Designing PEX Plumbing Systems to Optimize Performance and Efficiency

A presentation by the Plastics Pipe Institute

Contact:
Lance MacNevin, P.Eng.
PPI Director of Engineering - Building & Construction Division
lmacnevin@plasticpipe.org Tel (469) 499-1057
The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry
- PPI was formed in 1950 to develop test methods for plastic pressure pipes
- Today: Non-profit trade association serving North America

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

Members: PPI members share a common interest in broadening awareness and creating opportunities that expand market share and extend the use of plastics pipe in all of its many applications
The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry
- Today, PPI’s five divisions focus on solutions for multiple applications:
  - Building & Construction Division
  - Corrugated Plastic Pipe
  - Energy Piping Systems Division
  - Municipal & Industrial Division
  - Power & Communications Division

PCD: HDPE Conduit for fiber optic  
EPSD: Gas distribution piping  
MID: HDPE water mains
The Plastics Pipe Institute

PPI’s 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 and cooling, snow and ice melting, district heating and cooling, and ground source geothermal piping systems.

Materials: CPVC, HDPE (Geo), PEX, PE-RT, & PP

BCD involvement with industry groups
Course Introduction

- 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

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

- PEX systems are already established for residential applications, and are being adopted for commercial plumbing applications

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

- Much of the information in this course is taken from the PEX plumbing DESIGN GUIDE

- Both PPI and PPFA provided content for Home Innovation Research Labs*, which also conducted the included research

- The GUIDE is available as free download from: www.plasticpipe.org (BCD homepage) and www.homeinnovation.com

*Formerly known as the NAHB Research Center
Course Background

Plastic Pressure Pipe Design Calculator
- For design calculations related to pressure loss, pipe weight/volume, thermal expansion & contraction, expansion arm/loop design and to predict hydraulic shock & pressure surges, simply go to www.plasticpipecalculator.com and hit
Learning Objectives

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

1. Explain how the properties of PEX tubing and fittings can improve health, safety and welfare through improved plumbing materials
2. Describe three distinct plumbing layouts using PEX systems and compare advantages and disadvantages of each
3. Apply test data from published research to demonstrate how design of the plumbing layout can improve system performance and provide faster delivery of hot-water with reduced water waste
4. Direct an installer on correct installation techniques for PEX systems to ensure long-term safety and performance
5. Discuss how to access industry resources for material, design and installation info
1. How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

This Learning Objective will explain the piping components:

1. PEX Tubing: Crosslinked Polyethylene
2. PEX Fittings: Brass, copper and polymer materials, several designs
3. Plumbing Distribution Manifolds: Several designs and materials
4. Tubing Fasteners: Those intended for PEX plumbing systems

Courtesy NIBCO
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

1. PEX: Crosslinked Polyethylene
   - Introduced for radiant heating in the early 1970’s in Europe
   - Introduced to USA and Canada in 1984 for heating and plumbing
   - PEX is a high-temperature flexible pressure piping system
   - PEX tubing systems are used for water service lines, hot- and cold-water distribution, radiant heating and cooling, outdoor snow and ice melting, residential fire protection, geothermal ground loops and other demanding applications

Courtesy REHAU
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

PEX: Crosslinked Polyethylene
Formal Definition – “Crosslinked Polyethylene 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.”

Source: PPI Technical Note 17
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

PEX: Crosslinked Polyethylene
- PEX plumbing tubing is currently produced in nominal tubing sizes from 1/4 to 3
- 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 PEX Tubing and Fittings Can Improve Health, Safety and Welfare

Advantages of PEX Plumbing Systems
- Safety of potable water and long-term reliability
- Resistance to corrosion, erosion, water disinfectants
- Smooth wall, excellent flow characteristics
- High pressure capability/stability (reduced creep)
- Quiet operation, absorbs pressure surges (reduced water hammer)
- Flexibility to ease installations
- Many fitting and joining options; no open flames
- Proven long life, rigorous certifications, highly tested
- Water conservation is assisted with reduced heat loss
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

PEX Plumbing Systems are Sustainable
- Lower cost to the environment for production
- No mining operations for the ore
- 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
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

PEX Tubing Production Methods
The three common methods of crosslinking polyethylene are:
- Peroxide (PEX-a)
- Silane (PEX-b)
- Electron beam (PEX-c)

- Letter designations not related to any type of performance rating system

- PEX tubing produced by each of the three methods must meet the same technical requirements as specified in the relevant PEX standards
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

PEX Tubing Production Methods
The three common methods of crosslinking polyethylene are:

- **Peroxide (PEX-a):** *This method employs organic peroxides that generate reactive free radicals that splice PE chains together during extrusion*

