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

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- Plastics Pipe Institute
  www.plasticpipe.org
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- Home Innovation Research Labs
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Introduction

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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*

Advantages and Benefits of PEX Plumbing Systems

2

The advantages and benefits of PEX plumbing systems have been well-documented and realized by contractors, builders, specifiers, and owners for many years, and it is important to summarize these advantages within this Guide. Benefits of PEX plumbing systems are introduced in **Chapter 1** ***Introduction*** and explained in further detail below.

Cost Effectiveness

For a variety of reasons, PEX plumbing systems have lower installation costs than metallic plumbing systems. The primary reason for this is that installation time and labor are greatly reduced due to the flexibility of PEX tubing, long continuous lengths, and the speed of joining. This can allow PEX plumbing systems to be installed with significant time savings as compared with rigid piping systems, increasing the productivity of crews and completing projects faster.

In recent years, the cost differential between PEX and copper materials has increased, delivering further savings to plumbers, builders, and owners.

Once in service, the use of PEX plumbing systems can reduce energy and water costs by delivering hot water to the fixtures faster and by reducing heat loss in the piping.

Durability

Based on extensive testing and real-world material performance since the early 1970s, PEX tubing has proven to be a durable material that does not suffer from some of the historical problems associated with metallic piping, such as reduced interior dimension from mineral build-up (e.g., occlusion, scaling, tuberculation), corrosion (e.g., galvanic, pitting), electrolysis, filming, and erosion corrosion due to excessive velocity. PEX also delivers excellent chemical resistance, environmental stress crack resistance (ESCR), resistance to slow crack growth (SCG), toughness, impact and abrasion resistance (see **Chapter 3** ***Material Properties***).

In addition, PEX tubing will typically expand if water in the system accidentally freezes and will return to its original dimension when the ice thaws. Breakage due to freezing is rare.

Ease of Installation

The installation of PEX tubing is generally easier than rigid pipes. PEX tubing is available in long coils, which eliminates the need for most coupling joints. Its flexible nature allows it to be bent gently through curves and around obstructions, minimizing the use of fittings such as elbows. No solvent, chemical, or solder joining is required. Various types of fitting systems (e.g., crimp, press, cold-expansion, push-fit, mechanical compression) are secure and reliable when installed properly. PEX tubing is lightweight, making it safe to transport and easy to handle. For a comparison of the installation of rigid metal pipe to PEX pipe, refer to the PATH Field Evaluation in Lincoln, Neb.[1]

Energy Efficiency

PEX tubing offers reduced heat loss and improved thermal characteristics when compared to metallic pipe (see **Chapter 3 *Material Properties*** section "Thermal Conductivity/R-Value"). In addition, less water is wasted delivering hot water to fixtures because of shorter delivery times for hot water with parallel (i.e., home-run) plumbing systems. For explanations of how to design PEX parallel plumbing systems, see **Chapter 6 *PEX Plumbing Systems Layouts & Design***.[2]

Noise Reduction

When properly secured, PEX tubing is inherently less noisy and quieter than rigid piping systems due to its flexibility and its ability to absorb the kinetic energy from pressure surges caused by fast closing valves, such as those used in washing machines and ice makers (see **Chapter 3 *Material Properties*** section "Noise and Water Hammer (Surge Pressure) Resistance." The flexibility of PEX tubing combined with its comparatively thicker wall also help to reduce sound transmission and vibration through the pipe wall in cases of high water velocities.

Resilience

For piping materials, resilience refers to a material's ability to withstand anticipated hazards, adapt to changing conditions, withstand and limit negative effects caused by events, and return to service.

PEX tubing is one of the most resilient piping materials available thanks to several properties:

- Resistance to impact, even at cold temperatures
- Flexibility to resist kinking or breaking if soil or buildings move or settle during seismic or other events
- Fatigue resistance and the ability to withstand repeated load cycles (e.g., thermal expansion, pressure cycling) without damage
- Resistance to corrosion and aggressive water chemistry (e.g., low pH acidic water)
- Resistance to scale and mineral build-up
- Resistance to disinfectants chlorine and chloramines (see **Ch. 3 *Material Properties***)
- Freeze-break resistance (see **Chapter 3 *Material Properties*** and **PPI TR-52 *Resistance of PEX Pipe and Tubing to Breakage When Frozen (Freeze-Break Resistance)***

1 *Evaluation of Hot Water Distribution Systems by Numeric Simulation*, 2004. Building Technology Center, Oak Ridge National Laboratory.

2 *Performance Comparison of Residential Hot Water Systems*, 2002. NAHB Research Center report available at HomeInnovation.com.

- PEX tubing delivers a unique combination of toughness and flexibility, allowing it to withstand typical jobsite conditions without damage.

Sustainability

PEX is an enhanced version of high-density polyethylene (HDPE), an economical and highly cost-effective construction piping material based on one of the most popular plastic materials in the world. HDPE is also one of the most recycled materials in the world. Generally, as indicated by a peer-reviewed life cycle inventory report[3], the manufacturing of plastic pipe consumes less energy than producing similar lengths of metallic pipe.

As reported in a published study by TEPPFA[4], PEX has a significantly lower carbon footprint than copper tubing, and its production and usage can reduce carbon dioxide (CO_2) emissions and water consumption.

The lighter weight of PEX compared to metallic piping helps to reduce transportation costs and energy consumption. For example, 100 feet of 3/4 PEX tubing weighs just 10.1 pounds (4.6 kg), while 100 feet of type L copper tubing weighs 45.5 pounds (20.6 kg); in this example, PEX tubing is just 22% of the weight of copper (i.e., 78% lighter). This lighter weight not only reduces transportation costs, but it also improves worker safety on the jobsite.

At the end of its useful life, PEX tubing can be recycled in a variety of methods. A common technique used recycled PEX tubing as an inert filler material that can be incorporated into other polymers for specific applications and into other construction products, such as asphalt for road building. In 2023, one PEX manufacturer working with a team of other firms announced a full PEX recycling scheme, where scrap PEX tubing can be recycled into new PEX tubing for full circularity.

The use of PEX tubing in hot water plumbing systems also assists with conserving water and energy through faster delivery of hot water, as compared with metallic pipes (see **Chapter 8 *Performance Data***).

Due to its resistance to erosion and corrosion, which are known to occur to metallic piping systems and shorten their lifetimes, plastic piping systems such as PEX will often deliver longer service lifetimes.

Finally, PEX tubing does not contain lead, harmful VOCs, or bisphenol A (BPA) and is strictly regulated for drinking water safety through mandatory certifications to **NSF/ANSI/CAN 61 *Drinking Water Systems – Health Effects*** and **NSF/ANSI/CAN 372 *Drinking Water System Components – Lead Content***.

Versatility

In addition to being used for hot- and cold-water plumbing distribution, PEX tubing has numerous other applications that take advantage of its physical properties (e.g., high temperature resistance, long-term stability and strength, flexibility, ductility, reliability, ease of installation, etc.)

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3 *The Life Cycle Inventory Report Peer-Reviewed Life Cycle Inventory for the Production and Use of Installed Residential Piping Systems for three House Layouts*, February 3, 2011, commissioned by the Plastic Pipe and Fittings Association and prepared by Franklin Associates is available at ppfahome.org.

4 The European Plastic Pipes and Fittings Association

PEX is widely utilized for these and other applications:

- Reclaimed water piping
- Fire suppression systems (residential fire sprinklers)
- Municipal water service lines and building supply lines (buried pipes)
- Hydronic heating and cooling using warm or chilled fluids, including radiant systems
- Slab freeze protection below cold-storage freezers, ice rinks, and more
- Ground source (geothermal) ground heat exchangers
- Outdoor snow and ice melting
- Outdoor turf conditioning
- District energy pipelines
- Chilled water piping
- Ice surface piping

In addition, PEX systems are sometimes used for specialized industrial and mining applications.

Water Conservation

Lengthy delivery time for hot water in plumbing systems represents a significant waste of water and energy, a problem often exacerbated in larger homes. Properly designed PEX plumbing systems have the potential to conserve water (see **Chapter 7 *Optimizing Design*** and **Chapter 8 *Performance Data***).

The flexibility of PEX tubing, especially when supplied in coils, allows it to bend around corners and run continuously, reducing the need for fittings such as elbows and couplings. By using fewer fittings, pressure drop through the piping network is reduced. In some installations, this can allow downsizing the pipe diameter to nominal tubing size 3/8 for certain fixtures when this size is supported by hydraulic (i.e., pressure drop) calculations and permitted in codes. The volume of 3/8 PEX tubing is only 55% of that of 1/2 tubing, a 45% volume reduction. This reduction in tubing diameter directly reduces the amount of water flushed when a hot-water plumbing fixture is opened.

In 2002, Home Innovation Research Labs conducted software simulations and laboratory tests on a "typical" hot-water distribution system using a trunk and branch rigid pipe design and one that included a nominal tube size 3/8 parallel PEX system. Results indicated that parallel systems using shorter runs with a manifold reduced the wait time for hot water and wasted less water than longer runs of rigid pipe with numerous elbows and connections.[5]

As demonstrated in **Chapter 8 *Performance Data***, a PEX plumbing system piped in the parallel layout reduced the delivery time for hot water to reach a fixture by 30% to 40% as compared with a trunk and branch plumbing layout, depending on the length to the farthest fixture. Substituting 3/8 PEX for any type of 1/2 tubing, when hydraulic calculations and codes allow, can save even more water by minimizing the amount of hot water stored within pipes.

5 *Performance Comparison of Residential Hot Water Systems*, 2002. NAHB Research Center report available at HomeInnovation.com.

