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## *PEX Pipes for Service Line Applications*

- Introduction to PPI
- Introduction to PEX pipes for water service
- Industry standards and tests
- Reasons for using PEX pipes for water service
- PEX installation for water service
- PEX systems for other applications



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## *Who is PPI?*

- PPI is the major trade association representing all segments of the plastics piping industry
- PPI is dedicated to promoting the safe use of plastic piping systems through:
  - Contributing to development of standards
  - Educating designers, installers, users and government officials
  - Establishing a forum for problem solving and new ideas
  - Maintaining liaison with industry, educational and government groups
- PPI has five divisions: Municipal and Industrial, Corrugated Polyethylene Pipe, Fuel Gas, Conduit, Building and Construction



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## *Building and Construction Division: Mission Statement*

- To promote the expanded acceptance and use of high reliability plastic pressure pipe and tubing systems in building and construction environments by providing research, education, and code/standard development with a focus on delivering sustainable and safe plastic system solutions that enrich people's lives.



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## *Building and Construction Division: Members - Manufacturers of PEX Pipes*

- Bow Plastics
  - Foshan Rifeng
  - IPEX, Inc.
  - JM Manufacturing
  - Mercury Plastics
  - NIBCO
  - Reliance Worldwide USA
  - REHAU
  - Viega
  - Watts Water Technologies
  - Uponor
  - Zurn PEX, Inc.
- Other PPI members include manufacturers of polyethylene resin, compounds, and additives; test laboratories; consultants



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## *PEX Water Service Line - Introduction*

### **History:**

- PEX was first used for hot-water radiant heating in the early 1970's, and today is a reliable solution around the world for hot- and cold-water plumbing, radiant heating and cooling, outdoor snow and ice melting, residential fire protection, hydronic (hot-water) building services piping, and other demanding applications such as natural gas piping (outside of North America)



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## *PEX Water Service Line - Introduction*

### **History:**

- PEX was first used for service line connections in Europe in 1980's
- PEX was first used for service line connections in North America as early as 1997
  - Baltimore, MD
  - Kentville, NS (Canada)



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## *PEX Water Service Line - Introduction*

- PEX pipes are available in multiple colors, including blue
- PEX pipes are produced in nominal dimensions from 1/2" to 3"
- PEX pipes are available in coils or straight lengths, depending on the application

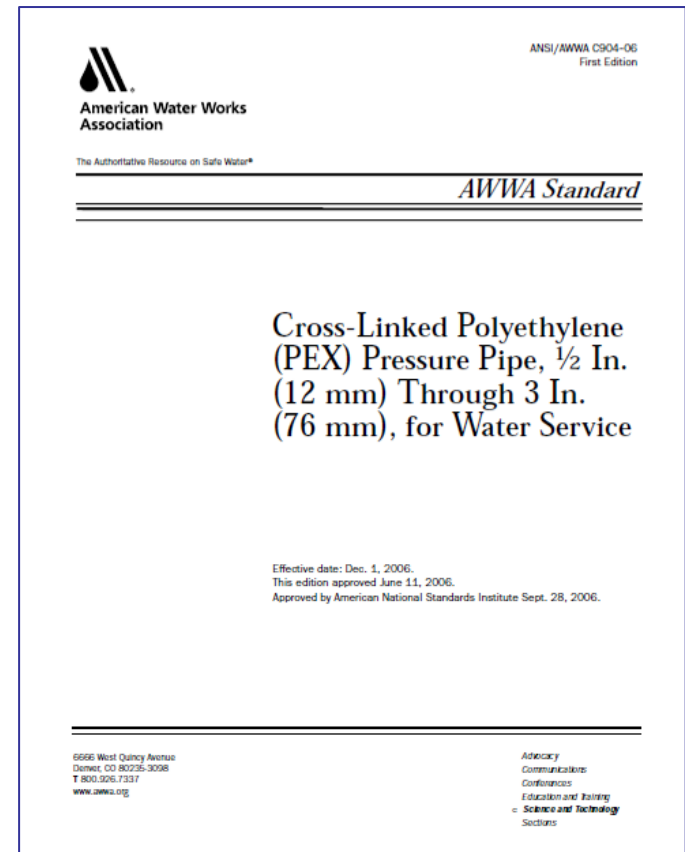




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## *PEX Water Service Line - Introduction*