- **Silane (PEX-b):** *This method 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):** *This method involves subjecting the extruded PE pipe to a dose of high-energy electrons*

- See *PPI Technical Note 17* for more details about each method
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PEX Tubing Standards
- There are two primary standards for PEX tubing in North America:
  - ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*
  - CSA B137.5 *Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications*
- Codes such as IPC, UPC and the NPC of Canada refer to these standards
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PEX Tubing Standards
- ASTM F876 and CSA B137.5 establish capabilities and test requirements, such as:
  - Dimensions
  - Long-term pressure ratings
  - Quick burst pressures
  - Chlorine resistance
  - UV resistance
  - Excessive pressure-temperature capability
  - Hot-bend and cold-bend tests
  - Marking requirements
  - Even more…
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PEX Tubing Standards: Dimensions
- PEX tubing is Nominal Tubing Size (NTS)
- All PEX tube dimensions are the same (within slight tolerances)
- PEX is Copper Tube Size (CTS, same OD as copper tubing)
- PEX is SDR9 (wall thickness is 1/9 of the OD) with tight tolerances on dimensions

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
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PEX Tubing Standards: “Tubing vs. Pipe”
- PEX “Tubing”: the actual Outside Diameter is 1/8 inch larger than the nominal size
- PEX “Pipe”: the actual Outside Diameter matches that of steel pipe of the same nominal size, or products where the actual OD matches the nominal size
  - PEX Pipe uses nominal sizes such as ‘NPS 3/4’
  - PEX Pipe is not widely used for plumbing in NA
- PEX Pipe is typically used in industrial applications and in larger diameters
- ASTM F2788 applies to PEX Pipe, not intended for plumbing applications

- While people often use “Tubing” and “Pipe” interchangeably, “Tubing” is accurate
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PEX Tubing Standards: Test Methods

- Specific test methods for PEX Tubing:
  - **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

PEX Tubing is also certified to:

- **NSF/ANSI Standard 61** Toxicological Evaluation for Materials in Contact with Drinking Water (“Health Effects”)
- **NSF/ANSI Standard 372:** Drinking Water System Components, Lead Content
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ASTM F876 & CSA B137.5 Categories for Performance – 3 Key Properties:
1. Chlorine Resistance
2. UV Resistance
3. Hydrostatic Design Strength (HDS), related to pressure ratings
   - Performance categories are defined in the “Material Designation Code” per F876
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Chlorine Resistance: Four (4) Categories of Performance

0: Not tested or not rated
1: 25% of time hot at 140°F, 75% of time at 73°F (e.g. intermittent hot water)
3: 50% of time hot at 140°F, 50% of time at 73°F (e.g. timed hot water recirculation, such as up to 12 hours per 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

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<th>Standard</th>
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<th>2</th>
<th>3</th>
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<td>F2023</td>
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<td>75 % at 73°F and 25 % at 140°F</td>
<td>Reserved</td>
<td>50 % at 73°F and 50 % at 140°F</td>
<td>Reserved</td>
<td>100 % at 140°F</td>
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</table>
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Chlorine Resistance: Four (4) Categories of Performance

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.
- Multiple specimens of tubing are tested to failure at three pressure and three temperatures, typically 95°C, 105°C and 115°C (203°F, 221°F and 239°F).
- “Extrapolated time-to-failure” of tubing at each end-use condition (1, 3, 5) is calculated using Miner’s Rule formula, based on end-use conditions of 80 psig @ 140°F.
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UV Resistance: Four (4) Categories of Performance

0: Not tested or not rated
1: 1 month
3: 3 months
5: 6 months

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<th>Standard</th>
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<th>1</th>
<th>2</th>
<th>3</th>
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<tr>
<td>Minimum UV Resistance</td>
<td>F2657</td>
<td>Not tested or rated</td>
<td>1 month</td>
<td>3 months</td>
<td>6 months</td>
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</table>

Details:
PEX samples are tested in accordance with ASTM Test Method F2657, exposed to natural sunlight (Arizona) during the most aggressive months of the year.
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PEX Tubing Standards: Burst Pressure
- Product standards have equivalent requirements for short-term burst pressure:
- Requirements:
  - ASTM F876 475 psig at 73°F
  - CSA B137.5 3.27 MPa @ 23°C (the SI equivalent)
- PEX tubing and systems are also tested for burst pressure capabilities at 180°F and 200°F (82°C and 93°C)

Details:
- PEX tubing is tested in accordance with ASTM D2837
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PEX Tubing Standards: Pressure Ratings

- Product standards have equivalent requirements for long-term pressure ratings:

  - Requirements:
    - ASTM F876 100 psig at 180°F
    - CSA B137.5 690 kPa @ 82°C (the SI equivalent)

- PEX tubing and systems are also tested for sustained pressure capabilities at 73°F and 200°F (23°C and 93°C)

Details:

- PEX tubing is tested 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
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PEX Tubing Standards: Flame and Smoke Ratings
- 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
- These values are generated in standardized testing in accordance with ASTM E84 and CAN/ULC S102.2 test methods using the “Steiner Tunnel” test

- Image of Steiner Tunnel at UL LLC
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PEX Tubing Standards: Flame and Smoke Ratings

- 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.
- Each PEX manufacturer submits its tubing for testing and publishes the listings.