Material Properties

3

Crosslinked polyethylene (PEX) is a polyethylene (PE) material, typically high-density polyethylene (HDPE), 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.

This crosslinking of the polymer chains results in improved performance properties such as elevated temperature strength, flexibility, chemical resistance, environmental stress crack resistance (ESCR), resistance to slow crack growth (SCG), toughness, and abrasion resistance. Crosslinking also makes PEX a "semi-thermoset" polymer, providing excellent long-term stability.

Polyethylene can be crosslinked using several technologies. All methods induce links between the single strands of HDPE to form a dense network or matrix through radical reactions. The number of links between the HDPE molecules determines the crosslink density and is an important factor in determining the physical properties of the material.

The three most common methods of crosslinking polyethylene are as follows:

Peroxide – This method employs organic peroxides that, when heated, generate reactive free radicals that splice PE chains together as the HDPE compound is extruded. This is sometimes referred to as the PEXa Process.

Silane – This method involves grafting a reactive silane molecule to the backbone of the polyethylene, which allows the HDPE compound to crosslink after extrusion as pipe when subjected to moisture and heat, such as with steam curing. This is sometimes referred to as the PEXb Process.

Electron beam – This method involves subjecting a dose of high-energy electrons to the extruded HDPE pipe. This is sometimes referred to as the PEXc Process.

Other crosslinking methods are also in commercial use. Although each method of crosslinking may produce slightly different characteristics, PEX tubing produced by any of the approved methods must meet the same qualification and performance requirements as specified in industry standards (e.g., ASTM F876, AWWA C904, CSA B137.5). The letter designations are not related to any type of rating system.

As required in any manufacturing process, procedures for each technology must be established and followed with stringent quality control checks in place to produce quality products.

Industry Standards for PEX Tubing

As a widely-recognized product within the plastic piping industry, there are several industry standards that are commonly referred to when describing PEX tubing for plumbing applications. These industry standards define minimum material and performance requirements for all PEX tubing and systems and have been adopted into model plumbing codes for USA and Canada.

These are the most relevant industry standards for PEX systems:

ASTM F876 ***Standard Specification for Crosslinked Polyethylene (PEX) Tubing***
Scope (Partial): "This specification covers crosslinked polyethylene (PEX) tubing that incorporates an optional polymeric inner, middle or outer layer and that is outside diameter controlled, made in nominal SDR9 tubing dimension ratios except where noted, and pressure rated for water at three temperatures. Included are requirements and test methods for material, workmanship, dimensions, burst pressure, hydrostatic sustained pressure, excessive temperature and pressure, environmental stress cracking, stabilizer functionality, bent-tube hydrostatic pressure, oxidative stability in potable chlorinated water, UV resistance, and degree of crosslinking. Requirements for tubing markings are also given."

ASTM F877 ***Standard Specification for Crosslinked Polyethylene (PEX) Hot- and Cold-Water Distribution Systems***
Scope (Partial): "This specification covers requirements, test methods, and marking requirements for system components when tested with nominal SDR9 crosslinked polyethylene (PEX) tubing as a system. Systems are intended for 100 psi (0.69 MPa) water service up to and including a maximum working temperature of 180°F (82°C). Requirements and test methods are included for materials, workmanship, dimensions and tolerances, burst pressure, hydrostatic sustained pressure, excessive temperature and pressure, corrosion resistance, and thermocycling tests."

ASTM F2023 ***Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water***
Scope: "This test method describes the general requirements for evaluating the long-term, chlorinated water, oxidative resistance of cross-linked polyethylene (PEX) pipe or tubing produced in accordance with PEX specifications, such as Specification F876 or Specification F2788/F2788M by exposure to hot, chlorinated water. This test method outlines the requirements of a pressurized flow-through test system, typical test pressures, test-fluid characteristics, failure type, and data analysis."

ASTM F2657 ***Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing***
Scope: "This test method describes the procedure for exposing crosslinked polyethylene (PEX) tubing produced in accordance with Specification F876 to natural (sunlight) ultraviolet (UV) radiation and evaluating the effects of the exposure. This test method outlines the requirements for specimen size and preparation, exposure orientation, minimum UV exposure energy, post exposure testing and reporting."

CSA B137.5 ***Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications***
Scope (Partial): "This Standard specifies requirements for crosslinked polyethylene (PEX) tubing systems that comprise tubing and fittings. Tubing covered by this Standard is made

in Standard Dimensional Ratio 9 (SDR 9). Systems are pressure rated at three temperatures: 1105 kPa at 23°C, 690 kPa at 82°C, and 550 kPa at 93°C, with a maximum working pressure of 690 kPa at 82°C."

AWWA C904 *Crosslinked Polyethylene (PEX) Pressure Tubing, 1/2 in. Through 3 in. for Water Service*
Scope: "This standard describes crosslinked polyethylene (PEX) pressure tubing made from material having a standard PEX material designation code of PEX 1306, or higher, according to ASTM F876 and intended for use as underground potable water, reclaimed water, and wastewater service lines in sizes 1/2 in. through 3 in. that conform to a standard dimension ratio of SDR9. Tubing may include an optional polymeric outer layer. Included in this standard are criteria for classifying PEX plastic tubing materials, and a system of nomenclature, requirements, and test methods for materials and tubing. Methods of markings are given."

IAPMO IS-31 *Installation Standard for PEX Tubing Systems for Hot- and Cold-Water Distribution*
Scope: "This Standard specifies requirements for the installation of SDR 9 CTS crosslinked polyethylene (PEX) tubing and fittings, including cold-expansion, crimp, press, push-fit, and mechanical compression fittings, intended for hot- and cold-water distribution systems within buildings."

NSF/ANSI 14 *Plastics Piping System Components and Related Materials*
Scope: "This standard establishes minimum physical, performance, and health effects requirements for plastic piping system components and related materials. These criteria were established for the protection of public health and the environment."

NSF/ANSI/CAN 61 *Drinking Water System Components - Health Effects*
Scope: "This standard establishes minimum health effects requirements for the chemical contaminants and impurities that are indirectly imparted to drinking water from products, components, and materials used in drinking water systems. This standard does not establish performance, taste and odor, or microbial growth support requirements for drinking water system products, components, or materials."

NSF/ANSI/CAN 372 *Drinking Water System Components – Lead Content*
Scope: "This standard establishes procedures for the determination of lead content based on the wetted surface areas of products. This standard applies to any drinking water system component that conveys or dispenses water for human consumption through drinking or cooking."

PEX Material Designation Code

Although PEX tubing is subjected to many performance tests during qualification testing, certification, and as regular quality control processes, three key performance measurements are categorized in the "PEX Material Designation Code" which is marked on the printline (i.e., markings) of all PEX tubing: chlorine resistance (minimum 50 years), UV resistance, and the hydrostatic design stress at 73°F (23°C) for sustained water pressure. The PEX Material Designation Code consists of the three letters "PEX" and four numeral digits where the first digit describes chlorine resistance, the second digit describes UV resistance, and the third and fourth digits describe the hydrostatic design stress (HDS) when tested using sustained water pressure at 73°F in units of 100 psi, with any decimal figures dropped (see **Figure 3.1**). This code is explained in detail within industry standards ASTM F876 and CSA B137.5.

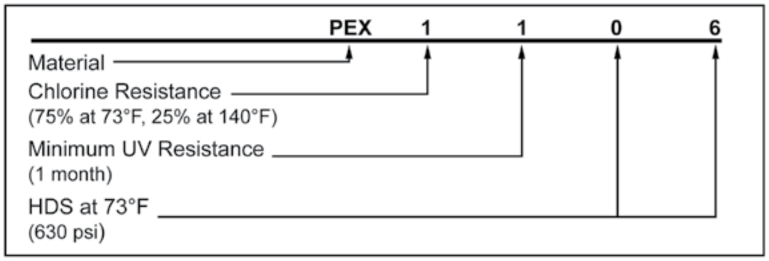

Figure 3.1 Pictorial Explanation of the PEX Material Designation Code

First digit: Chlorine resistance

The first digit of the PEX Material Designation Code is related to resistance to hot chlorinated water. PEX tubing for drinking water applications is required to have a minimum extrapolated time-to-failure of fifty (50) years when tested in accordance with ASTM F2023 for chlorine resistance and evaluated in accordance with ASTM F876 or CSA B137.5. Continuous recirculation, timed recirculation, and traditional domestic conditions are evaluated by ASTM F2023 and categorized within those standards as part of the PEX Material Designation Code.

- **0:** Not tested or not rated
- **1:** PEX tubing has been tested and meets the minimum requirements for chlorine resistance at the end use condition of 25% of the total time at 140°F (60°C) and 75% of the total time at 73°F (23°C). This is sometimes referred to as the Traditional Domestic application, with exposure to hot water (i.e., 140°F) up to 6 hours/day.
- **3:** PEX tubing has been tested and meets the minimum requirements for chlorine resistance at the end use condition of 50% of the total time at 140°F and 50% of the total time at 73°F. This is sometimes referred to as the Timed Recirculation application, with exposure to hot water (i.e., 140°F) up to 12 hours/day.
- **5:** PEX tubing has been tested and meets the minimum requirements for chlorine resistance at the end use condition of 100% of the total time at 140°F. This is sometimes referred to as the Continuous Recirculation application, with exposure to hot water (i.e., 140°F) up to 24 hours/day.

Second digit: UV resistance

The second digit of this code is related to resistance to outdoor weathering and ultraviolet (UV) light for the PEX material when tested in accordance with ASTM F2657 and evaluated in accordance with ASTM F876 or CSA B137.5.