- PEX has been approved for service line applications in model plumbing and building codes in the US since 1997
- PEX was recognized for water service applications with publication of AWWA C904-06 in 2006
  - AWWA C904-06 is available at [www.awwa.org/bookstore](http://www.awwa.org/bookstore)







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## *PEX Water Service Line - Introduction*

- There also is a draft AWWA Committee Report in process:
- “Design and Installation of Cross-linked Polyethylene (PEX) Pipe Made in Accordance with AWWA C904”

AWWA C904 Subcommittee:

- Chair: *Camille Rubeiz*, PE, PPI
- *Sarah Chung*, Jana Labs., P.Eng., Principal Author
- *Randy Knapp*, Uponor
- *Gary Morgan*, Watts
- *Lance MacNevin*, REHAU, Inc.
- *Gary Runyan*, Zurn PEX Inc.



## *PEX is Crosslinked (X) Polyethylene Description from PPI Technical Note-17*

- “PEX is a polymeric material formed by the chemical joining of individual polyethylene molecules in a process called crosslinking. Crosslinking alters the performance of the original polyethylene polymer improving several key properties.”
- “The primary reason for crosslinking polyethylene (PE) is to increase the material’s elevated temperature performance under load. In addition, crosslinking substantially improves the pipe’s environmental stress crack resistance (ESCR), resistance to slow crack growth, chemical resistance, toughness and abrasion resistance.”



# *PEX is Crosslinked (X) Polyethylene*

## *Description from PPI Technical Note-17*

- PEX pipes as compared with HDPE pipes, from PPI TN-17:

Crosslinked Polyethylene  
(PEX) Pipe & Tubing  
TN-17/2008

Property	From PE to PEX
Density	Unchanged or Decreases
Tensile Strength @ 73°F (23°C)	Unchanged
Environmental Stress Crack Resistance	Increases
Resistance to Slow Crack Growth	Increases
Creep Resistance	Increases
Hydrostatic Design Basis (HDB) <ul style="list-style-type: none"><li>• HDB @ 73°F (23°C)</li><li>• HDB @ 180°F (82°C)</li></ul>	Unchanged Increases
Hydrocarbon Permeation	Unchanged
Chemical Resistance *	Increases

\*. The chemical resistance of thermoplastics is complex and is generally a function of the polymer's resistance to applied load, temperature and environment



## *How is PEX Pipe made?*

- There are 3 commercial processes known as:
  - PEXa: High-pressure peroxide method; 1960's
  - PEXb: Silane method; 1970's
  - PEXc: Electron Beam method; 1970's
- Each method is proven to make product that meets the strict requirements of product standards by ASTM, AWWA, CSA, NSF and other organizations
- Further detail of each method follows:



## *High-Pressure Peroxide Method*

- Special high-pressure screw extruders
- Small amount of peroxide mixed to special PE resin before extrusion
- Crosslinking takes place in extruder/die, driven by temperature and high pressure
  - Pipe is crosslinked as it is extruded
  - Peroxide is consumed during crosslinking reaction



## *Silane Method*

- Uses a conventional screw-type extruder
- Modified HDPE material is extruded
- Most crosslinking takes place after the material has left the extruder
- Crosslinking is driven by moisture and temperature through exposure to hot water or steam



## *Electron Beam Method*

- Uses a conventional screw-type extruder
- Normal HDPE pipe is extruded
- Crosslinking occurs in a secondary “beaming” operation - driven by the strength of the electron beam



