CALCULATOR
PlasticPipeCalculator.com

For more information:
[Click Here](#)

Accessing Industry Resources

BCD Webpages

- Technical Publications
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- **Presentations** and recorded webinars
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- Case studies



PPI PRESENTATION SLIDE DECKS

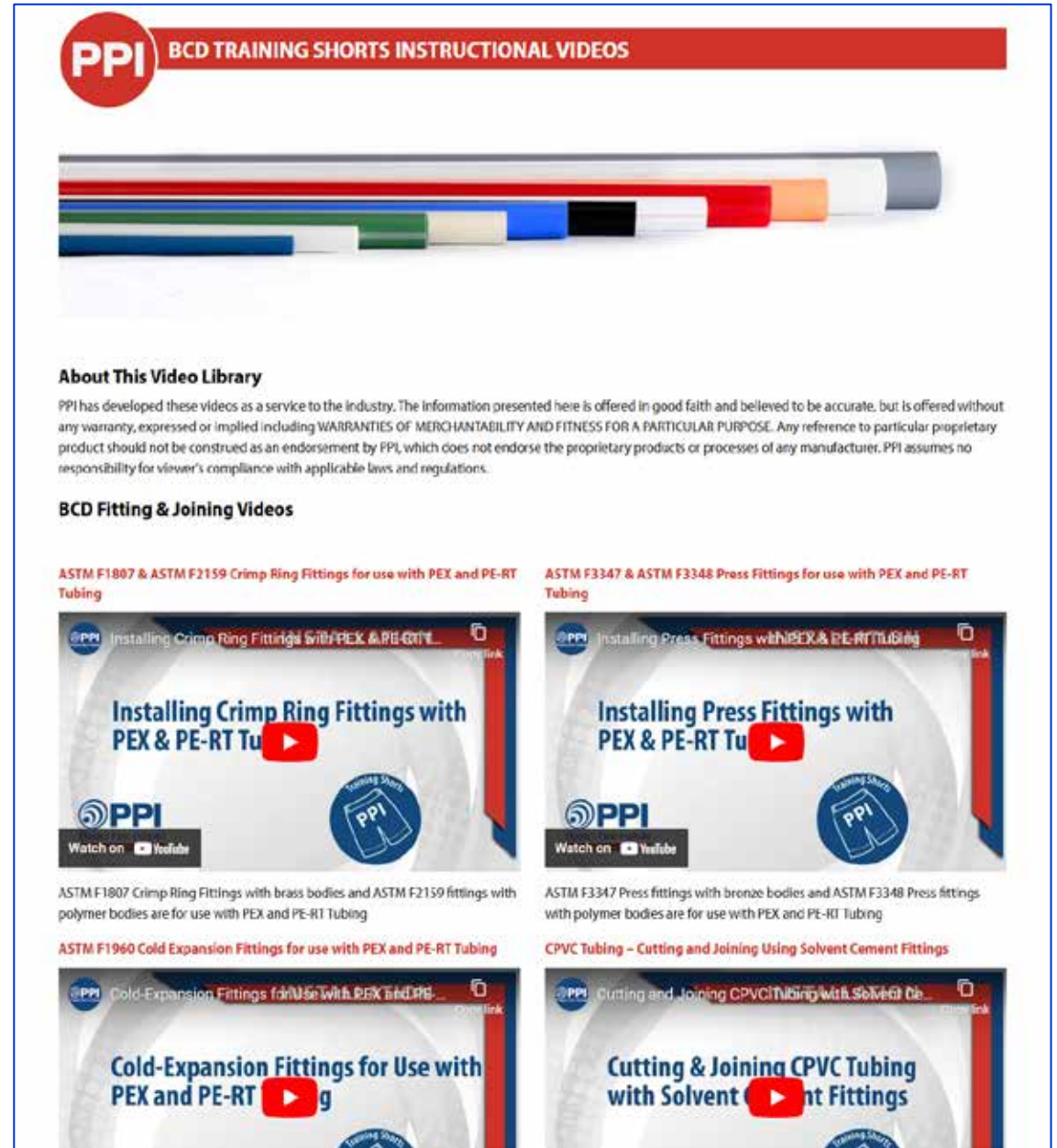
Click on images below to view PDF presentations.