- **0:** Not tested or not rated
- **1:** PEX tubing has been tested and meets the minimum requirements for UV resistance of 1 month.
- **2:** PEX tubing has been tested and meets the minimum requirements for UV resistance of 3 months.
- **3:** PEX tubing has been tested and meets the minimum requirements for UV resistance of 6 months.

Third digit: Hydrostatic design stress (HDS) at 73°F (23°C)
The hydrostatic design stress (HDS) is equal to a PEX material's hydrostatic design basis (HDB) value multiplied by the approved design factor (DF), which is currently 0.50 for PEX. These stress values are based on the hoop strength of the PEX material and not directly related to internal water pressure. See ASTM F876 and ASTM D2837 for additional details about HDS and HDB values.

- **06** = 630 psi HDS value
- **07** = 700 psi HDS value
- **08** = 800 psi HDS value

According to ASTM F876 and CSA B137.5, the minimum PEX material designation code for tubing intended for potable water is **PEX 1106**, which means:

- The first digit of "1" indicates that this material has been tested and meets the F876 requirement for minimum chlorine resistance at the end use condition of 25% of the total time at 140°F and 75% of the total time at 73°F.
- The second digit of "1" indicates that this material has been tested and meets the F876 requirement for minimum UV resistance of 1 month.
- The third and fourth digits of "06" indicates that this material has a 630 psi maximum recommended HDS using a 0.5 design factor at 73°F.

PEX Tubing Dimensions

PEX tubing products are produced to strict dimensional controls, as found within the aforementioned industry standards with very tight tolerances on outside diameter (OD), wall thickness, and out-of-roundness. The dimensions within each industry standard are harmonized to be identical. See **Table 3.1** PEX Tubing Dimensions.

Table 3.1 PEX Tubing Dimensions

Nominal Diameter	OD inches[A]	Wall inches[B]	ID[C] inches	Weight lb/ft	Volume[D] gallon/100ft
3/8	0.500	0.075	0.350	0.04	0.5
1/2	0.625	0.075	0.475	0.05	1.0
5/8	0.750	0.088	0.574	0.07	1.3
3/4	0.875	0.102	0.671	0.10	1.9
1	1.125	0.132	0.862	0.17	3.2
1 1/4	1.375	0.161	1.054	0.25	4.7
1 1/2	1.625	0.191	1.244	0.35	6.5
2	2.125	0.248	1.629	0.60	11.1
2 1/2	2.625	0.307	2.011	0.92	16.5
3	3.125	0.363	2.399	1.29	23.5
4	4.125	0.478	3.169	2.24	41.0

[A] Average Outside Diameter (OD) from ASTM F876
[B] Average Wall thickness from ASTM F876
[C] Inside Diameter (ID) is calculated from OD and wall thickness
[D] Typical tubing volumes in US gallons

In the piping industry, the term "tubing" refers to products where the actual outside diameter (OD) is 1/8 inch larger than the nominal size, the same as copper tubing. Products with an OD that matches copper tubing are sometimes referred to as "copper tube size" (CTS) or "nominal tube size" (NTS). PEX products used for hot- and cold-water plumbing distribution are CTS.

The term "pipe" refers to products whereby the actual outside diameter matches that of steel pipe of the same nominal size, or products where the actual OD matches the nominal size. Those products are sometimes referred to as "iron pipe size" (IPS) or "nominal pipe size" (NPS).

Within this Guide, the terms "tubing" and "pipe" may be used interchangeably, although the technically-accurate term for the PEX described in this Guide is "tubing."

Color

PEX tubing is available in natural (translucent) or colors such as red, white, and blue. Tubing may be pigmented with color throughout or coated with a pigmented layer to apply the color, or not pigmented at all. Some installers prefer to use red and blue PEX for hot- and cold-water distribution piping, respectively, while others prefer to have one uniform color, such as white, throughout the system.

Model plumbing codes do not dictate the use of any particular color for hot- and cold-water distribution piping. PEX tubing of all colors must meet the same technical requirements.

Corrosion Resistance

Corrosion, an electrolytic process, requires the presence of electrically conductive materials such as lead, iron, steel, or copper. PEX is a dielectric material which is electrically non-conductive and does not pit or corrode like metal pipes.

Corrosion factor adjustments, commonly used with metal piping systems, are not needed when sizing a PEX system.

Erosion Corrosion

Erosion corrosion is defined as the degradation of a surface due to mechanical action coupled with a secondary corrosion element. Erosion is often caused by abrasion from suspended solids, cavitation, or turbulent fluid flow wearing away the passivation layer protecting an underlying material and causing rapid damage to the material through both physical wear of the material and further chemical attack.

PEX tubing has a smooth interior surface and can withstand high velocities without erosion. Under the test conditions reported in **PPI TN-26 *Erosion Study on Brass Insert Fittings Used in PEX Piping Systems***, PEX tubing and brass fittings were subjected to extraordinarily high water velocities in excess of 12 ft/sec using hot chlorinated water for months of continuous flow testing. This test utilized potable water with corrosive pH levels between 6.5 and 6.7, much lower and more aggressive than levels found in common potable water systems. At the conclusion, no detectable erosion of the tubing surface occurred despite the very high flow velocities of aggressive water.

In PEX plumbing systems, design velocities are generally restricted by factors other than the capabilities of the PEX tubing or fittings (e.g., pressure drop, energy conservation, water hammer).

Tuberculation

Tuberculation is a type of scaling build-up that occurs within pipes that can be a result of bacteria feeding on iron within pipe walls. It typically occurs in response to the deposition of minerals onto the surface of the pipe and subsequent corrosive action with the base material of the pipe. PEX tubing has a smooth interior surface, which provides minimal opportunity for the precipitation of minerals such as calcium carbonate, and contains no iron content. The potential for tuberculation of PEX tubing is minimal, which means that PEX tubing resists mineral build-up.

Drinking Water Safety

The plastic piping industry is highly regulated within USA and Canada with systems of standards, codes, and third-party certifications which are extremely rigorous with regards to pipe materials (ingredients), production controls, and finished products.

To ensure drinking water safety, plastic pipe, tubing, and system components (e.g., fittings) must comply with federal regulations. **NSF/ANSI/CAN 61 *Drinking Water System Components – Health Effects*** is the legally-recognized national standard in the United States and Canada for evaluating the human health effects of drinking water materials, components, and devices, and ensuring that approved materials are safe for drinking water. All PEX components must be tested and certified to this standard.

In addition, plastic pipe, tubing, and system components must also be tested and certified to **NSF/ANSI/CAN 372 *Drinking Water System Components – Lead Content*** to demonstrate that they are lead-free.

Finally, plastic pipe, tubing, and system components must also comply with **NSF/ANSI Standard 14 *Plastic Pipe System Components and Related Materials*** which focuses on other aspects of performance and quality control.

As part of these certification processes, certifiers know exactly what materials are used in each pipe, tubing, or fitting formulation, and the safety of these products is repeatedly verified through frequent unannounced plant inspections.

PEX tubing systems for potable water are tested at water pH levels from 5.0 to 10.0, both extreme acidity and alkalinity beyond typical levels encountered in potable water systems, and at both cold and hot water temperatures.

PEX tubing does not contain lead, harmful volatile organic compounds (VOCs), or BPA (Bisphenol A).

Flexibility

Crosslinked polyethylene remains a flexible material even at temperatures well below freezing. In fact, PEX tubing remains flexible and can still be bent at temperatures below -40°F (-40°C).

The flexibility and low stiffness of PEX allows it to be bent gently around obstructions and installed as one continuous run without fittings, if desired. Slight changes in direction are made easily by cold-bending the tubing by hand; snap-on bend supports can hold the tubing in 90-degree sweeps in place of elbow fittings (see **Figure 3.2**). Minimizing joints and connections can result in quicker installations, less potential for leaks at fittings, and less resistance by reducing pressure drop through fittings. Bend supports should be used to facilitate rigid bends and to alleviate stress on PEX joints when bends are needed in close proximity to such joints.

The free (unsupported) bending radius for PEX tubing, measured at the mid-point of the bend, shall be not less than (i.e., no tighter than) six times the actual outside diameter of the tubing, unless otherwise specified by the PEX manufacturer (see **Figure 3.3**).

Refer to **Table 3.2** for a list of minimum bend radii based on tubing diameter.

Figure 3.2 Examples of Snap-on Bend Supports for PEX Tubing

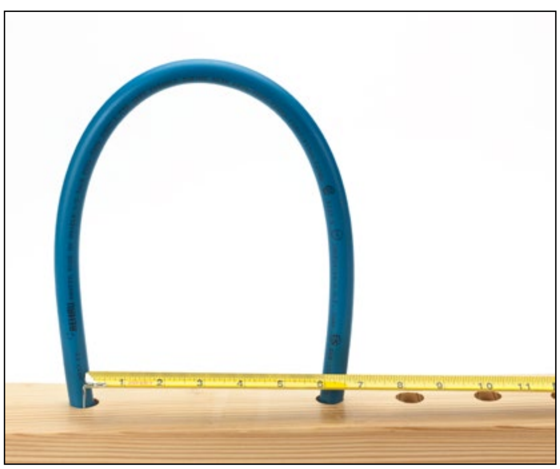

Figure 3.3 PEX Tubing Bent at a Radius of 6 Times the Outside Diameter

Table 3.2 Minimum Bend Radii of PEX Tubing

Nominal Tubing Size	Tubing OD (Actual) in.	6 times Bend Radius in.
3/8	0.500	3.0
1/2	0.625	3.8
3/4	0.875	5.3
1	1.125	6.8
1 1/4	1.375	8.3
1 1/2	1.625	9.8
2	2.125	12.8
2 1/2	2.625	15.8
3	3.125	18.8
4	4.125	24.8

Noise and Water Hammer (Surge Pressure) Resistance

As water flows through pipes, pressure in the system gives moving water energy, known as kinetic energy. Kinetic energy increases with the speed of water and with the mass of flowing water. When the flow of water is suddenly stopped, such as when a fast-acting valve or faucet is closed, this kinetic energy must be dissipated in the system and a short-term surge in water pressure will result.