## *Industry Standards for PEX Systems*

- ASTM F876 - Materials, dimensions and performance for PEX tubing
- ASTM F877 - Performance standard for tube/fitting systems
- ASTM F2023 - Chlorine resistance test method for PEX pipes
- ASTM F2657 - UV resistance test method for PEX pipes
- ASTM fitting standards such as ASTM F1807, F1960 and F2080
- AWWA C904 - “Cross-Linked Polyethylene (PEX) Pressure Pipe, ½ In. (12 mm) Through 3 In. (76 mm), for Water Service”
- CSA B137.5 – Materials, dimensions, performance for PEX systems
- NSF/ANSI Standard 61 - “Drinking Water System Components”
- NSF/ANSI Standard 14 - “Plastics Piping System Components and Related Materials”





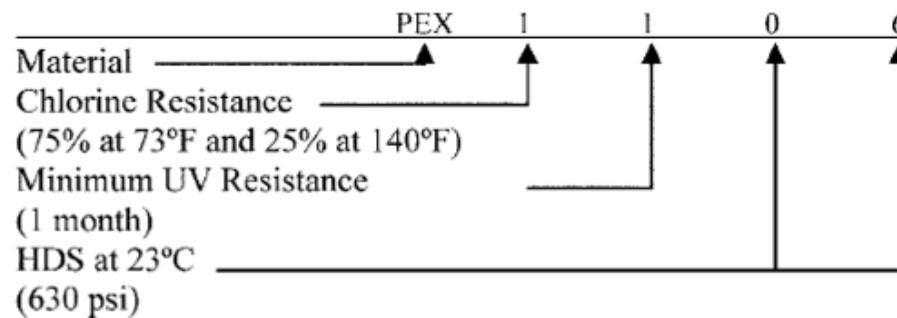
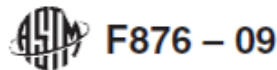
## *Industry Standards for PEX Systems*

- **ASTM F876 “Standard Specification for Crosslinked Polyethylene Tubing”**
  - Pipes are CTS, SDR9, with tight tolerances on dimensions
  - Minimum Quick Burst Capability:
    - 475 psi @ 73.4°F, 210 psi @ 180°F, 180 psi @ 200°F
  - Long-term Pressure Ratings:
    - 160 psi @ 73.4°F, 100 psi @ 180°F, 80 psi @ 200°F
  - Sustained Pressure Tests
    - Up to 16,000 hours accelerated laboratory hydrostatic testing is required for PPI “Standard Grade” listings



## Industry Standards for PEX Systems

- **ASTM F876** has categories for performance in three key properties\*
  - *\*PEX pipes have no “cell classification”*
- Performance categories are defined in the “Material Designation Code”
  - Example shown from ASTM F876



For example ASTM F876 PEX tubing marked with the material designation code PEX 1106 is a PEX tubing meeting the chlorine resistance requirement for 25% of the time at 140°F and 75% of the time at 73°F having a Minimum UV resistance of 1 month and having an HDS for water at 73°F of 630psi (HDB of 1250 psi).



## *Chlorine Resistance*

- **ASTM F2023 “Standard Method for Evaluating Resistance to Hot Chlorinated Water”** is the test method for PEX pipes
  - Minimum test condition of 825 mV ORP (typical of treated water with 4.0 ppm chlorine, pH 6.8)
  - Pipe life is extrapolated at 80 psig pressure at various temperature combinations
- **ASTM F876** contains the actual performance requirements, in Section 6.10: “PEX tubing intended for use in the transport of potable water shall have a minimum extrapolated time-to-time failure of 50 years when tested and evaluated in accordance with...”
- *see next slide...*



## *Chlorine Resistance*

- **ASTM F876** has four categories for chlorine resistance, as part of the Material Designation Code:

**0:** Not tested or not rated

**1:** 25% of time at 140°F, 75% of time at 73.4°F

**3:** 50% of time at 140°F, 50% of time at 73.4°F

**5:** 100% of time at 140°F, 0% of time at 73.4°F



## *UV Resistance*

- **ASTM F2657 “Standard Method for Outdoor Weathering Exposure of Crosslinked Polyethylene”** is the test method
  - Pipes are exposed in desert near Phoenix, AZ for natural UV radiation exposure for specified time periods
  - Exposed pipes are then re-tested for ASTM F2023 chlorine resistance to show no significant reduction in pipe lifetime
  - Manufacturer reports acceptable UV exposure limits based on this testing, in accordance with ASTM F876
- *see next slide...*



## *UV Resistance*

- **ASTM F876** has four categories for UV resistance, as part of the Material Designation Code:
  - 0:** Not tested or not rated
  - 1:** 1 month
  - 2:** 3 months
  - 3:** 6 monthsAdditional UV designations are also proposed at ASTM
- Each PEX pipe manufacturer publishes a maximum recommended UV exposure limit, based on the UV resistance of the pipe when tested in accordance with ASTM F2657



## *Industry Standards for PEX Systems*

- **ASTM F877 “Standard Specification for Crosslinked Polyethylene Plastic Hot- and Cold- Water Distribution Systems”**
  - Applies to pipes with fittings and/or manifolds, tested as a system
  - Quick burst capabilities, sustained pressure requirements
  - Excessive Temperature and Pressure test:
    - 150 psi @ 210°F for 720 Hrs. (30 days)
  - Thermo cycle Test:
    - Pressurize with 100 psi Nitrogen gas
    - 2 minutes in 60°F water, 2 minutes in air, 2 minutes in 180°F water = one cycle
    - Repeat 1,000 times with no leaks



## *Reasons to use PEX for Service Line*

- Corrosion resistance to soil and water
- Toughness and durability:
  - Abrasion resistance, impact resistance, freeze resistance
- Strength: Long-term Pressure Rating of 160 psi @ 73.4°F
- Flexibility to ease installation and to absorb pressure surges
- Smooth interior reduces pressure loss
- Reliable joining using various connections
- Oxidative resistance
- Proven long life and reliability in this application
- A green solution





## *Corrosion Resistance*

- PEX pipe is corrosion resistant (corrosion is not possible with PEX) to both soils and water
- No build-up of minerals inside the pipe which could reduce flow
- High velocities are tolerated by PEX pipes without erosion corrosion
- See *Joining* section for information on corrosion resistance of fittings





## *Abrasion Resistance*

- PEX offers outstanding slow crack growth (SCG) resistance and environmental stress crack resistance (ESCR)
  - Crosslinking of HDPE molecules into PEX matrix improves resistance to gouges and scratches from rocks that might damage other piping materials
- PEX may be used in horizontal directional drilling applications



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## *Impact Resistance*

- PEX withstands higher impacts, reducing the need for repairs and installation downtime
- PEX does not crush, kink or collapse when proper backfill techniques are used
- Native backfill can often be used, saving time and costs





## *Freeze Resistance*

- PEX is freeze-resistant: it typically expands along its length when frozen, while copper is more likely to split
- PEX may be thawed using available hot water injection equipment, warm wet rags or a hot air gun; do not use an open flame
- PEX can immediately be put back into service after thawing





## *Hydrostatic Strength*

- Minimum strength according to ASTM F876 and CSA B137.5:
- Minimum Short-term Burst Strength
  - 475 psi @ 73.4°F (3,310 kPa @ 23°C)
  - 210 psi @ 180°F (1,450 kPa @ 82°C)
  - 180 psi @ 200°F (1,240 kPa @ 93°C)
- Long-term Pressure Ratings<sup>1</sup>
  - 160 psi @ 73.4°F (1105 kPa @ 23°C)
  - 100 psi @ 180°F (690 kPa @ 82°C)
  - 80 psi @ 200°F (550 kPa @ 93°C)

