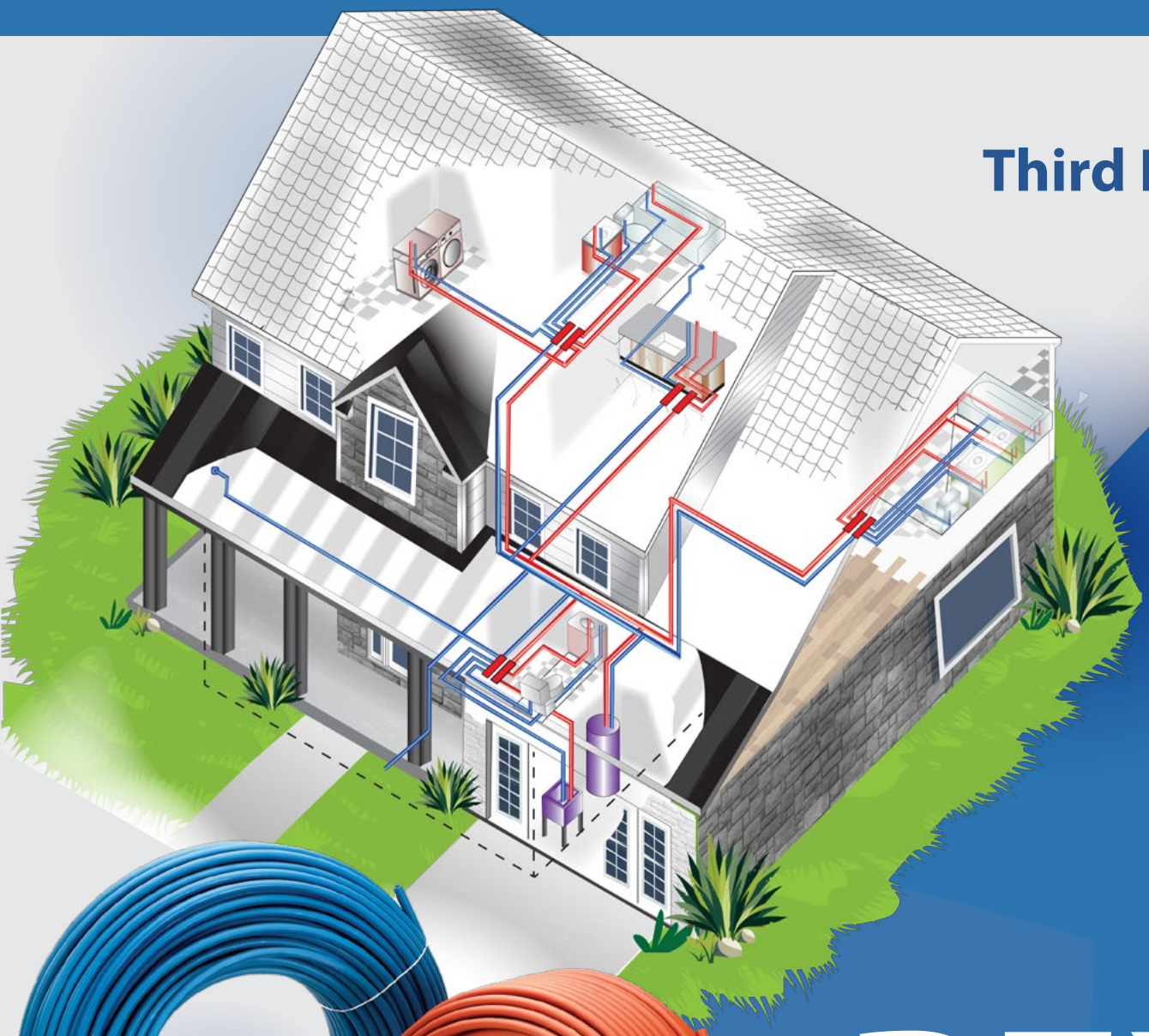
Third Edition



PEX

Plumbing Distribution Systems Design and Installation Guide

Advantages | Material Properties | Codes & Standards

Joining Methods | PEX Plumbing Layouts | Optimizing Design

Installation Guidelines | Water Service Line | Other Applications

IAPMO

PPI Plastics Pipe Institute The Voice of an Industry.