The surge pressure that can result from fast-closing valves (e.g., washing machines, ice makers, irrigation systems) can produce instantaneous pressure spikes of 300 to 400 psig, which can, over time, cause damage to rigid pipes, fittings, fixtures, valves, and hot water tanks.

The ability of a plumbing pipe to absorb and dissipate energy due to surges in water pressure is based on the pipe's modulus of elasticity, a measure of material stiffness. A higher modulus of elasticity means the material is more rigid. Copper tubing is approximately 180 times more rigid than PEX tubing, and less capable of absorbing pressure spikes.

Ultimately, this means that with rigid piping systems, pressure surges can produce noticeable banging sounds as energy is dissipated through the piping network, thus causing what is known as "water hammer."

Note: Other audible "water hammer" noise can also be caused by a moving column of water cavitating as pressure waves reverberate within pipes. This noise is typically not related to excessive surge pressures and is not damaging to plumbing system components. This effect may be more likely in low water-pressure systems. Even the most flexible pipe cannot prevent all noises in certain situations.

Surge Pressure Performance Testing

In a research project conducted at Home Innovation Research Labs (formerly known as NAHB Research Center), a test apparatus was constructed and operated such that pressurized flowing water in 20-foot straight lengths of pipe was abruptly interrupted by a fast-acting solenoid valve with a closing speed estimated at approximately 25 milliseconds. Several rigid and flexible, metal and plastic, nominal tubing size 1/2 materials were subjected to a test regime that included flow rates of 2, 2 1/2, 3, 4, and 6 gallons per minute using cold (54°F) and hot (130°F) test water. Pipes were mounted at hanger intervals according to the International Plumbing Code (PEX and CPVC at 32 inches, copper at 72 inches). The system was pressurized to a static pressure of 60 psig.

Results of the pressure measurements taken at the location of the fast-acting valve showed that plastic tubing materials exhibited significantly lower peak pressure measurements than Type L copper tubing at all flow rates and water temperatures.

For example, test results using nominal 1/2 tubing with 54°F (12°C) "cold" water at a typical flow rate of 2.5 GPM showed that peak pressures were reduced by up to 37% for PEX tubing as compared with copper. Test results using nominal 1/2 tubing with 130°F (54°C) "hot" water at the same flow rate of 2.5 GPM showed that peak pressures were reduced by up to 33% for PEX tubing as compared with copper. Results are shown in **Tables 3.3** and **3.4**.

At higher flow rates, the percentage of the surge pressure reduction increases.

Table 3.3 First Peak Pressure for Each Piping Material and Flow Rate

Flow Rate, GPM	2	2.5	3	4	6	2	2.5	3	4	6
Pipe Material (NTS 1/2)	Maximum Measured Pressure, psi									
	54°F Water					130°F Water				
1/2 Type L Copper	194	239	266	318	422	149	181	204	250	306
1/2 CPVC	155	173	201	222	296	142	157	174	203	252
1/2 PEX-1	143	168	177	212	274	108	113	124	141	175
1/2 PEX-2	136	150	169	193	244	113	122	123	141	174

Note: Pressure response measurements include 60 psi static pressure.

Note: Two types of PEX, indicated as "PEX-1" and "PEX-2" were tested.

Table 3.4 Peak Pressure Comparison – 2.5 GPM

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

In summary, the flexibility of PEX tubing material allows it to absorb energy from pressure surges and eliminate or reduce the occurrence of water hammer and the potentially harmful surge pressures that may damage other plumbing systems components such as faucets, toilets, etc.

Note: For full details of this testing, see the report ***Surge Pressure in Plumbing Pipe Materials*** available on the PPI website.

Refer to the PPI **Plastic Pipe Design Calculator** (www.plasticpipecalculator.com) for Hydraulic Shock calculations.

Resistance to Freeze Damage

The material properties of PEX tubing provide it with inherent benefits when subjected to freezing conditions.

First, PEX materials have lower thermal conductivity than metallic piping materials, which reduces the thermal exchange rate and can extend the time required to freeze the water within the system.

Second, the flexibility of PEX allows it to be installed with fewer fittings than other piping materials, reducing the potential for ice blockage events at transition locations, thus allowing the increased pressure that can build up in a freezing piping system to be distributed throughout the piping system.

Third, if the freezing of water within PEX *does* occur, the elastic nature of PEX materials at temperatures even below -40°F (-40°C) enable for circumferential and axial expansion of the tubing that correlates to the increase in volume of the fluid during a freezing event, usually preventing breakage. If an unintended freeze event does occur, then the properties of PEX tubing are such that, in many instances, the tubing will not burst when the fluid inside is frozen.

There are situations where freezing fluid can damage or burst PEX tubing, and this should be prevented through proper planning and installation of PEX systems. See **PPI TR-52 *Resistance of PEX Pipe and Tubing to Breakage when Frozen (Freeze-Break Resistance)*** for more details on this topic.

Temperature and Pressure Capabilities

Consensus standards published by ASTM International and CSA Group specify temperature and pressure capabilities of and requirements for PEX systems and components.

A pressure rating is the estimated maximum pressure that the fluid in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur. Pressure ratings are always given at a specified temperature. PEX tubing and systems are pressure-rated at multiple temperatures, related to operation in cold- and hot-water systems. The minimum pressure ratings for PEX according to industry standards are 160 psig at 73°F (1,100 kPa at 23°C) and 100 psig at 180°F (690 kPa at 82°C). Some PEX tubing is also rated for 80 psig at 200°F (550 kPa at 93°C).

Pressure ratings for plastic pipes and tubing are based on an extrapolated time-to-failure prediction as defined in **ASTM Test Method D2837 *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products***. Pressure ratings are calculated using the hydrostatic design basis (HDB) and hydrostatic design stress (HDS) values. These values are recommended by The Plastics Pipe Institute (PPI) or other certification bodies.

One example of these test requirements is the Hydrostatic Sustained Pressure Strength test. This laboratory test is performed at several temperatures and results are used to demonstrate the pressure ratings which will be marked on PEX tubing. Each PEX tubing manufacturer must subject its PEX tubing material(s) at multiple temperatures and multiple pressures for thousands of hours of hydrostatic testing to satisfy the qualification requirements as found within ASTM D2837, ASTM F876, AWWA C904, CSA B137.5, PPI TR-3, and other industry standards.

PEX tubing and fitting systems must also be subjected to the excessive temperature and pressure test found within the standards. In the event of a water heating system malfunction, PEX systems are designed to accommodate short-term conditions 150 psig at 210°F (1,034 kPa at 99°C) until repairs can be made to the water heating system. This requirement is based on the most commonly used Temperature & Pressure (T&P) Relief valves which activate (open) at either that temperature or pressure condition (i.e., 150 psig or 210°F) in case a water heater does not deactivate when it reaches its temperature setpoint. All PEX systems must be tested to withstand this condition (i.e., 150 psig or 210°F) for a minimum of 720 hours (30 days) to ensure that safety requirements are met. As such, PEX systems DO NOT require the use of a special T&P relief valve.

Thermal Conductivity / R-Value

PEX material has a low thermal conductivity as compared to metal piping materials such as copper which reduces heat transfer through the tubing wall. This means that condensation is less likely to form on cold-water PEX tubing in humid environments and less heat is lost to the environment in hot-water applications. This can also delay the freezing of water within PEX tubing, potentially preventing freezing events.

For similar material thickness, PEX is approximately 68 times less conductive than copper, which will delay heat transfer into or out of the contained fluid. According to **PPI TR-48 *R-Value and Thermal Conductivity of PEX and PE-RT Tubing***, the normalized thermal conductivity (K-factor) for PEX is **2.86 (BTU·in)/(ft²·hr·°F)**. This compares with a thermal conductivity (K-factor) for copper tubing material of **196 (BTU·in)/(ft²·hr·°F)**, a factor of 68 times.

Another way of expressing the relatively low thermal conductivity of PEX is to convert this to an R-value expressed with the units ft²·°F·h/BTU. The higher the Resistance value, the slower the rate of heat transfer through the insulating material.

The wall thickness of each diameter of PEX tubing varies, based on a standard dimension ratio (SDR) of 9, with the wall getting increasingly and proportionally thicker as diameter increases. In fact, in all diameters, the wall thickness of PEX tubing is higher than that of copper tubing, so a direct comparison of R-values is not linear. See **Table 3.5** for the R-value of PEX tubing by nominal diameter.

Table 3.5 R-value of PEX Tubing by Nominal Tubing Size (i.e., diameter)

Property	Nominal Tubing Size (NTS)						
	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Wall Thickness (in)	0.070-0.080	0.070-0.080	0.097-0.107	0.125-0.138	0.153-0.168	0.181-0.200	0.236-0.260
R-Value (ft²°F-h/BTU)	0.028	0.028	0.038	0.049	0.060	0.072	0.093

Note: Normalized R-values are based on standardized material thickness of 1.00 inch

Resistance to Disinfectants

The U.S. Environmental Protection Agency (EPA) recommends that all drinking water be disinfected, typically using free chlorine, chloramines, or other less common methods.

Currently, the majority of potable drinking water in the United States and Canada is disinfected using free chlorine while the second most common method of disinfection is chloramines. For water treated with free chlorine or chloramines, the EPA sets a maximum disinfectant level of 4.0 parts per million (ppm) within a public water distribution system.