- Suggested spec language: “PEX tubing shall have a Flame Spread Index ≤ 25 and a Smoke Developed Index ≤ 50 listed to ASTM E84 (USA) or CAN/ULC S102.2 (Canada). This listing may require the tubing to be installed in a rated insulation material or an approved steel support channel.”
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PEX Performance: Freeze Break Resistance
- PEX tubing is less susceptible to the effects of cold temperatures, retaining its flexibility even below freezing
- This flexibility means that if water-filled PEX tubing freezes, the elasticity of the material 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 within walls or ceilings for plumbing applications
- Water-filled PEX tubing allowed to freeze inside a slab or highly-compacted soil may not be able to expand evenly, and may be damaged

- Consult with tubing manufacturer for more information
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PEX Performance: R-Value and Conductivity

PPI TR-48: R-Value and Thermal Conductivity of PEX and PE-RT reports these findings:
- PEX k-value: 2.86
- Copper k-value: 196 (68 times more conductive)

Thermal Resistance of PEX
- PEX size: 1/2" 3/4" 1" 1 1/4" 1 1/2" 2"
- R-value: 0.028 0.038 0.049 0.060 0.072 0.093

Although PEX tubing has inherent insulating properties, insulation is still recommended for certain installations
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

PEX Performance Vs. Copper Tubing
- Corrosion resistance, erosion resistance (no pinholes)
- Resistance to scale and build-up
- Flexibility absorbs surge pressures, water hammer
- Quiet operation, no vibration transfer
- Tolerates high velocities
- Better heat retention, less condensation
- No flame used for joining, less burn risk
- No solder or flux added at joints
- Light weight, easier to transport
- A more sustainable choice, better design options
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2. PEX Fittings
- There are several types of fittings designed for use with PEX tubing
- PEX fittings are produced from lead-free brass alloys, copper and polymers
- Polysulfone (PLS) and polyphenylsulfone (PPSU) are thermoplastic polymers known for their toughness, stability at high temperatures, and chlorine resistance
- These are the typical polymers used for fittings and manifolds as part of PEX systems
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

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

- These standards define the performance of the joints/connections, test methods, etc.
  - Burst pressure, long-term sustained pressure
  - Hot- and cold-water thermocycling
- PEX fittings must also meet **NSF/ANSI Standard 61 for health effects**

- Numerous individual product standards have been written for PEX fitting designs
  - Examples: ASTM F1807, ASTM F1960, ASTM F2080, ASTM F2159 and ASSE 1061
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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

ASTM F1807 Crimp Assembly
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**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.
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Press fittings using stainless steel sleeve. Available in polymer and lead-free brass.
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ASTM F1960 Cold-expansion fitting using a PEX ring. Available in polymer and lead-free brass.

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

Courtesy REHAU
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ASSE 1061 Push-fit fittings
Available in polymer and lead-free brass.
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

ASSE 1061 Push-fit fittings
Available in polymer and lead-free brass.
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

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.
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Commercial Applications – Adapting to Other Piping Materials
- Various adapters available: Press fittings, Flanges, Grooved, MPT and FPT adapters
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Commercial Applications – Adapting to Other Piping Materials
- Various adapters available: Copper sweeps, various adapters

Courtesy Uponor
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

PEX Fittings Standards
- Keep in mind that not all PEX fittings are approved for use with all PEX tubing
  - Some combinations are not approved!
- Tubing manufacturers test and certify the specific fitting designs before they may recommend them for use with their tubing
- The standard designation(s) of the fitting system(s) for which the tubing is recommended by the tubing manufacturer and that is specifically qualified for use with PEX is marked on the tubing
- In other words, look for markings such as “F1807”, “F1960”, “F2080”, “F2159” or “ASSE 1061” on the tubing print line to show compatibility and approval
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PEX Fittings Standards
- Look for markings such as “F1807”, “F1960”, “F2080”, “F2159” or “ASSE 1061” on the tubing print line to show compatibility and approval.
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3. PEX Distribution Manifolds
- Several styles of manifolds are available in several materials
  - Copper, polymer*
  - Valved, valveless