Home Innovation RESEARCH LABS™

PPFA Plastic Pipe and Fittings Association

ES ICC EVALUATION SERVICE®

PEX

Plumbing Distribution Systems Design and Installation Guide

Third Edition

Prepared for

Plastics Pipe Institute, Inc. (PPI)
105 Decker Court, Suite 825
Irving, TX 75062
www.plasticpipe.org

and

Plastic Pipe and Fittings Association (PPFA)
800 Roosevelt Road, Building C, Suite 312
Glen Ellyn, IL 60137
www.ppfahome.org

Prepared by

Home Innovation Research Labs
400 Prince George's Boulevard
Upper Marlboro, MD 20774
www.HomeInnovation.com

April 2026

This document was developed as the result of a consensus process involving the Plastics Pipe Institute, the Plastic Pipe and Fittings Association, and representatives from numerous piping and fitting manufacturers. It was prepared by Home Innovation Research Labs.

Acknowledgements

The following companies are recognized for their contributions of pictures, graphics, data, and/or personnel in the development of this Guide:

- Borealis
- GF Building Flow Solutions (Uponor)
- Legend Valve
- MrPEX Systems
- REHAU
- RWC (Reliance Worldwide Corp.)
- SACO AEI Polymers
- Viega LLC
- Watts Water Technologies
- Zurn

Disclaimer

The Home Innovation Research Labs, Inc., the Plastics Pipe Institute, Inc., and the Plastic Pipe and Fittings Association make no warranties, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this publication or that such use may not infringe privately owned rights. None of the aforementioned entities assume any liability with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this publication, or any responsibility for statements made or opinions expressed by individual authors. The user must determine which code/s are applicable to each specific project and must ensure compliance with all local, state, and federal codes, regulations, and standards.

Further Information

Please consult the following websites for the latest version of this publication, reference publications, and other related information:

- Plastics Pipe Institute
  www.plasticpipe.org
- Plastic Pipe and Fittings Association
  www.ppfahome.org
- Home Innovation Research Labs
  www.HomeInnovation.com
- ICC Evaluation Service, LLC
  www.icc-es.org
- International Association of Plumbing and Mechanical Officials
  iapmo.org

  Use of the IAPMO logo does not imply partnership, support, or recommendation of the standards contained herein, or any products or services associated herewith.

1 Introduction

The Third Edition

We are proud to publish the 3rd Edition of the PEX Plumbing Distribution Systems Design and Installation Guide. This edition includes updates to reflect the advancements in PEX materials (e.g., tubing, manifolds, and fittings), updates to code acceptance for PEX plumbing systems, new design recommendations, and revisions to installation techniques and practices.

New information has been added to every chapter of this Guide including new information about the acceptance of PEX plumbing in Chapter 1, updated information about the advantages of PEX plumbing systems in Chapter 2, material properties and standards updates in Chapter 3, updates to all applicable national plumbing, mechanical, and building codes in Chapter 4, additional fitting systems in Chapter 5, new information about design and sizing systems in Chapter 6, new information about selecting layouts in Chapter 7, new design information on fixture flow rates and water hammer in Chapter 8, revised installation instructions in Chapter 9, and an all-new Chapter 10 Water Service Lines / Building Supply Lines about water service line applications, and an updated Appendix B on other Applications.

History of this Guide and PEX Plumbing in North America

Development of this Guide began in 2005 as a cooperative agreement between The Plastics Pipe Institute, Inc. (PPI) and the National Association of Home Builders Research Center (NAHB-RC), now known as Home Innovation Research Labs (HIRL). The Plastic Pipe and Fittings Association (PPFA) also contributed to the development of this Guide, which was first published in December 2006.

This original development was partially funded by The Department of Housing and Urban Development's (HUD) Office of Policy Development and Research (PD&R). Both HUD and NAHB had recognized that PEX plumbing systems delivered safety, reliability, and value to the public and many advantages to home builders, yet adoption of PEX plumbing was slow in the US at that time.