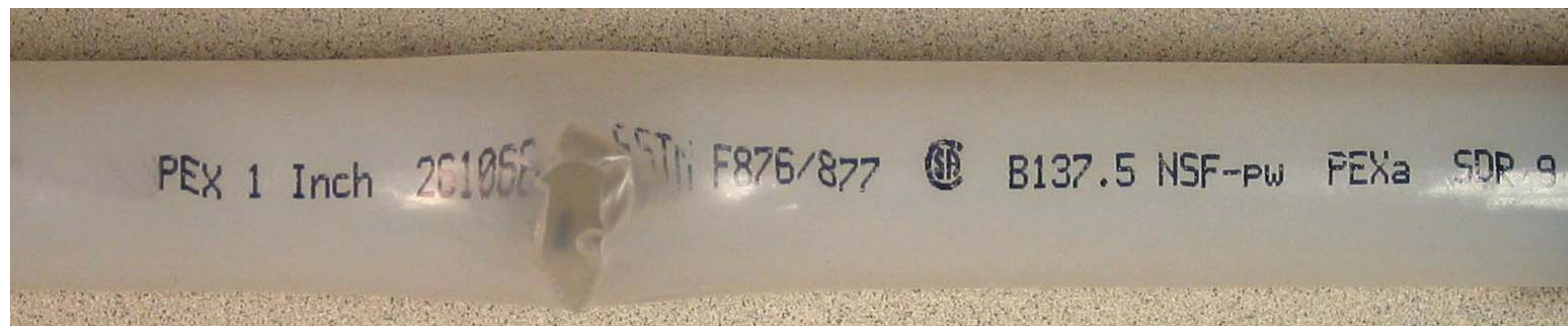
<sup>1</sup>Temperature/Pressure ratings are based on an extrapolated time-to-failure prediction as defined in ASTM D2837, with Design Factor 0.50 on pressure



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## *Hydrostatic Strength*

- Maximum test pressure up to 200 psig
  - Minimum short-term burst pressure for PEX is 475 psig
- Air or water tests are acceptable
- PEX is ductile, will not shatter even if it does burst
  - No shards will break away from pipe





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## *Flexibility*

- PEX is a flexible pipe, allowing for faster installation
- Lightweight material is easy and safe to transport and handle
- Long coils reduce waste and the number of joints, improving installation efficiency

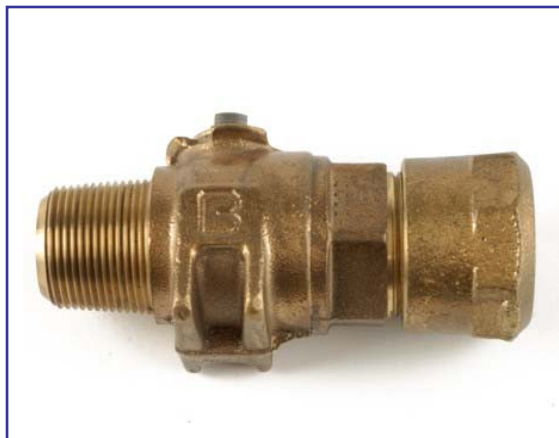




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## *Joining – AWWA C800 Connections*

- PEX is copper tube size (CTS), SDR9, and is compatible with CTS AWWA C800 compression-joint brass valves and fittings using stainless steel inserts at connections
- Just as with HDPE pipes, inserts have negligible effect on pressure loss







## *Joining – Tensile Testing*

### **The test:**

- PEX was connected to standard AWWA C800 compression-joint brass fittings with stainless steel inserts in independent testing using a tensile testing machine
  - Set for fixed elongation rate of 2 inches per minute
- Test is run to failure of pipe or connection, whichever comes first