- All manifolds must meet the same requirements as PEX fitting systems: ASTM F877

*Polysulfone (PLS) and polyphenylsulfone (PPSU) are thermoplastic polymers known for their toughness, stability at high temperatures, and chlorine resistance. These are the typical polymers used for fittings and manifolds as part of PEX systems.
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

3. PEX Distribution Manifolds
   - Several styles of manifolds are available in several materials
     - Copper, polymer*
     - Valved, valveless
   - More images in next LO
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

4. PEX Tubing Fasteners
- PEX tubing is extremely tough and durable and is compatible with several types of fasteners – usually plastic holders
- Manufacturers have preferred fasteners and some might have prohibited fasteners
- Contractors/installers have preferred fasteners for various construction types
- This topic will be addressed in greater detail in Learning Objective #4 “Installation”

Holders  Isolators  PE Sleeving  Talons
How PEX Tubing and Fittings Can Improve Health, Safety and Welfare

Summary: This Learning Objective explained the piping components

1. PEX Tubing: Crosslinked Polyethylene
2. PEX Fittings: Brass, copper and polymer materials, several designs
3. Plumbing Distribution Manifolds: Several designs and materials
4. Tubing Fasteners: Those intended for PEX plumbing systems
2. Plumbing Layouts Using PEX

This Learning Objective describes three layout options:

1. Trunk and Branch (a.k.a. traditional)
2. Parallel pipe systems (a.k.a. home run)
3. 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 longevity, comfort, cost, installation time, environmental soundness and performance.
Plumbing Layouts Using PEX

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

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

- T&B is commonly used in commercial plumbing design
Plumbing Layouts Using PEX

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

- **Parallel** technique employs 3/8” or 1/2” pipes which are “home-run” to each fixture
  - Small tubing of one size is easy to install
- Tubing is connected to central manifolds (hot and cold)
  - Manifolds (often valved) are located near the 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

Courtesy Viega
Plumbing Layouts Using PEX

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” pipes 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)

*Courtesy Uponor*
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 might be the slowest installation technique
- Experienced plumbers may reduce installation time and/or materials in 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 Parallel systems

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

- Parallel systems may be ideal for certain designs, especially small residential systems, shorter lengths
Plumbing Layouts Using PEX

Comments on Parallel systems

- Although PEX tubing works well in a parallel home-run layout, this technique requires a lot of tubing, many holes in studs and plates, greater need for fasteners, and potentially longer installation time
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Plumbing Layouts Using PEX

Comments on Parallel systems

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

- **Parallel systems** may be ideal for certain designs, especially small residential systems, shorter lengths.
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 over T&B and Parallel

- **Zoned systems** may be ideal for certain designs, especially when 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

<table>
<thead>
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<td><strong>Factor</strong></td>
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<td>Minimize Pipe Used</td>
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<tr>
<td>Minimize Fittings and Joints</td>
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<tr>
<td>Sequential Flow Hot Water Delivery Time</td>
</tr>
<tr>
<td>Minimize Hot Water Wait Time</td>
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<tr>
<td>Single Fixture Pressure</td>
</tr>
<tr>
<td>Pressure Stability with Use of Multiple Fixtures</td>
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<tr>
<td>Centralize Shut-off Valving</td>
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<td>Joint Accessibility During Installation</td>
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* *** 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

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<th>Tube Size (nominal)</th>
<th>Tube OD (average) in. *</th>
<th>Wall thickness (average) in. *</th>
<th>Tube ID (average) in. *</th>
<th>Weight of tube only, pounds per foot</th>
<th>Weight of tube &amp; water, pounds per foot</th>
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<th>Volume per 100 ft. (gallon)</th>
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<td>1.054</td>
<td>0.25</td>
<td>0.63</td>
<td>0.045</td>
<td>4.5</td>
</tr>
<tr>
<td>1 1/2</td>
<td>1.625</td>
<td>0.191</td>
<td>1.244</td>
<td>0.35</td>
<td>0.88</td>
<td>0.063</td>
<td>6.3</td>
</tr>
<tr>
<td>2</td>
<td>2.125</td>
<td>0.248</td>
<td>1.629</td>
<td>0.60</td>
<td>1.50</td>
<td>0.108</td>
<td>10.8</td>
</tr>
<tr>
<td>2 1/2</td>
<td>2.625</td>
<td>0.307</td>
<td>2.011</td>
<td>0.92</td>
<td>2.29</td>
<td>0.165</td>
<td>16.5</td>
</tr>
<tr>
<td>3</td>
<td>3.125</td>
<td>0.364</td>
<td>2.397</td>
<td>1.29</td>
<td>3.24</td>
<td>0.235</td>
<td>23.5</td>
</tr>
</tbody>
</table>