- Designing PEX Plumbing Systems to Optimize Performance and Efficiency**
A presentation by The Plastics Pipe Institute
ASPE CEU PROVIDER
Contact: Lorne MacIver, P. Eng., PPI Director of Engineering - Building & Construction Division, 1990 Central Expressway, Suite 200, St. Catharines, ON L2R 1C7
- Selecting Optimal Pressure Pipe Material(s) for Commercial Plumbing Systems**
A presentation by The Plastics Pipe Institute
ASPE CEU PROVIDER
Contact: Lorne MacIver, P. Eng., PPI Director of Engineering - Building & Construction Division, 1990 Central Expressway, Suite 200, St. Catharines, ON L2R 1C7
- PEX Tubing for Water Service Line Applications**
A presentation by The Plastics Pipe Institute
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Contact: Lorne MacIver, P. Eng., PPI Director of Engineering - Building & Construction Division, 1990 Central Expressway, Suite 200, St. Catharines, ON L2R 1C7

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- Case studies

PPI BCD TRAINING SHORTS INSTRUCTIONAL VIDEOS

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BCD Fitting & Joining Videos

ASTM F1807 & ASTM F2159 Crimp Ring Fittings for use with PEX and PE-RT Tubing

ASTM F3347 & ASTM F3348 Press Fittings for use with PEX and PE-RT Tubing

ASTM F1960 Cold Expansion Fittings for use with PEX and PE-RT Tubing

CPVC Tubing – Cutting and Joining Using Solvent Cement Fittings

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- Plastic Pipe Design Calculator
- Presentations and recorded webinars
- Educational videos
- **Case studies** →



PPI CASE STUDIES

Case Study
CANADA'S LARGEST GEOTHERMAL PROJECT READY TO GO
Vancouver International Airport Underlying Wine Industry Award

Case Study
SNOW-MELT SYSTEM SHARES INDUSTRY HONOR
Keeps Main Clear for Thousands of Students and Daily Transverse Utah's Longest Pedestrian Bridge

Case Study - Project in Action
AIR FORCE BASE WATER SUPPLY PIPING SYSTEM CHALLENGE MET
JOINT BASE SAN ANTONIO-LACKLAND Texas - Building the United States Air Force's new base training facility at Joint Base San Antonio-Lackland, Texas required large diameter pipe and fittings to move 150" diameter pipe and fittings throughout the campus (SFC) water effluents throughout the campus at 90 psi. The problem was that the 8,000 feet of pipe would need to be installed in crew spaces, trenches, and in rear locations. Some 200 fittings would be needed. The goal was to have a system that would provide long term performance and need as little maintenance as possible.

* Denotes Items with available Field Report video. Click [here](#) to view those Field Report Videos as well as other great videos from BCD.

Plumbing

- **PPI Award Winner:** Use of PEX and PP-RCT Pipes Key to the Success for "Society Orlando" High-Rise HVAC and Plumbing Systems (2023)*
- **PPI Award Winner:** Joint Base San Antonio-Lackland Water Supply Piping Challenge Met with PP-RCT Piping System (2021)*
- Reno Revels in Potable Water Installation: Development "Experiences" Pluses of PEX Plumbing
- Riyadh, Saudi Arabia: King Abdullah Financial District (KAFFD) 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 System Award Winning Building
- Homeowners, Frustrated by Pinhole Leaks in Copper Plumbing, Find Relief with PEX
- Uponor PEX Saves Time and Money for Residential High Rise
- Uponor Plumbing Systems Overcome Re-pipe Challenge

Radiant Heating & Cooling

- **PPI Award Winner:** Radiant Heating and Cooling System at University of Chicago Helps to Meet Aggressive Energy Saving Goals (2017)
- **PPI Award Winner:** Heated Drying Slab Project Uses PEX To Save

Geothermal

- **PPI Award Winner:** Vancouver International Airport (YVR) Uses Over 850,000 ft. of HDPE Ground Source Geothermal Pipes (2020)
- **PPI Award Winner:** Whisper Valley Net-Zero Ready Community in Austin, TX Uses PEX based Ground Source Geothermal System

Hydronic Piping

- **PPI Award Winner:** Use of PEX and PP-RCT Pipes Key to the Success for "Society Orlando" High-Rise HVAC and Plumbing Systems (2023)*
- **PPI Award Winner:** Joint Base San Antonio-Lackland Water Supply Piping System Challenge Met Using PP-RCT (2021)*
- **PPI Award Winner:** Wilshire Grand Center in Los Angeles, CA uses 20 Miles of PEX Tubing for Thermal Cooling of Slab (2018)*
- **PPI Award Winner:** Heated Drying Slab at Big Bear Area Regional Wastewater Agency in California Uses PEX Based Heating System (2016)*
- Mechanical Joining System Benefits New Napa Valley Resort
- These Pipes Make HVAC Systems Run More Efficiently