Chlorine and Chloramines

To ensure the reliability of PEX tubing systems in hot chlorinated water applications, it is a requirement of the PEX product standard specification ASTM F876 that all PEX tubing intended for use with potable water have a minimum extrapolated lifetime of fifty (50) years when tested in accordance with **ASTM Test Method F2023** ***Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water***.

The test conditions of ASTM F2023 require that the test fluid has a minimum oxidative reduction potential (ORP) of 825 mV. ORP is a measure of how likely a solution is to give or receive electrons given the right circumstances. To produce test fluid with such an elevated ORP, third-party test laboratories typically use reverse osmosis-purified water with a free chlorine concentration of 4.3 +/- 0.3 ppm (4.3 mg/L) and pH of 6.8 +/- 0.2, resulting in an ORP of 825 mV or higher. This represents a very aggressive water quality which gives conservative results in terms of expected pipe lifetime. This test procedure is designed to extrapolate the life expectancy of a hot-water plumbing pipe when used at a pressure up to 80 psig at a water temperature up to 140°F. Continuous recirculation, timed recirculation, and traditional domestic (i.e., intermittent) conditions are evaluated by ASTM F876.

All PEX tubing intended for potable water applications must be tested and certified by qualified third-party certification agencies to meet the requirements of ASTM F876, including chlorine resistance. The minimum performance requirement applies to traditional domestic applications; F876 states "PEX tubing intended for use in the transport of potable water shall have a minimum extrapolated time-to-failure of 50 years and comply with the requirements for a first digit of "1" or higher in the PEX Material Designation Code." See the previous section ***PEX Material Designation Code*** for more details about chlorine resistance requirements. For more information about chlorine resistance of PEX tubing, please see **PPI TN-53** ***Guide to Chlorine Resistance of PEX Pipes and Tubing for Potable Water Applications***.

Fittings used with PEX tubing must comply with ASTM standards and are made from brass, copper, or high temperature engineered polymers that are also chlorine resistant.

According to the U.S. EPA, chloramines are disinfectants used to treat drinking water, and are formed when ammonia is added to chlorine. To evaluate the resistance of PEX tubing to chloramines, a research project coordinated by the PPI examined the relative oxidative aggressiveness of both free chlorine and chloramines.

According to the study, published as **PPI Statement A** ***Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants on Crosslinked Polyethylene (PEX) Pipes used in Treated Potable Water***, it is the position of PPI that chloramines are less aggressive than free chlorine to PEX tubing. Testing of oxidative resistance using free chlorine, in accordance with ASTM F2023, will provide a conservative estimate of the time-to-failure for PEX tubing when used with the disinfectant chloramines.

In summary, PEX tubing has shown itself to be resistant to attack from chlorine and chloramines under a wide range of conditions and has performed reliably in all regions of North America.

Chlorine Dioxide

While chlorine dioxide (ClO_2) is a far less common water disinfectant that is rarely used as a secondary (i.e., residual) water disinfectant in public potable water systems, in certain types of large facilities such as hospitals, nursing homes, hotels, apartment buildings, and office buildings, it is sometimes added to plumbing distribution systems to treat or control outbreaks of harmful bacteria such as Legionella.

In such facilities, specialized chlorine dioxide generation devices can be added to inject ClO_2 in measured doses directly into the piping system before hot water is delivered throughout the building. Chlorine dioxide is a dissolved gas and is highly volatile and efficient as an oxidizing agent for disinfection. It is used in different concentrations than free chlorine or chloramines and has a different mechanism of attack on the various materials and substances to which it is exposed.

PPI TN-67 *Chlorine Dioxide and Plastic Hot- And Cold- Water Plumbing Distribution Pipes* addresses this topic. Based on data that has been analyzed regarding the effects of chlorine dioxide on piping materials in hot- and cold-water plumbing systems, it is apparent that this compound can be very aggressive to materials such as crosslinked polyethylene. PPI recommends caution when considering the use of ClO_2 as a chemical disinfectant to treat water for the control of Legionella or other pathogens and recommends contacting each piping system supplier for guidance on the use of their pipe and fitting material(s) in circumstances where chlorine dioxide has been selected as the disinfection chemical.

Outdoor Weathering / Ultraviolet (UV) Resistance

Like most plastics, the long-term performance of PEX will be affected by ultraviolet (UV) radiation from sunlight. Although most PEX tubing has good UV resistance, PEX tubing should not be stored outdoors where it is exposed to the sun. PEX tubing should not be installed outdoors unless buried in earth or properly protected from UV exposure, either direct or indirect.

Indirect (diffused) and reflected sunlight also emit UV energy. If PEX will be exposed to sunlight continuously after installation, such as in an unfinished basement, installers should cover the pipe with a UV-blocking sleeve or pipe insulation as approved by the PEX manufacturer.

To ensure the reliability of PEX tubing systems when exposed to sunlight, it is a requirement of the industry standards ASTM F876 and CSA B137.5 that all PEX tubing intended for use with potable water has a minimum UV resistance of 1 month when tested in accordance with **ASTM Test Method F2657 *Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing***. ASTM F876-25 states, "PEX tubing intended for use in the transport of potable water shall comply with the requirements for a second digit of "1" or higher in the PEX Material Designation Code." See the previous section "PEX Material Designation Code" for more details about UV resistance requirements.

Each PEX tubing manufacturer publishes the maximum recommended UV exposure time limit based on the UV resistance of each type and color of PEX tubing, as determined in accordance with ASTM F2657 and the requirements published in ASTM F876. Central Arizona is used as the basis of the exposure time limits as it represents the worst-case North American location for UV energy. As part of the test procedure, exposed pipes are then re-tested for chlorine resistance in accordance with ASTM F2023 and must show no significant reduction in pipe lifetime.

PPI TN-32 *UV Labelling Guidelines for PEX Pipe and Tubing* suggests the following information be labelled on all PEX packaging to clearly inform the user on the form of a NOTICE label:

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

Fitting Materials Used with PEX Tubing

The following materials for construction of PEX fittings are approved in one or more of the ASTM or ASSE fitting standards listed in **Chapter 5 *Joining Methods***. Each of these industry standards describes exactly which fitting material or materials may be used for the manufacturing of that particular fitting design.

Brass and bronze fittings

Many of the fitting systems listed in **Chapter 5 *Joining Methods*** are produced using lead-free brass or bronze materials. Multiple alloys with various combinations of copper and other elements, suitable for manufacturing processes such as casting, forging, and machining, are approved within those industry standards. Each of these materials is selected to provide the required strength, forgeability, machinability, and resistance to corrosion as required for potable water applications.

It is a requirement of the Uniform Plumbing Code (UPC) that fittings and valves produced from copper alloys containing more than 15% zinc by weight shall be resistant to dezincification and stress corrosion cracking in compliance with the test outlined in **NSF/ANSI 14**.

According to the US EPA, Section 1417 of the Safe Drinking Water Act (SDWA) establishes the definition for "lead free" as a weighted average of 0.25% lead calculated across the wetted surfaces of a pipe, pipe fitting, plumbing fitting, and fixture and 0.2% lead for solder and flux. The Act also provides a methodology for calculating the weighted average of wetted surfaces.

The Act prohibits the "use of any pipe, any pipe or plumbing fitting or fixture, any solder, or any flux, after June 1986, in the installation or repair of (i) any public water system; or (ii) any plumbing in a residential or non-residential facility providing water for human consumption, that is not lead free."

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1 The allowed UV exposure time of "**X** days" shall be recommended by the tubing manufacturer. Additionally, the third-party testing of the product is according to ASTM Test Method F2657 and requirements which are published in standards such as ASTM F876, AWWA C904, and CSA B137.5

All brass and bronze fittings for PEX tubing systems intended for use in potable water applications must be tested and certified to **NSF/ANSI/CAN 372** to ensure compliance with the ≤0.25% maximum weighted average lead content requirement and must be tested and certified to **NSF/ANSI/CAN 61** to ensure safety for drinking water.

Polysulfone (PSU) and Polyphenlysulfone (PPSU)

Many of the polymeric fitting systems listed in **Chapter 5 *Joining Methods*** may be produced using polysulfone (PSU) and/or polyphenylsulfone (PPSU) materials, typically produced via injection molding. These engineered plastic materials are tough and rigid to ensure tightness, durability, and dimensional stability. These materials are resistant to corrosion and bacterial deposits and are free of heavy metals.

Polyphenylene sulfide (PPS)

Some of the fitting systems listed in **Chapter 5 *Joining Methods*** may be produced using polyphenylene sulfide (PPS) materials. Polyphenylene sulfide is a type of engineered plastic known for its mechanical strength, high melting point (>275°C), excellent heat resistance, excellent chemical resistance against both organic and inorganic substances, low water absorption, and dimensional stability. It is suitable for the fitting systems for the above characteristics especially chemical resistance, low water absorption and high dimensional stability.

Polyvinylidene fluoride (PVDF)

Some of the fitting systems listed in **Chapter 5 *Joining Methods*** may be produced using polyvinylidene fluoride (PVDF) materials. Polyvinylidene fluoride is a type of engineered plastic known for its mechanical strength, excellent heat resistance, excellent chemical resistance against both organic and inorganic substances, purity, low water absorption, and dimensional stability. It is suitable for the fitting systems for the above characteristics especially chemical resistance, low water absorption and high dimensional stability.