*Based on average OD and wall thickness dimensions as per ASTM F876/CSA B137.5
Plumbing Layouts Using PEX

Volume and Weights of PEX Tubing Sizes
- BCD Calculator also does Volume* of PEX tubing sizes. Example: ¾ nominal PEX

Images from www.plasticpipecalculator.com

*Based on average OD and wall thickness dimensions as per ASTM F876/CSA B137.5
Plumbing Layouts Using PEX

Volume and Weights of PEX Tubing Sizes
- BCD Calculator also does Volume* of PEX tubing sizes. Example: 1 ½ nominal PEX

Images from www.plasticpipecalculator.com

*Based on average OD and wall thickness dimensions as per ASTM F876/CSA B137.5
Plumbing Layouts Using PEX

Summary: This Learning Objective described 3 layout options

1. Trunk and Branch (a.k.a. traditional)
2. Parallel pipe systems (a.k.a. home run)
3. Zoned systems (a.k.a. remote manifolds)

In Learning Objective #3 we’ll see how to optimize designs
3. Optimizing Design

This Learning Objective discusses performance of the three layout options (Learning Objective #2) for four types of residences:

1. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths
2. Ranch: 1,300 square feet, one story, 2 full baths
3. Townhouse: 1,000 square, three levels, 1 full bath, 1 half bath
4. 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
Optimizing Design

The primary goal of hot-water plumbing is to deliver hot water as soon as possible with minimal waste
- Good plumbing design can help to achieve this goal
- Also important is the architecture/design of the house as related to plumbing

For example:
1. Group fixtures together in a common location, stacking bathrooms
2. Centrally locate the distribution points for hot and cold water
3. Create spaces for bundled pipe runs
   - For Parallel piping, group pipes together (hot-with-hot, cold-with-cold)
4. Insulate pipes where necessary
   - Although PEX tubing is an insulator as compared with copper, code requirements and common sense still apply
   - See PPI TR-48 R-Value and Thermal Conductivity of PEX and PE-RT
## Optimizing Design

### ASPE Time-to-Tap Performance Criteria

<table>
<thead>
<tr>
<th>Volume in the Pipe (ounces)</th>
<th>Minimum Time-to-Tap (seconds) at Selected Flow Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.25 gpm</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>24</td>
<td>45</td>
</tr>
<tr>
<td>32</td>
<td>60</td>
</tr>
<tr>
<td>64</td>
<td>120</td>
</tr>
<tr>
<td>128</td>
<td>240</td>
</tr>
</tbody>
</table>

- **Acceptable Performance**: $\leq 10$ seconds
- **Marginal Performance**: $> 10 \leq 30$ seconds
- **Unacceptable Performance**: $> 30$ seconds

With proper design, PEX plumbing systems can help to reduce wait time for hot water.

Optimizing Design

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

1. Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths
2. Ranch: 1,300 square feet, one story, 2 full baths
3. Townhouse: 1,000 square, three levels, 1 full bath, 1 half bath
4. Condo: 1,200 square feet, one level, 2 full baths
Optimizing Design

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

Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths
- Parallel Design (home run)
Optimizing Design

Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths
- Zoned Design (remote manifolds)
Optimizing Design

Colonial: 2,000 square feet, basement, two levels, 4 BR, 2 full baths
- Material Summary in Table 7.4

<table>
<thead>
<tr>
<th>System</th>
<th>Length of Cold Pipe</th>
<th>Length of Hot Pipe</th>
<th>Fittings</th>
<th>Manifolds/Multi-port Tees</th>
<th>Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1”</td>
<td>3/4”</td>
<td>1/2”</td>
<td>1”</td>
<td>3/4”</td>
</tr>
<tr>
<td>Trunk and Branch</td>
<td>27’</td>
<td>80’</td>
<td>110’</td>
<td>0’</td>
<td>80’</td>
</tr>
<tr>
<td>Parallel</td>
<td>33’</td>
<td>12’</td>
<td>602’</td>
<td>0’</td>
<td>12’</td>
</tr>
<tr>
<td>Zone</td>
<td>27’</td>
<td>93’</td>
<td>152’</td>
<td>0’</td>
<td>93’</td>
</tr>
</tbody>
</table>
Optimizing Design

Ranch: 1,300 square feet, one story, 2 full baths
- Three designs were compared
Optimizing Design

Ranch: 1,300 square feet, one story, 2 full baths
- Material Summary in Table 7.6