Turf Conditioning

- PGA Championship Course in Tulsa, OK Installs Hydronic Green Conditioning
- Cleveland Browns NFL Stadium - Turf Conditioning System

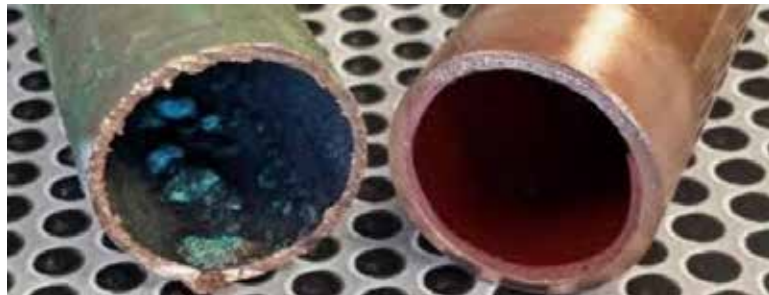
Snow & Ice Melting

- **PPI Award Winner:** This is the Place Heritage Park in Salt Lake City, Utah Uses PEX Snow and Ice Melting System (2022)*
- **PPI Award Winner:** Utah Valley University (UVU) in Orem, Utah Keeps Students Safe with a PEX Snow and Ice Melting System (2021)*
- **PPI Award Winner:** Sun Valley Ski Resort Near Ketchum, ID Uses 32 Miles of PEX Tubing to Melt Snow and Ice (2014)

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: NTS ½ PEX tubing has **87%** of the copper ID (0.475" vs. 0.545")
- Smooth interior surface of PEX provides superior flow through its entire life
- Elimination of most elbows using sweeps reduces pressure drop
- 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 Selection¹

Pipe/Tubing Material: PEX

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

Wall Type (SDR/Schedule): SDR 9

Nominal Pipe/Tubing Size²: 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 % Antifreeze³): 100% Water

Average Fluid Temperature⁴: 73 °F

Annex 2: Reasons to Select PEX Plumbing Systems

PEX Plumbing Systems are Safe, Smart, and Proven

- 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 and Resilient

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



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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

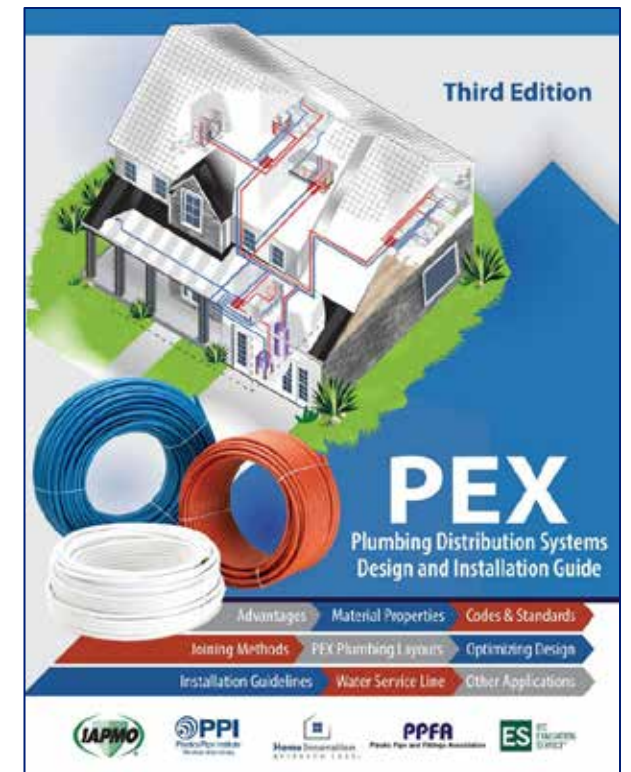
Conclusion

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

Additional information about design and installation of PEX plumbing systems is found within the *PEX Plumbing Systems Design and Installation Guide*

Please refer to this document for details not covered in this presentation

Access the Guide at plasticpipe.org/buildingconstruction



Designing PEX Plumbing Systems to Optimize Performance and Efficiency

Contact

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