PEX Tubing Markings

Per requirements of standards ASTM F876 and CSA B137.5, PEX tubing shall have the following markings on the print line, spaced at intervals of not more than 5 ft:

- Nominal tubing size and "SDR 9"
- Manufacturer's name or trademark
- Production code indicating date of production
- PEX material designation code (e.g., "PEX xxxx")
- "F876" and other standard designations (e.g., "CSA B137.5")
- Pressure ratings at 73°F and 180°F (e.g., 160 psi at 73°F, 100 psi at 180°F)
- Seal or mark of the laboratory certifying the tubing for use with potable water
- Standard designation(s) of the fitting system(s) for which the tubing is recommended for use by the tubing manufacturer (e.g., "F1807", "F1960") – see **Chapter 5 *Joining Methods***

Code Acceptance

4

PEX plumbing systems are recognized in all major plumbing and building model codes and are commonly used for hot- and cold-water distribution applications, water service lines, fire protection and radiant heating/cooling systems. The following is a summary of relevant model code requirements which specifically pertain to PEX plumbing systems for hot- and cold-water distribution systems.

The following sections are direct extracts from the latest model codes from USA and Canada, as applicable to PEX plumbing systems, with permission of the publishers. The code edition of each extract is stated.

Note: PEX has been accepted for hot- and cold-water distribution piping in North American model codes since 1993 and codes are constantly reviewed and updated. 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.

International Plumbing Code (IPC 2024)

PIPING SUPPORT

308.1 General. Plumbing piping shall be supported in accordance with this section.

308.2 Piping seismic supports. Where earthquake loads are applicable in accordance with the *International Building Code*, plumbing piping supports, anchorage, and bracing shall be designed and installed for seismic forces in accordance with Chapter 16 of the *International Building Code*.

308.3 Materials. Hangers, anchors and supports shall support the piping and the contents of the piping. Hangers and strapping material shall be of *approved* material that will not promote galvanic action.

308.4 Structural attachment. Hangers and anchors shall be attached to the building construction in an *approved* manner.

308.5 Interval of support. Pipe shall be supported in accordance with Table 308.5.
Exception: The interval of support for piping systems designed to provide for expansion/contraction shall conform to the engineered design in accordance with Section 316.1.

308.9 Parallel water distribution systems. Piping bundles for manifold systems shall be supported in accordance with Table 308.5. Support at changes in direction shall be in accordance with the manufacturer's instructions. Where hot water piping is bundled with cold water piping, hot water piping shall be insulated in accordance with Section 607.5.

601.3 Existing piping used for grounding. Existing metallic water service piping used for electrical grounding shall not be replaced with nonmetallic pipe or tubing until other *approved* means of grounding is provided.

603.1 Size of water service pipe. The water service pipe shall be sized to supply water to the structure in the quantities and at the pressures required in this code. The water service pipe shall be not less than 3/4 inch (19.1 mm) in diameter.

604.3 Water distribution system design criteria. The water distribution system shall be designed, and pipe sizes shall be selected such that under conditions of peak demand, the capacities at the fixture supply pipe outlets shall be not less than shown in Table 604.3. The minimum flow rate and flow pressure provided to fixtures and appliances not listed in Table 604.3 shall be in accordance with the manufacturer's installation instructions.

604.10 Gridded and parallel water distribution system manifolds. Hot water and cold water manifolds installed with gridded or parallel connected individual distribution lines to each fixture or fixture fitting shall be designed in accordance with Sections 604.10.1 through 604.10.3.

604.10.1 Manifold sizing. Hot water and cold water manifolds shall be sized in accordance with Table 604.10.1. The total gallons per minute is the demand of all outlets supplied.

605.3 Water service pipe. Water service pipe shall conform to NSF 61 and shall conform to one of the standards listed in Table 605.3 (ASTM F876, AWWA C904, CSA B137.5). Water service pipe or tubing, installed underground and outside of the structure, shall have a working pressure rating of not less than 160 psi (1100 kPa) at 73.4°F (23°C). Where the water pressure exceeds 160 psi (1100 kPa), piping materials shall have a working pressure rating not less than the highest available pressure

605.4 Water distribution pipe. Water distribution pipe and tubing shall conform to NSF 61 and shall conform to one of the standards listed in Table 605.4 (ASTM F876, CSA B137.5). Hot water distribution pipe and tubing shall have a pressure rating of not less than 100 psi (690 kPa) at 180°F (82°C). Where the water pressure exceeds 160 psi (1100 kPa), piping materials shall have a working pressure rating not less than the highest available pressure.

605.5 Fittings. Pipe fittings shall be *approved* for installation with the piping material installed and shall comply with the applicable standards listed in Table 605.5. Pipe fittings utilized in water supply systems shall also comply with NSF 61.

605.16 PEX plastic. Joints between cross-linked polyethylene plastic tubing and fittings shall comply with Sections 605.16.1 through 605.16.3.

605.16.1 Flared joints. Flared pipe ends shall be made by a tool designed for that operation.

605.16.2 Mechanical joints. Mechanical joints shall be installed in accordance with the manufacturer's instructions. Fittings for crosslinked polyethylene (PEX) plastic tubing shall comply with the applicable standards listed in Table 605.5 and shall be installed in accordance with the manufacturer's instructions. PEX tubing shall be factory marked with the appropriate standards for the fittings that the PEX manufacturer specifies for use with the tubing.

605.16.3 Push-fit joints. Push-fit joints shall conform to ASSE 1061 and shall be installed in accordance with the manufacturer's instructions.

International Residential Code (IRC 2024)

P2605.1 General. Piping shall be supported in accordance with the following:

1-4. *Not applicable to PEX hanger support spacing*
5. Piping shall be supported at distances not to exceed those indicated in Table P2605.1.

PIPING MATERIAL	MAXIMUM HORIZONTAL SPACING (feet)	MAXIMUM VERTICAL SPACING (feet)
Crosslinked polyethylene (PEX), 1 inch and smaller	2.67 [32 inches]	10[b]
Crosslinked polyethylene (PEX), 1 1/4 inches and larger	4 [48 inches]	10[b]

[b] For sizes 2 inches and smaller, a guide shall be installed midway between vertical supports

P2609.3 Plastic pipe, fittings, and components. Plastic pipe, fittings, and components shall be third-party certified as conforming to NSF/ANSI 14.

P2609.5 Water supply systems. Water service pipes, water distribution pipes and the necessary connecting pipes, fittings, control valves, faucets and appurtenances used to dispense water intended for human ingestion shall be evaluated and *listed* as conforming to the requirements of NSF/ANSI/CAN 61.

P2903.9 Gridded and parallel water distribution systems. Hot water and cold water manifolds installed with parallel-connected individual distribution lines and cold water manifolds installed with gridded distribution lines to each fixture or fixture fitting shall be designed in accordance with Sections P2903.8.1 through P2903.8.5.

P2903.9.1 Sizing of manifolds. Manifolds shall be sized in accordance with Table P2903.8.1. Total gallons per minute is the demand for all outlets.

P2903.9.2 Minimum size. Where the *developed length* of the distribution line is 60 feet (18 288 mm) or less, and the available pressure at the meter is not less than 40 psi (276 kPa) for the size of individual distribution lines shall be not less than 3/8 inch (10 mm) diameter. Certain fixtures such as one-piece water closets and whirlpool bathtubs shall require a larger size where specified by manufacturer. Where a water heater is fed from the end of a cold water manifold, the manifold shall be one size larger than the water heater feed.

P2903.9.3 Support and protection. Plastic piping bundles shall be secured in accordance with manufacturer's installation instructions and supported in accordance with Section P2605. Bundles that have a change in direction equal to or greater than 45 degrees (0.79 rad) shall be protected from chafing at the point of contact with framing members by sleeving or wrapping.

P2903.9.4 Valving. Fixture valves, when installed, shall be located at either the fixture or at the manifold. Valves installed at manifold shall be *labeled* indicating the fixture served.

P2904 Dwelling Unit Automatic Sprinkler Systems

P2904.1 General. The design and installation of automatic sprinkler systems shall be in accordance with NFPA 13D or Section P2904, which shall be considered to be equivalent to NFPA 13D. Partial automatic sprinkler systems shall be permitted to be installed only in buildings not required to be equipped with an automatic sprinkler system. Section P2904 shall apply to stand-alone and multipurpose wet-pipe sprinkler systems that do not include the use of antifreeze. A multipurpose automatic sprinkler system shall provide domestic water to both fire sprinklers and plumbing fixtures. A stand-alone automatic sprinkler system shall be separate and independent from the water distribution system. A backflow preventer shall not be required to separate an automatic sprinkler system from the water distribution system, provided that the sprinkler system complies with all of the following:

1. The system complies with NFPA 13D or Section 2904.
2. The piping material complies with Section P2906.
3. The system does not contain antifreeze.
4. The system does not have a fire department connection.

P2904.2 Sprinklers. Sprinklers shall be new *listed* residential sprinklers and shall be installed in accordance with the sprinkler manufacturer's instructions.

P2904.3 Sprinkler piping system. Sprinkler piping shall be supported in accordance with requirements for cold water distribution piping. Sprinkler piping shall comply with the requirements for cold water distribution piping. For multi-purpose piping systems, the sprinkler piping shall connect to and be a part of the cold water distribution piping system.

Exception: For plastic piping, it shall be permissible to follow the manufacturer's installation instructions.

P2904.3.1 Non-metallic pipe and tubing. Nonmetallic pipe and tubing, such as CPVC, PEX, and PE-RT shall be *listed* for use in residential fire sprinkler systems.

P2904.3.1.1 Non-metallic pipe protection. Nonmetallic pipe and tubing systems shall be protected from exposure to the living space by a layer of not less than 3/8 inch thick (9.5 mm) gypsum wallboard, 1/2 inch thick (13 mm) plywood, or other material having a 15-minute fire rating.

P2904.4 Determining system design flow. The flow for sizing the sprinkler piping system shall be based on Sections P2904.4.1 and P2904.4.2.