<table>
<thead>
<tr>
<th>System</th>
<th>Length of Cold Pipe</th>
<th>Length of Hot Pipe</th>
<th>Fittings</th>
<th>Manifolds/ Multi-port Tees</th>
<th>Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1&quot;</td>
<td>3/4&quot;</td>
<td>1/2&quot;</td>
<td>1&quot;</td>
<td>3/4&quot;</td>
</tr>
<tr>
<td>Trunk and Branch</td>
<td>25'</td>
<td>75'</td>
<td>112'</td>
<td>0'</td>
<td>72'</td>
</tr>
<tr>
<td>Parallel</td>
<td>25'</td>
<td>10'</td>
<td>413'</td>
<td>0'</td>
<td>10'</td>
</tr>
<tr>
<td>Zone</td>
<td>25'</td>
<td>59'</td>
<td>196'</td>
<td>0'</td>
<td>59'</td>
</tr>
</tbody>
</table>
Optimizing Design

Townhouse: 1,000 square, three levels, 1 full bath, 1 half bath
- Material Summary in Table 7.8

<table>
<thead>
<tr>
<th>System</th>
<th>Length of Cold Pipe</th>
<th>Length of Hot Pipe</th>
<th>Fittings</th>
<th>Manifolds/Multi-port Tees</th>
<th>Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1”</td>
<td>3/4”</td>
<td>1/2”</td>
<td>1”</td>
<td>3/4”</td>
</tr>
<tr>
<td>Trunk and Branch</td>
<td>0’</td>
<td>66’</td>
<td>86’</td>
<td>0’</td>
<td>30’</td>
</tr>
<tr>
<td>Parallel</td>
<td>0’</td>
<td>42’</td>
<td>247’</td>
<td>0’</td>
<td>11’</td>
</tr>
<tr>
<td>Zone</td>
<td>0’</td>
<td>67’</td>
<td>100’</td>
<td>0’</td>
<td>30’</td>
</tr>
</tbody>
</table>
Optimizing Design

Condo: 1,200 square feet, one level, 2 full baths
- Material Summary in Table 7.10

<table>
<thead>
<tr>
<th>System</th>
<th>Length of Cold Pipe</th>
<th>Length of Hot Pipe</th>
<th>Fittings</th>
<th>Manifolds/ Multi-port Tees</th>
<th>Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1”</td>
<td>3/4”</td>
<td>1/2”</td>
<td>1”</td>
<td>3/4”</td>
</tr>
<tr>
<td>Trunk and Branch</td>
<td>0’</td>
<td>45’</td>
<td>120’</td>
<td>0’</td>
<td>45’</td>
</tr>
<tr>
<td>Parallel</td>
<td>0’</td>
<td>10’</td>
<td>295’</td>
<td>0’</td>
<td>10’</td>
</tr>
<tr>
<td>Zone</td>
<td>0’</td>
<td>35’</td>
<td>132’</td>
<td>0’</td>
<td>35’</td>
</tr>
</tbody>
</table>
Optimizing Design

Measuring Performance
- *Home Innovations* built a simulated house in their plumbing lab and measured results
- Same simulated house, plumbed three ways:
  - Trunk & Branch
  - Parallel
  - Zoned

*Figure 8.1 – Fixture Layout for Laboratory Testing*
Optimizing Design

Measuring Performance
- *Home Innovations* built a simulated house in their plumbing lab and measured results
- Same simulated house (Colonial), plumbed three ways:

![Image 1](image1.png)

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

![Image 2](image2.png)

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

Measuring Performance: Wait Time for Hot Water, from 53°F to 110°F:

- Distance of 60 ft.
  - T&B: 53 sec
  - Parallel: 37 sec
  - Zoned: 53 sec
  - Parallel is faster by 30%

- Distance of 100 ft.
  - T&B: 92 sec
  - Parallel: 56 sec
  - Zoned: 89 sec
  - Parallel is faster by 38%
Optimizing Design

Measuring Performance: Test Summary

- **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** 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.

- **DESIGN GUIDE** includes measured data about pressures.
Optimizing Design

Notes on Tube Sizing
- According to NAHB report “Fixture Flow Rate Comparison: PEX and Copper Tubing” PEX tubing can typically be installed in place of copper pipes on a size-for-size basis
  - Fixtures actually control the flow!
  - Many pipe designs are oversizing pipes today
- Although the ID of PEX tubing is slightly less than copper (e.g. 0.485” vs. 0.500” for ½ in. nominal), thanks to smooth wall and elimination of most elbows, codes allow for size-for-size replacement
- Details in DESIGN GUIDE

Exception: Alternate system designs may actually reduce pipe diameter requirements
Optimizing Design