Within a few years after the publication of the 1st Edition in 2006, innovative performance testing about properly designing and sizing PEX plumbing systems, funded primarily by PPI, had been completed by Home Innovations Research Labs. This information, along with other updates, was incorporated in the 2nd Edition of this Guide, published in 2013.

As reported by HUD PD&R in an online article in 2018, "The residential housing market is notoriously slow to adopt new products, and PEX was no exception. Many studies have shown that it can take more than 20 years for a new product to gain significant market share. Market surveys from Home Innovation Research Labs reported that in 1997, PEX had a 10% share of the U.S. plumbing market in single-family home construction. More recent market studies from Home Innovation Research Labs report that PEX has achieved a market share of 63% in single-family construction in 2016."

Since the 2nd Edition of this Guide was published, PEX has achieved even greater success in residential construction with the latest data from Home Innovation Research Labs indicating that more than 65% of residential builders are utilizing PEX plumbing systems. At the same time, commercial plumbing specifiers and contractors are now selecting PEX tubing for its numerous advantages, so there is a greater need for design and sizing information, as well as more comprehensive advice about installation techniques, for both residential and commercial applications.

Work on this 3rd Edition occurred between 2021 and 2026 and includes new information that is applicable to multi-family and commercial plumbing projects.

Thank you for taking the time to review this document.

Objective

This Guide provides information and resources necessary to design and install crosslinked polyethylene (PEX) hot- and cold-water plumbing distribution systems in residential and commercial buildings. It includes comprehensive design concepts and installation guidelines to increase the acceptance and proper use of PEX. This document is targeted to meet the needs of plumbers, home builders, designers, estimators, and other building professionals. Its primary purpose is to introduce potential users to PEX plumbing systems and to enable current users to optimize their PEX plumbing systems, while minimizing system costs. In addition, it will allow code inspectors and homeowners to become familiar with the applications, performance characteristics, recommended installation practices, and benefits of PEX hot- and cold-water plumbing distribution systems.

Background

Crosslinked polyethylene (PEX) is a high-temperature, flexible, polymer pipe. Crosslinking technology was first developed in Europe in the late 1960s and has since come into use around the world for a variety of applications. PEX has a 50-year history of successful use in the European market with extensive testing for durability and material performance.

PEX was first introduced in North America in the early 1980s, when it was primarily used for radiant floor heating. The first US industry standards for PEX tubing and systems, ASTM F876 and F877 respectively, were published in 1984. In the 1990s, PEX was approved and adopted into codes for both mechanical (e.g., hydronic) and hot- and cold-water distribution systems (see **PPI TR-56** ***History of Crosslinked Polyethylene (PEX) tubing in North America and the Evolution of ASTM Standard Specification F876 from 1984 – 2024***).

Today, PEX is approved for potable hot- and cold-water distribution systems, as well as many other applications (e.g., hydronic heating/cooling, snow and ice melting, geothermal ground loops, water service and building supply lines, etc.) in all model plumbing and mechanical codes across the United States and Canada.

In addition, PEX is approved for use in sprinkler systems for one- and two-family dwellings and manufactured homes covered by NFPA 13D when it is certified to meet the requirements of UL 1821 and/or other local requirements.

Just as all metals are not the same, not all plastics are the same. A result of modern polymer technology, PEX tubing performs in ways that provide superior reliability, durability, and safety. Also, current testing requirements for PEX are much more stringent than at any other time in history.

Available in nominal tubing sizes from 1/4 to 4, PEX tubing can generally be installed in place of copper tubing on a size-for-size basis. PEX systems offer flexibility in system design to meet the needs of builders, contractors, and homeowners in various types of building structures to optimize the performance and efficiency of the water distribution systems.

PEX Certifications

The PEX piping industry is highly regulated and all products intended for plumbing applications must be third-party tested and certified for that application. Internationally accredited certification agencies regularly conduct strenuous performance and quality control testing on pipes and fittings, including unannounced plant inspections and annual monitoring testing. Standards, specifications, and code requirements define tight material and production quality controls, as well as requirements for drinking water safety.