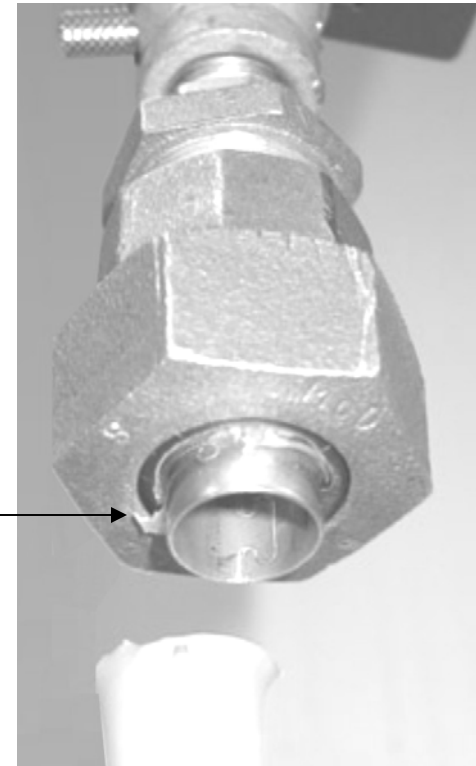
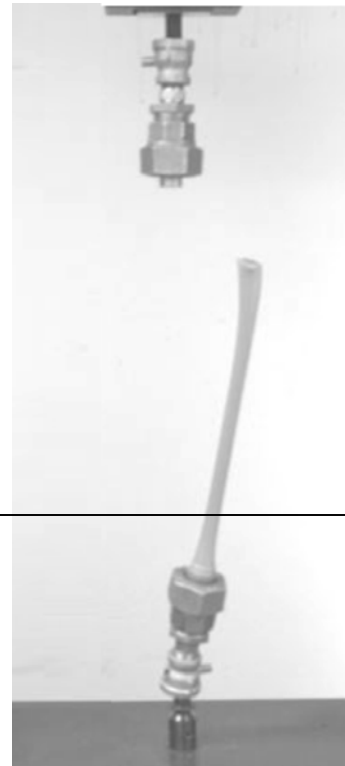




## *Joining – Tensile Testing*

### **Failure location: Pipe**

- Ductile failure of pipe, after extensive elongation
- Failure was at the connection, but PEX pipe did not pull out of the joint
  - Pipe and insert remained in the compression joint assembly





## *Joining – Other PEX fittings*

- Several other PEX fitting systems are approved by AWWA C904
- These fittings are according to ASTM standard specifications:
  - F1807: Brass or Copper Insert Fittings with Copper Crimp Rings
  - F1960: Cold Expansion Fittings with PEX Reinforcing Rings
  - F2080: Cold Expansion Fittings with Metal Compression-Sleeves





## *Joining –PEX Fittings Erosion Corrosion*

- To evaluate the topic of erosion corrosion for PEX fittings, PPI coordinated laboratory testing of typical PEX fittings
- See **PPI Technical Note-26: “Erosion Study on Brass Insert Fittings Used in PEX Piping Systems”**
- “The objective of this test program was to subject different brass insert fittings for PEX plumbing systems to flow rates that represented the maximums that could occur if a plumbing system was sized according to the 2000 version of the Uniform Plumbing Code and then flowing enough hot, chlorinated water through them to be equivalent to 40 years of service in typical single family residence.”
- *see next slide...*



## *Joining –PEX Fittings Erosion Corrosion*

- According to **PPI Technical Note-26:**
- “Conclusions: “The results indicate that very little erosion occurs at the test conditions chosen. The water conditions chosen were at the severe end of normal potable water conditions and the water flow rates were the maximum that should be experienced when all fixtures on a given line are open and flowing at capacity.””



## *Joining –PEX Fittings Corrosion Resistance*

- NSF/ANSI Standard 14 establishes minimum performance criteria for dezincification resistance (DZR) and stress corrosion cracking (SCC) resistance for PEX fittings intended for potable water
- Some manufactures of PEX fittings such as F1807, F1960 and F2080 permit the use of these fittings in underground applications only with the use of waterproof tape or heat shrink sleeving to prevent ground contact



## *Resistance to Chloramines*

- See **PPI Statement A: “Relative Oxidativeness of Chloramines and Free Chlorine Disinfectants... on PEX Pipe”**
- “Jana Laboratories, an accredited laboratory, examined the relative oxidative aggressiveness of the common potable water disinfectants free chlorine and chloramines on crosslinked polyethylene (PEX) pipes.”
- “Based on these results, it is the position of PPI [BCD] that chloramines are less aggressive than free chlorine to PEX pipes, and that testing using free chlorine, in accordance with ASTM F2023, will conservatively estimate the time-to-failure for PEX pipes when used with the disinfectant chloramines.”