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

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

Access the data as demonstrated in the DESIGN GUIDE to compare design options for any type of building
4. Installation Techniques

This Learning Objective discusses correct installation techniques for PEX plumbing systems

1. Bending and flexibility
2. Fasteners
3. Protection
4. Installation under slabs
5. Linear expansion and contraction
6. Pressure testing
Installation Techniques

Bending and Flexibility

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

For example:

<table>
<thead>
<tr>
<th>Tube Size (nominal)</th>
<th>Tube OD (actual)</th>
<th>6X Minimum Bend</th>
<th>8X Minimum Bend</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 in.</td>
<td>0.500 in.</td>
<td>3.0 in.</td>
<td>4.0 in.</td>
</tr>
<tr>
<td>1/2 in.</td>
<td>0.625 in.</td>
<td>3.8 in.</td>
<td>5.0 in.</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>0.875 in.</td>
<td>5.3 in.</td>
<td>7.0 in.</td>
</tr>
<tr>
<td>1 in.</td>
<td>1.125 in.</td>
<td>6.8 in.</td>
<td>9.0 in.</td>
</tr>
<tr>
<td>1 1/4 in.</td>
<td>1.375 in.</td>
<td>8.3 in.</td>
<td>11.0 in.</td>
</tr>
<tr>
<td>1 1/2 in.</td>
<td>1.625 in.</td>
<td>9.8 in.</td>
<td>13.0 in.</td>
</tr>
<tr>
<td>2 in.</td>
<td>2.125 in.</td>
<td>12.8 in.</td>
<td>17.0 in.</td>
</tr>
</tbody>
</table>
Installation Techniques

Bending and Flexibility

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

For example:

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

Bending and Flexibility

- Bend supports/support bends/sweeps may be used to replace most elbows
- These accessories can save the time and cost of installing elbows
Installation Techniques

Bending and Flexibility

- Some installers prefer to install elbows
- Elbows may be necessary in confined areas
Installation Techniques

Fastening PEX

- Horizontal runs should be supported every 32 inches (80 cm) for sizes ≤1” and every 48 inches (120 cm) on diameters >1”
- Vertical runs must be supported every 60 inches
- Steel support channel can extend hanger spacing to 8 ft (2.4 m)
  - Support channel is often used in commercial installations

Courtesy REHAU
Installation Techniques

Fastening PEX: Commercial Applications with Support Channel

- Galvanized steel support channel reduces hanger spacing and thermal expansion
- Channel is typically used with clevis hangers @ 6 to 8 ft. (1.8 - 2.4 m) hanger spacing
Installation Techniques

Fastening PEX: Commercial Applications with Support Channel

- Galvanized steel support channel reduces hanger spacing and thermal expansion
- Channel is typically used with clevis hangers @ 6 to 8 ft. (1.8 - 2.4 m) hanger spacing
Installation Techniques

Protection

- Protect PEX from abrasion and obvious abuse like cuts or gouges
- Use sleeves or plastic isolators through metal studs (not required in wood studs) to avoid continuous abrasion
Installation Techniques

Protection

- Use hangers that are smooth without sharp edges - plastic is preferred
  - Hangers should not pinch the tube
- Use nail plates where PEX passes within 2 in. (5 cm) of a nailing surface on a stud
Installation Techniques

Fire Stopping

- When plastic pipe penetrates a fire-rated assembly (i.e., floor, ceiling, wall), the penetration must be protected by an approved through-penetration firestop system.
- Solutions include intumescent caulks, wrap strips, pass-through devices, collars and cast-in-place sleeves.
- Many firestop manufacturers have products listed for use with PEX tubing.
Installation Techniques

Installation Under Slabs

- PEX plumbing is recommended for use under slabs in most applications
- Installers must protect PEX from abrasion
  - Sleeve tubing where it passes through concrete to protect against abrasion
- It’s recommended to insulate hot-water PEX tubing within slabs
Installation Techniques

Longitudinal Expansion and Contraction

- Linear expansion rate of PEX: **1.1 inch per 10°F per 100 ft. length**
- Expansion is usually accommodated by the tubing’s flexibility ≤ 1 inch sizes
  - Allow **1/8 inch slack per foot** of installed tubing
- Offsets and loops can accommodate high expected expansion and contraction
Installation Techniques

Longitudinal Expansion and Contraction

- Expansion loops/arms/legs may be needed, depending on installation type, the expected temperature changes and tubing size
- www.plasticpipecalculator.com helps with these calculations
Installation Techniques

Pressure Testing

- Pressure test as required by manufacturer or local code
- Minimum recommended test pressure 40 psi; Maximum up to 200 psig
- Water tests are acceptable – do not allow water to freeze

Air Testing:
- PEX is a ductile material, does not separate when burst, even at cold temperatures
- See PPI Recommendation F: “Testing PEX Pipe and Tubing Systems with Air”
- “It is the recommendation of PPI that PEX piping systems be permitted to be tested with compressed air or inert gas, provided that the manufacturer’s instructions are followed and that all testing is performed in accordance with the local regulations.”