P2904.5 Water supply. The water supply shall provide not less than the required design flow rate for sprinklers in accordance with Section P2904.4.2 at a pressure not less than that used to comply with Section P2904.6

P2904.6 Pipe sizing. The piping to sprinklers shall be sized for the flow required by Section P2904.4.2. The flow required to supply the plumbing fixtures shall not be required to be added to the sprinkler design flow.

P2906.4 Water service pipe. Water service pipe shall conform to NSF/ANSI/CAN 61 and shall conform to one of the standards indicated in Table P2906.4. Water service pipe or tubing, installed underground and outside of the structure, shall have a working pressure rating of not less than 160 pounds per square inch at 73°F (1103 kPa at 23°C).

P2906.5 Water distribution pipe. Water distribution piping within dwelling units shall conform to NSF/ANSI/CAN 61 and shall conform to one of the standards indicated in Table P2906.5. Water distribution pipe and tubing shall have a pressure rating of not less than 100 psi at 180°F (689 kPa at 82°C).

P2906.9 Plastic pipe joints. Joints in plastic piping shall be made with approved fittings by solvent cementing, heat fusion, corrosion-resistant metal clamps with insert fittings or compression connections.

P2906.10 Cross-linked polyethylene plastic (PEX). Joints between crosslinked polyethylene plastic tubing or fittings shall comply with Section P2906.9.10.1 or Section P2906.9.10.2.

P2906.10.2 Mechanical joints. Mechanical joints shall be installed in accordance with the manufacturer's instructions. Fittings for cross-linked polyethylene (PEX) plastic tubing shall comply with the applicable standards indicated in Table P2906.6 and shall be installed in accordance with manufacturer's instructions. PEX tubing shall be factory marked with applicable fitting standards for the fittings that the PEX manufacturer specifies for use with the tubing.

P2906.18 Joints between different materials. Joints between different piping materials shall be made in accordance with Section P2906.18.1, P2906.18.2, P2906.18.3 or P2906.18.4, or with a mechanical joint of the compression or mechanical sealing type having an elastomeric seal conforming to ASTM D1869 or ASTM F477. Joints shall be installed in accordance with the manufacturer's instructions.

P2906.18.3 Plastic pipe or tubing to other piping material. Joints between different types of plastic pipe or between plastic pipe and other piping material shall be made with an *approved* adapter fitting.

Uniform Plumbing Code (UPC 2024)

301.2.3 Plastic Pipe, Plastic Pipe Fittings, and Components. Plastic pipe, plastic pipe fittings, and components other than those for gas shall comply with NSF/ANSI 14.

312.0 Protection of Piping, Tubing, Materials, and Structures.

312.9 Steel Nail Plates. Plastic piping or tubing, and copper or copper alloy piping or tubing penetrating framing members to within 1 inch (25.4 mm) of the exposed framing shall be protected by steel nail plates not less than No. 18 gauge (0.0478 inches) (1.2 mm) in thickness. The steel nail plate shall extend along the framing member not less than 1 1/2 inches (38 mm) beyond the outside diameter of the pipe or the tubing.

313.0 Hangers, Supports and Anchors.

313.3 Suspended Piping. Suspended piping shall be supported at intervals not to exceed those shown in Table 313.3.

313.4 Alignment. Piping shall be supported in such a manner as to maintain its alignment and prevent sagging.

604. Materials.

604.1 Pipe, Tube, and Fittings. Pipe, tube, fittings, solvent cement, thread sealants, solders, and flux used in potable water systems intended to supply drinking water shall comply with NSF/ANSI/CAN 61. Where pipe fittings and valves are made from copper alloys containing more than 15 percent zinc by weight and are used in plastic piping systems, they shall be resistant to dezincification and stress corrosion cracking in compliance with NSF/ANSI 14.

Materials used in the water supply system, except valves and similar devices, shall be of a like material, except where otherwise approved by the Authority Having Jurisdiction.

Materials for building water piping and building supply piping shall comply with the applicable standards referenced in Table 604.1.

604.10 Plastic Materials. Approved plastic materials shall be permitted to be used in building supply piping, provided that where metal building supply piping is used for electrical grounding purposes, replacement piping, therefore, shall be of like materials.

Exception: Where a grounding system acceptable to the Authority Having Jurisdiction is installed, inspected, and approved, the metallic pipe shall be permitted to be replaced with nonmetallic pipe.

604.10.1 Tracer Wire. Plastic materials for building supply piping outside underground shall have an electrically continuous corrosion-resistant blue insulated copper tracer wire, or other approved conductor, installed adjacent to the piping. Access shall be provided to the tracer wire, or the tracer wire shall terminate above-ground at each end of the nonmetallic piping. The tracer wire size shall be not less than 14 AWG and the insulation type shall be suitable for direct burial.

604.13 Water Heater Connectors. PEX, PEX-AL-PEX, PE-AL-PE, or PE-RT tubing shall not be installed within the first 18 inches (457 mm) of piping connected to a water heater.

605.9 PEX Plastic Tubing and Joints. PEX plastic tubing and fitting joining methods shall be installed in accordance with the manufacturer's instructions and shall comply with Section 605.9.1 through Section 605.9.3.

605.9.1 Fittings. Fittings for PEX tubing shall comply with the applicable standards referenced in Table 604.1. PEX tubing that complies with ASTM F876 shall be marked with the applicable standard designation for the fittings, specified by the tubing manufacturer for use with the tubing.

605.9.2 Mechanical Joints. Mechanical joints shall be installed in accordance with manufacturer's installation instructions.

605.9.3 Push Fit Fittings. Removable and nonremovable push fit fittings that employ a quick assembly push fit connector shall comply with ASSE 1061

605.16.2 Plastic Pipe to Other Materials. Where connecting plastic pipe to other types of piping, approved types of adapter or transition fittings designed for the specific transition intended shall be used.

National Standard Plumbing Code (NSPC 2024)

3.1.3 Standards Applicable to Plumbing Materials. A material shall be considered approved if it is listed or certified by a recognized certification body as complying with one or more of the standards cited in Table 3.1.3, and in the case of plastic pipe, fittings and solvent cement also NSF 14.

3.4.1.1 Plastic Piping. Plastic piping materials used for the conveyance of potable water shall comply with NSF 14 and be marked accordingly.

3.4.2 Water Service Piping. Water service piping to the building water supply control valve shall be of materials listed in Table 3.4, and shall be water pressure rated not less than 160 psi at 73°F. *See Table 3.4.2.* Water service pipe and pipe fittings shall comply with NSF 61.

NOTE: The working pressure rating of plastic pipe varies depending on the water temperature, plastic composition, dimension ratio or pipe schedule and size, and method of joining. Refer to Table 3.4.2 for plastic piping suitable for water service.

3.4.3 Water Distribution Piping. Water piping for the distribution of hot and cold water within buildings shall be of materials listed in Table 3.4 and shall be water pressure rated for not less than 100 psi at 180°F and 160 psi at 73°F. Plastic piping used for hot water distribution shall be installed in accordance with the requirements of Section 10.15.8. Water distribution pipe and pipe fittings shall comply with NSF 61.

NOTE: The working pressure rating of plastic pipe varies depending on the water temperature, plastic composition, dimension ratio or pipe schedule and size, and method of joining. Refer to Table 3.4.3.

3.4.4 Fittings.

a. Fittings for water supply piping shall be compatible with the pipe material used.

b. Insert fittings for plastic tubing shall be the metallic or plastic type that comply with the standards listed in Table 3.1.3.

8.7 Support of Plastic Pipe.

a. Plastic drain, waste, vent, and pressure pipe shall be installed and supported as recommended by the manufacturer's instructions.

b. Maximum horizontal support spacing shall be based on the pipe schedule or wall thickness, the pipe size, the system operating temperature, the ambient temperature, and any concentrated loads.

c. Vertical pipe shall be maintained in straight alignment with supports at each story height. Intermediate supports shall be provided where required for stability.

d. Pipe shall also be supported at changes of direction or elevation.

e. Supports shall not compress, distort, cut, or abrade the piping and shall allow free movement.

f. Provisions shall be made for expansion and contraction of the piping.

10.5.9 Protection from Fire Systems.

Exceptions:

(2) Backflow preventers shall not be required in NFPA 13D multipurpose or network residential fire sprinkler systems that supply both plumbing fixtures and residential fire sprinklers. The piping in such systems shall be approved for potable water. Such systems shall not have a fire department connection.

10.15.8 Plastic Piping.

a. Plastic piping used for hot water distribution shall conform to the requirements of Section 3.4.3 and Table 3.4.3. Piping shall be water pressure rated for not less than 160 psi at 73°F and 100 psi at 180°F.

NOTE: The working pressure rating for plastic piping varies depending on material composition, dimension ratio or pipe schedule and size, and method of joining. *See Table 3.4.3*.

b. Plastic piping shall not be used downstream from instantaneous water heaters, immersion water heaters, and other heaters not having approved temperature safety devices.

c. Plastic piping shall not be installed within six inches of the exhaust flues for gravity-vented gas-fired equipment and similar high temperatures.

d. The operating pressure in water distribution piping systems utilizing approved plastic piping shall not be more than 80 psi. When necessary, one or more pressure reducing valves shall be provided to regulate the hot and cold water supply pressure to not more than 80 psi. Ref to Section 10.14.6.

National Plumbing Code of Canada (NPCC 2025)

2.2.5.6. Crosslinked Polyethylene Pipe and Fittings

1) Crosslinked polyethylene pipe and manufacturer-approved fittings used in hot and cold *potable water systems* shall conform to CSA 137.5, "Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications" (See Note A-2.2.5.6(1))

2.3.4.4 Support for Vertical Piping.

1) Except as provided in Sentence (2), vertical piping shall be supported at its base and at the floor level of alternate storeys by rests, each of which can bear the weight of pipe that is between it and the rest above.