## *Resistance to Chlorine Dioxide*

- See report **09-1190** from Jana Laboratories, July 12, 2010:
  - **“Usage and effects of Chlorine Dioxide on PEX Plumbing and Water Distribution System in North America”**
- Jana examined the usage pattern of Chlorine Dioxide in North America to determine the potential impact of Chlorine Dioxide residuals within the distribution network on crosslinked polyethylene (PEX) piping distribution and plumbing systems.
- *see next slide...*





## *Resistance to Chlorine Dioxide*

- Executive Summary of **Jana Report 09-1190**:
- “Based on the analysis of available test data, current ASTM F876/F2023 requirements for chlorine resistance of PEX pipe in potable water plumbing applications appear robust enough to ensure minimum performance of both PEX distribution and residential plumbing systems for the vast majority of potential chlorine dioxide exposure levels in North America.”
  - [www.plasticpipe.org](http://www.plasticpipe.org)
  - [www.janalab.com/research\\_knowledge.php](http://www.janalab.com/research_knowledge.php)



## *Proven Long Life*

- PEX was first used for service line connections in Europe in 1980's
- PEX was first used for service line connections in North America as early as 1997 with successful results
  - Baltimore, MD
  - Kentville, NS (Canada)
- SDR9 dimension for wall thickness gives good mechanical strength
- PEX pipes have been used for hot- and cold-water applications for almost 40 years and are well-suited for service line applications due to corrosion resistance, toughness, oxidative resistance, and reliability of connections



## *PEX is a Green Solution*

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



## *Reasons to use PEX for Service Line*

- Corrosion resistance to soil and water
- Toughness and durability:
  - Abrasion resistance, impact resistance, freeze resistance
- Strength: Long-term Pressure Rating of 160 psi @ 73.4°F
- Flexibility to ease installation and to absorb pressure surges
- Reliable joining using various connections
- Proven long life and reliability in this application
- Oxidative resistance
- A green solution



## *PEX Installation - Overview*

- As a flexible pipe, installers should allow a slight curve while laying PEX in the trench to accommodate expansion and contraction due to temperature changes





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## *PEX Installation - Linear Expansion*

- Linear expansion rate of PEX:
  - 0.93 inch per 10°F per 100 ft. length
- Installers must allow for movement with correct installation, allowing a slight curve in the trench





## *PEX Pressure Testing*

- Pressure test as required by manufacturer or code
- Maximum test pressure up to 200 psig
  - Minimum short-term burst pressure for PEX is 475 psig
- Air or water tests are acceptable



## *Case Studies and Other Publications*

- PPI Technical Note 17: “Crosslinked Polyethylene Pipe and Tubing”
- PPI Technical Note-26: “Erosion Study on Brass Insert Fittings Used in PEX Piping Systems”
- PPI Statement A: “Relative Oxidativeness of Chloramines and Free Chlorine...”
- Many case studies are available from PPI at:  
[www.plasticpipe.org](http://www.plasticpipe.org)
- Test reports available from Jana Laboratories at:  
[www.janalab.com/research\\_knowledge.php](http://www.janalab.com/research_knowledge.php)





## *Other Applications for PEX Pipes*

- Hot- and cold-water plumbing, residential and commercial
- Radiant heating and cooling, residential and commercial
- Outdoor snow and ice melting
- Residential fire protection
- Hydronic (hot-water) building services piping
- Renewable energy (ground source geothermal piping)
- Insulated energy transfer pipes



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*Thank You for your attention!*

*Questions?*

*For more info, please visit us at:*

[www.plasticpipe.org](http://www.plasticpipe.org)