WARNING: Compressed air or inert gas (e.g. nitrogen) used for pressure testing has high potential (stored) energy. Any uncontrolled release of that energy can lead to a sudden rupture which may present serious safety hazards.
Installation Techniques

Summary: This Learning Objective discussed installation techniques

1. Bending and flexibility
2. Fasteners
3. Protection
4. Installation under slabs
5. Linear expansion and contraction
6. Pressure testing
5. Industry Resources

PPI’s BCD webpages provide access to:

- Technical Publications
- Plastic Pressure Pipe Design Calculator
- Educational videos
- Case studies
- Presentations and recorded webinars
- Industry Links: Connecting with other organizations for quick access to codes and standards
- www.plasticpipe.org
Industry Resources

PPI’s BCD webpages provide access to:

- Technical Publications
- Plastic Pressure Pipe Design Calculator
- Educational videos
- Case studies
- Presentations and recorded webinars
- Industry Links: Connecting with other organizations for quick access to codes and standards
- [www.plasticpipe.org](http://www.plasticpipe.org)
Industry Resources

PPI Technical Notes and Reports

Example: **TN-53: Guide to Chlorine Resistance Ratings of PEX Pipes and Tubing for Potable Water Applications**

**Excerpt:**

“Thanks to the many benefits of PEX tubing materials and the associated fittings and system components, it has become common for engineers, builders and plumbers to employ PEX potable water systems for drinking water applications.

“However, for operating conditions beyond the typical “domestic hot” temperature of 140°F (60°C) or system pressure of 80 psig (0.55 MPa), users should contact the specific PEX tubing manufacturer to determine whether such conditions are approved for use.”
Industry Resources

PPI Statements

Example: Statement A: Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants used in Treated Potable Water on Crosslinked Polyethylene (PEX) Pipe

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

PPI Recommendations

Example: Recommendation E: Recommendation Against Mixing Hydronic Heating Water with Potable Water

Excerpt:
“Therefore, it is the recommendation of the PPI that designers and installers not specify or build systems where the mixing of hydronic water with potable water may occur.”
Industry Resources

PPI Recommendations

Example: Recommendation F: Testing PEX Pipe and Tubing Systems with Air

Excerpt:
“It is the recommendation of the PPI that PEX pipe and tubing systems be permitted to be tested with compressed air or inert gas, provided that the manufacturer’s instructions are followed and that all testing is performed in accordance with the local code regulations.”
Industry Resources

PPI Recommendations


Excerpt: “Therefore, it is the recommendation of the Plastics Pipe Institute that epoxy repair coatings not be applied to plumbing distribution systems which contain plastic pressure pipes, tubing, fittings or valves of materials such as CPVC, PE-RT, PEX, or PP-R/PP-RCT. All plastic components should be isolated from metal piping before the installation of such coatings.”
Industry Resources

Educational Videos

- Short videos explaining how to work with PEX tubing and fittings
- PEX Sizes and Colors
- Using Manifolds
- Support Bends
Industry Resources

Educational Presentations

Presentations:
- Achieving Net-Zero with Plastic Piping Solutions
- Designing PEX Plumbing Systems…
- PEX for NFPA 13D Residential Fire Sprinkler…
- PEX for Water Service Line Applications
Industry Resources

Industry Links Webpage

- Get direct access to standard development organizations, product certification agencies, code bodies and other associations through this BCD webpage

http://plasticpipe.org/building-construction/bcd-links.html
Course Review

By this time, participants should be able to:

1. Explain how the properties of PEX tubing and fittings can improve health, safety and welfare through improved plumbing materials
2. Describe three distinct plumbing layouts using PEX systems and compare advantages and disadvantages of each
3. Apply test data from published research to demonstrate how design of the plumbing layout can improve system performance and provide faster delivery of hot-water with reduced water waste
4. Direct an installer on correct installation techniques for PEX systems to ensure long-term safety and performance
5. Discuss how to access industry resources for material, design and installation info
Conclusion

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

Much 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
Designing PEX Plumbing Systems to Optimize Performance and Efficiency

Thank you!

Contact Info:
Lance MacNevin, P.Eng.
PPI Director of Engineering, Building & Construction Division
lmacnevin@plasticpipe.org Tel (469) 499-1057