Mandatory testing, as specified in the published standards, includes, but is not limited to, the following performance measures:

- Short-term burst testing
- Resistance to thermocycling
- Long-term hydrostatic pressure testing
- Cold-bend and hot-bend pressure testing
- Environmental stress crack resistance testing
- Resistance to excessive temperature and pressure
- Evaluation of resistance to hot chlorinated water
- Evaluation of resistance to ultraviolet (UV) exposure
- Drinking water safety

Industry Acceptance

According to industry data from Home Innovation Research Labs' Builders Practices Survey reports, PEX is now the most popular piping material for hot- and cold-water plumbing distribution systems, with a reported market share of over 60% of residential construction for more than 10 years.

Product acceptance has been the result of several industry trends:

- Widespread code acceptance
- Familiarity of installers and builders
- Shortage of skilled labor in the trades
- Improved industry education for specifiers and engineers
- Higher cost of copper plumbing materials, increasing cost advantages of PEX systems
- Industry research and empirical testing demonstrating the ability of PEX systems to deliver hot water faster with sufficient flow and pressure and the ability to absorb pressure spikes and reduce water hammer
- Proven track record of performance and durability in a wide range of applications across North America and the entire world

There are numerous opportunities for more widespread use of PEX plumbing systems in North American residential and commercial markets. The development of new fittings, tools, and accessories has enhanced the ease of installations and the development of larger PEX diameters allows it to be used for a wider variety of commercial applications such as multi-family residential high-rise buildings, hotels, schools, offices, businesses, and more.

All model plumbing codes permit the use of PEX tubing, but obstacles to its acceptance still remain. There is anecdotal and research information that shows:

- Some plumbers are reluctant to use PEX tubing due to a lack of experience with installation methods and design requirements (e.g., parallel plumbing systems)
- A few jurisdictions still prohibit the use of PEX tubing for plumbing distribution, even though it has been approved for use in all model plumbing codes for many years
- Codes and pipe sizing tables were originally written for trunk and branch systems; while codes have been amended to include PEX tubing systems, they do not provide many system design details for manifold systems, such as found within this Guide

Although these opportunities for further acceptance exist, the following benefits of PEX plumbing systems are widely recognized:

- **Availability of Tubing Sizes –** PEX tubing is available in a wide range of diameters, from nominal tubing sizes 1/4 to 4.
- **Certification –** PEX tubing and fittings are tested by independent third-party agencies and must meet strict performance requirements, verified through annual retesting and frequent factory inspections.
- **Cost Effectiveness –** PEX tubing is less expensive than copper and PEX plumbing systems require less labor to install and can optimize system performance.
- **Durability and Toughness –** PEX tubing can withstand difficult jobsite conditions.
- **Ease of Installation –** PEX tubing is compatible with a wide range of code-approved connection types that eliminate the need for solder, flame, and chemicals (see **Chapter 5 *Joining Methods*** for examples of fitting systems). Its light weight makes it easier to transport to and on the jobsite. Finally, the use of manifolds can speed installation and improve performance.

- **Energy Efficiency –** PEX tubing minimizes heat transmission through the wall (see **PPI TR-48 *R-Value and Thermal Conductivity of PEX and PE-RT*** and **Chapter 3 *Material Properties***).
- **Environmentally Sound –** PEX is an inert material and does not contain volatile organic compounds (VOCs); its embodied energy and carbon footprint are significantly lower than copper tubing materials according to a published Life Cycle Analysis (LCA) report from The European Plastic Pipe and Fitting Association (TEPPFA).
- **Flexibility –** Its flexible nature allows it to bend around obstructions without the use of fittings. Availability in long coil lengths assists with reducing the number of fittings and joints in a piping system.
- **Light weight –** With a weight that is less than half of metal pipes, PEX tubing is easier to transport and safer for workers to move materials through a jobsite.
- **Resilience –** PEX tubing is inherently resilient because of resistance to corrosion, aggressive water chemistry, scale, and mineral build-up, as well as the ability to resist and withstand freezing (i.e., freeze-break resistance). PEX is also resilient due to its combination of toughness and flexibility, which allows it to withstand typical jobsite conditions without damage, while also being flexible to resist kinking, cracking, or breaking if buildings move or settle during seismic or other events.
- **Resistance to Corrosion and Erosion –** PEX tubing will not pit or corrode and resists erosion, even at high velocities.
- **Resistance to Disinfectants –** Through mandatory testing, PEX plumbing systems are proven to be resistant to water disinfectants chlorine and chloramines.
- **Resistance to Freeze Damage –** Under many circumstances, water in PEX tubing can be frozen and thawed without damaging the tubing or fittings. See **PPI TR-52 *Resistance of PEX Pipe and Tubing to Breakage When Frozen (Freeze-Break Resistance)*** and the section "Resistance to Freeze Damage" in **Chapter 3 *Material Properties***.
- **Safety of potable drinking water –** It is mandatory according to product standards that all PEX tubing and fitting systems must be certified to NSF/ANSI/CAN 61 to ensure safety for drinking water.
- **Scaling Resistance –** The smooth interior wall of PEX tubing makes it highly resistant to mineral build-up, which can reduce flow in metal pipes.
- **Speed –** PEX systems typically install faster than metal piping systems, saving time and money.
- **Sustainability –** PEX systems are sustainable solutions as compared with metallic piping thanks to lower cost to the environment for production, lighter weight and lower costs for transportation, smooth pipe wall that does not suffer from mineral build-up and reduced flow, and longer life without the chance of corrosion.
- **Water Conservation –** Properly designed and installed PEX plumbing systems can reduce the wait time for hot water to reach fixtures, saving both water and energy.

This Guide provides information and resources necessary to design and install safe, efficient, and cost-effective PEX plumbing distribution systems in residential and certain types of commercial buildings. It illustrates various plumbing configurations for a variety of housing types, as well as installation guidelines for each method. Properly designed and installed PEX tubing systems are beneficial for plumbing designers, installers, and homeowners.

Applications

PEX piping can be used in a wide variety of applications in residential and commercial construction. This Guide is focused on the design and installation of PEX hot- and cold-water distribution systems, which can be used for both new construction and remodeling or retrofit projects.

Other applications for PEX are described in a separate section of this Guide, and include:

- Fire suppression systems (residential fire sprinklers)
- Municipal water service pipe in underground applications
- Hydronic heating and cooling systems, including chilled water
- Radiant heating and cooling systems (floors, walls, or ceilings)
- Snow and ice melting systems for sidewalks, driveways, entrances, and ramps
- Turf conditioning for greenhouses, golf courses, and outdoor sports field surfaces
- District energy heating and cooling systems, including thermal energy networks
- Ground-source (geothermal) heat pump systems
- Water reuse and reclamation systems

How to Use this Design and Installation Guide

The ***PEX Plumbing Distribution Systems Design and Installation Guide*** is intended to assist in the design and installation of a new or retrofit PEX tubing system for both residential and commercial plumbing applications. It can be used by the novice as an introduction to PEX tubing and fittings, or by an experienced designer and plumber to optimize planning and estimating.

Builders can use this guide to learn about the advantages and appropriate application of PEX hot- and cold-water distribution systems for discussions with sales staff and homeowners. Building code officials can use this Guide as a consolidated source of information on the application of PEX tubing in hot- and cold-water distribution systems as well as water service line applications. Installers, inspectors, trainers, and others can use this guide as a primary source of information regarding the correct installation of PEX systems for these applications.

Each section of this guide focuses on various aspects of using PEX tubing systems:

- **Chapter 1 – Introduction:** Background information to educate the user about the history and uses of PEX tubing
- **Chapter 2 – Advantages:** Various advantages to using PEX tubing for plumbing systems
- **Chapter 3 – Material Properties:** Unique properties of PEX tubing and fittings materials including capabilities and limitations
- **Chapter 4 – Code Acceptance:** Information on major plumbing codes and relevant jurisdictional code provisions for PEX tubing and fitting systems
- **Chapter 5 – Joining Methods:** Explanations of the most common types of PEX fittings and their joining methods
- **Chapter 6 – PEX Plumbing System Layouts & Design:** Descriptions of the three most common types of PEX piping system layouts and advice for selecting designs
- **Chapter 7 – Optimizing PEX Plumbing Designs:** Performance details of the three plumbing layouts for four typical house configurations to assist in evaluating which system provides the best balance of performance, ease of installation, and cost for a particular structure
- **Chapter 8 – Lab Testing and Performance Data:** System performance comparison of the three most common plumbing layouts for various plumbing designs
- **Chapter 9 – Installation:** Industry guidance for installing PEX tubing in typical hot- and cold-water distribution system installations
- **Chapter 10 – PEX Water Service Lines/Building Supply Lines:** Information on advantages, requirements, connections, installation, and testing when using PEX tubing as a water service line or building supply line
- **Appendix A:** Additional lab testing data, referenced in Chapter 8
- **Appendix B:** Other Applications: Other common uses of PEX tubing systems

Abbreviations

AHJ	Authority Having Jurisdiction
ASPE	American Society of Plumbing Engineers
ASSE	American Society of Sanitary Engineers
ASTM	ASTM International, formerly American Society for Testing and Materials
CPVC	Chlorinated Polyvinyl Chloride
CSA	Canadian Standards Association
CTS	Copper tube size
DF	Design factor
DHWR	Domestic hot water recirculation
DWV	Drain, waste and vent
HDB	Hydrostatic design basis
HDS	Hydrostatic design strength
HIRL	Home Innovation Research Labs
IAPMO	International Association of Plumbing and Mechanical Officials
IC	Insulation contact
ICC	International Code Council
ID	Inside diameter
IMC	International Mechanical Code
IPC	International Plumbing Code
IRC	International Residential Code
LTHS	Long-term hydrostatic strength
MSS	Manufacturers Standardization Society of the Valve and Fitting Industry
NFPA	National Fire Protection Association
NPC	National Plumbing Code of Canada
NPS	Nominal pipe size
NSPC	National Standard Plumbing Code
NTS	Nominal tubing size
OD	Outside diameter
ORP	Oxidative reduction potential

PB	Polybutylene
PEX	Crosslinked polyethylene
PFAS	Per-and PolyFluoroAlkyl substances
PFOS	PerFluoroOctane Sulfonic acid
PP	Polypropylene
PPFA	Plastic Pipe and Fittings Association
PPI	Plastics Pipe Institute
PSU	Polysulfone
PPS	Polyphenylene sulfide
PPSU	Polyphenlysulfone
PVDF	Polyvinylidene fluoride
SDR	Standard dimension ratio
SDWA	Safe Drinking Water Act
SPF	Spray polyurethane foam
SWCP	Static water column pressure
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
USHGC	Uniform Solar, Hydronic and Geothermal Code
UV	Ultraviolet light
WDC	Water Demand Calculator

Definitions

Corrosion: deterioration in metals caused by oxidation or chemical action

Crosslinked polyethylene (PEX): a polyethylene material which has undergone a change in molecular structure using a chemical or a physical process whereby a majority of the polymer chains are chemically linked

Elasticity: a measure of material stiffness or the ability of the material to stretch or deform temporarily under a load

Fitting: a device or connection that allows tubing to change direction or size or to adapt to other piping materials (e.g., tee, elbow, drop-ear elbow, coupling, reducer coupling, cap, plug, male thread adapter, female thread adapter, sweat adapter, press adapter, CPVC adapter)

Fixture: a device or appliance at the end of a water supply distribution pipeline (e.g., lavatory, water closet, tub/shower, dishwasher, bidet, washing machine outlet)

Joint: the connection of the PEX tubing to a fitting, fixture, or manifold

Manifold: a device having a series of ports that are used to connect distribution lines for several fixtures

Outlet: see fixture

Parallel: a plumbing design that utilizes a central manifold and distribution tubing that is home-run to each hot- and cold-water fixture

pH: a scale ranging from 0 to 14 that ranks how acidic or alkaline a liquid is; water with a pH below 7 is considered acidic and water with a pH above 7 is considered alkaline

Scaling: process of mineral buildup on the interior of a pipe, fitting, valve, fixture, etc.

Thermoplastic: a plastic that can repeatedly be softened by heating and hardened by cooling through a temperature range characteristic of the plastic and that in the softened state can be shaped via processes such as injection molding or extrusion (e.g., a plastic fitting or manifold)

Thermoset: a plastic that, after having been cured by heat or other means (e.g., crosslinking) is no longer capable of being softened and reformed into a different shape in the manner of a thermoplastic material

Trunk and branch: a plumbing layout that has a large main line that feeds smaller branch pipes to individual fixtures

Ultraviolet (UV): high energy light waves found in sunlight that can lead to the degradation of many types of materials

Wait time: the time it takes for hot water to be delivered to a Test Fixture (i.e., hot water delivery time)

Water hammer: a banging noise heard in a water pipe following an abrupt alteration of the flow speed or direction with resultant pressure surges

Zoned: a plumbing layout that uses trunk lines from the water source to remote manifolds at grouped fixtures, such as a bathroom; these manifolds can be flow-through or closed end styles

Industry Technical Support

If you have questions that have not been answered in this Guide, you can contact PEX tubing manufacturers directly. The following websites provide a wealth of general information on PEX tubing and systems:

- The Plastics Pipe Institute www.plasticpipe.org
- Plastic Pipe and Fittings Association www.ppfahome.org
- Home Innovation Research Labs www.HomeInnovation.com

Manufacturers of PEX tubing and fittings can also provide specific technical assistance during the design, planning, and installation phases. Contact information for each of these manufacturers can be found at the PPI and PPFA websites and on the individual manufacturers' sites.

See also the following PPI documents available at www.plasticpipe.org/buildingconstruction

PPI 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 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 Technical Notes

- PPI TN-17 *Crosslinked Polyethylene (PEX) Pipe & Tubing Systems*
- PPI TN-26 *Erosion Study on Brass Insert Fittings Used in PEX Piping Systems*
- PPI TN-31 *Differences Between PEX and PB Piping Systems for Potable Water Plumbing Applications*
- PPI TN-32 *UV Labeling Guidelines for Crosslinked PEX Tubing and Pipe*
- PPI TN-39 *Recommended Practices Regarding Application of Pesticides and Termiticides near PEX Pipes*

- PPI TN-52 *Guide to High-Temperature Applications of Non-Potable PEX Pipe and Tubing Systems*
- PPI TN-53 *Guide to Chlorine Resistance Ratings of PEX Pipes and Tubing for Potable Water Applications*
- PPI TN-55 *Plastic Piping Materials for Ground Source Geothermal Heating and Cooling Applications*
- PPI TN-56 *Installation of Plastic Pressure Piping Materials Near Insulation Contact-Rated and Non-IC-Rated Recessed Lighting Fixtures*
- PPI TN-65 *Insulation Recommendations for Plastic Pressure Piping Materials in Residential Applications*
- PPI TN-67 *Chlorine Dioxide and Plastic Hot- and Cold-Water Plumbing Distribution Pipes*
- PPI TN-69 *Recommendations When Applying Spray Polyurethane Foam Insulation On and Around Plastic Pressure Pipes & Fittings*
- PPI TN-72 *Potential Effects of Artificial Lighting on Crosslinked Polyethylene (PEX) Pipe and Tubing and Recommended Installation Practices*

PPI Technical Reports

- PPI TR-11 *Resistance of Thermoplastic Piping Materials to Micro- and Macro-Biological Attack*
- PPI TR-19 *Chemical Resistance of Plastic Piping Materials*
- PPI TR-48 *R-Value and Thermal Conductivity of PEX and PE-RT Tubing*
- PPI TR-52 *Resistance of PEX Pipe and Tubing to Breakage When Frozen (Freeze-Break Resistance)*
- PPI TR-56 *History of Crosslinked Polyethylene (PEX) Tubing in North America and the Evolution of ASTM Standard Specification F876 from 1984 – 2024*

ISBN 978-0-9776131-2-0