2) The maximum spacing of supports shall be 7.5 m.

2.3.4.5 Support for Horizontal Piping.

1) Nominally horizontal piping that is inside a building shall be braced to prevent swaying and buckling and to control the effects of thrust.

2) Nominally horizontal piping shall be supported as stated in Table 2.3.4.5 (PEX = 0.8 m)

4) Where PEX , PE-RT, PP-R, PE/AL/PEX or PEX/AL/PEX plastic pipe or tube is installed, hangers shall not compress, cut or abrade the pipe.

A-2.2.5.6(1) Crosslinked Polyethylene Pipe and Fittings. There are some special installation requirements for the use of crosslinked polyethylene pipe and its associated fittings. Reference should, therefore, be made to the installation information in CSA B137.5, "Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications."

2.3.4.6 Support for Underground Horizontal Piping

1) Except as provided in Sentence (2), nominally horizontal piping that is underground shall be supported on a base that is firm and continuous under the whole run of pipe. (See Note: A-2.3.4.6(1).)

2) Nominally horizontal piping installed underground that is not supported as described in Sentence (1) may be installed using hangers fixed to a foundation or structural slab provided that the hangers are capable of

a) keeping the pipe in alignment, and

b) supporting the weight of

i. the pipe,
ii. its contents, and
iii. the fill over the pipe.

2.6.3.1 Design, Fabrication & Installation

(See Note A-2.6.3)

1) *Water distribution systems* shall be designed to provide peak demand flow when the flow pressures at the supply openings conform to the plumbing supply fitting manufacturer's specifications.

2) *Potable water systems* shall be designed, fabricated and installed in accordance with good engineering practice, such as that described in the ASHRAE Handbooks and ASPE Plumbing Engineering Design Handbooks (See Note A-2.6.3.1(2).)

3) In one- and two-family dwelling units and manufactured homes, multi-purpose systems that combine *potable water systems* and residential fire sprinkler systems shall be designed, fabricated and installed in accordance with NFPA 13D, "Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes."

Joining Methods

5

There are several types of joining methods or fittings used with PEX tubing in plumbing systems. Each of these fitting styles utilizes mechanical compression forces to make the seal on the inside or the outside of the PEX tubing wall. PEX tubing cannot be joined by solvent cementing or typical heat fusion methods.

Several PEX tubing manufacturers have developed a unique fitting system, but each of these technologies must deliver the same minimum performance as specified in PEX system standards ASTM F877 and CSA B137.5. Many of these fitting systems are also described in their own ASTM standard specifications, covering everything from materials to dimensions to assembly to performance testing. Each of these standards requires fittings and joints to be 100% leak-free under a wide range of pressures and temperatures.

Note: Not all fittings are compatible with all PEX tubing. Consult your tubing manufacturer for acceptable joining methods or review the markings on the tubing which indicate which fitting system type or types have been approved for use with that tubing.

The method of connection should comply with the tubing manufacturer's recommendations and instructions. Fittings are regulated to comply with performance and material criteria from recognized standards. They should be marked by a certified third-party agency such as NSF, IAPMO, CSA, ICC, UL, or other third-party testing and listing agency. The most common types of PEX fitting systems used are shown in the following pages.

In all cases, it is important that the appropriate tool is used and that the manufacturer's installation instructions are followed.

See **Chapter 3 *Material Properties*** for detailed information about the types of brass, bronze, stainless steel, and polymer materials which are permitted to be utilized for PEX fittings.

ASTM F1807: Standard Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring, or Alternate Stainless Steel Clamps, for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

These types of fittings are inserted into the PEX tubing and use a copper crimp ring or a stainless-steel clamp that is compressed around the PEX tubing to produce a tight seal. ASTM F1807 fittings may be produced from copper, stainless steel, lead-free brass, or bronze (see **Figures 5.1**, **5.2**, and **5.3**).

Prior to making the connection, the crimp ring or clamp is slid over the end of the PEX tube. The fitting has a barbed or ribbed annular end which is inserted into the tubing. The crimp ring is positioned over the fitting ribs and a manual or electric tool is used to compress the crimp ring around the assembly to produce a tight seal. Alternatively, the clamp is positioned over the fitting ribs and a tool is used to tighten the clamp to produce a tight seal.

Figure 5.1 ASTM F1807 Metal Insert Fittings with a Copper Crimp Ring

Figure 5.2 ASTM F1807 Metal Insert Fittings in Various Diameters with Copper Crimp Rings

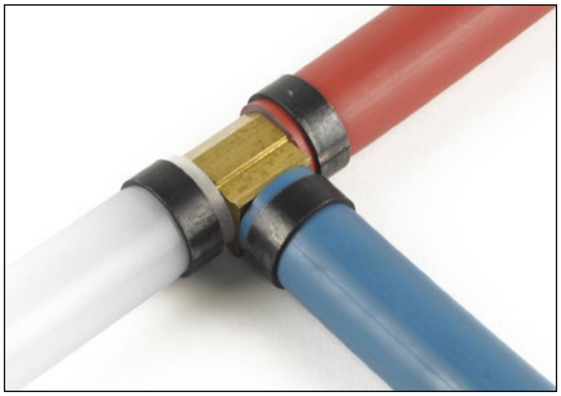


Figure 5.3 ASTM F1807 Metal Insert Fitting Assembled with Copper Crimp Rings

ASTM F1960: Standard Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Crosslinked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing

This type of fitting requires that the PEX tubing with a reinforcing PEX ring placed over the end of the tube is expanded before the fitting is inserted into the tube end. The tube is not heated before this expansion, so it is referred to as a "cold expansion" system (see **Figures 5.4**, **5.5**, and **5.6**).

The expanded tube end will naturally retract onto the fitting to form the seal—the "memory" of the tube with the PEX ring allows it to tighten over the fitting to produce a tight seal. A manual or electric expander tool is required to expand the PEX tubing and the PEX ring together. These fittings are produced from lead-free brass, Stainless Steel, and polymer materials.

Figure 5.4 ASTM F1960 Cold Expansion Fittings, Metal and Polymer, with PEX Reinforcing Rings

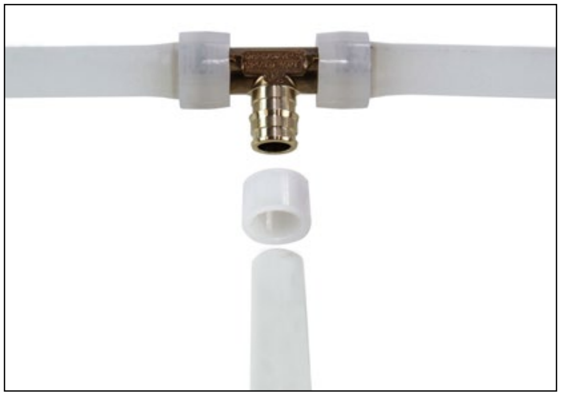


Figure 5.5 ASTM F1960 Cold Expansion Brass Fitting with PEX Reinforcing Ring

Figure 5.6 ASTM F1960 Cold Expansion Polymer Fitting with PEX Reinforcing Ring

ASTM F2080: Standard Specification for Cold Expansion Fittings with Metal Compression Sleeves for Crosslinked Polyethylene (PEX) Pipe and SDR9 Polyethylene of Raised Temperature (PE-RT) Pipe

This type of fitting requires that the PEX tubing is cold expanded before the fitting is inserted into the end of the tubing. The tubing is not heated before this expansion, so it is referred to as a "cold-expansion" system (see **Figures 5.7** and **5.8**).

The tube shrinks down over the fitting insert, then a metal compression sleeve is pulled over the connection axially, compressing the tube over the fitting to produce a tight seal. A manual or electric tool is required to expand the tube and to pull the compression-sleeve over the tube. These fittings are produced from lead-free brass materials.

Figure 5.7 ASTM F2080 Cold Expansion Fitting

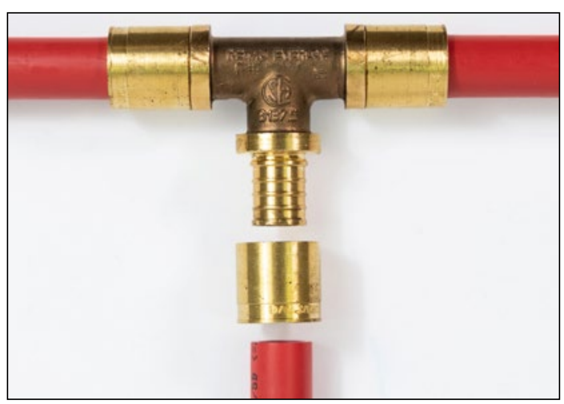


Figure 5.8 ASTM F2080 Cold Expansion Fitting with Metal Compression Sleeve

ASTM F2159: Standard Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring, or Alternate Stainless Steel Clamps, for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

These types of fittings are inserted into the PEX tubing and use a copper crimp ring or a stainless-steel clamp that is compressed around the PEX tubing to produce a tight seal. ASTM F2159 fittings are produced from polymer (see **Figures 5.9** and **5.10**).

Prior to making the connection, the crimp ring or clamp is slid over the end of the PEX tube. The fitting has a barbed or ribbed annular end which is inserted into the tubing. The crimp ring is positioned over the fitting ribs and a manual or electric tool is used to compress the crimp ring around the assembly to produce a tight seal. Alternatively, the clamp is positioned over the fitting ribs and a tool is used to tighten the clamp to produce a tight seal.

Figure 5.9 ASTM F2159 Plastic Insert Fittings

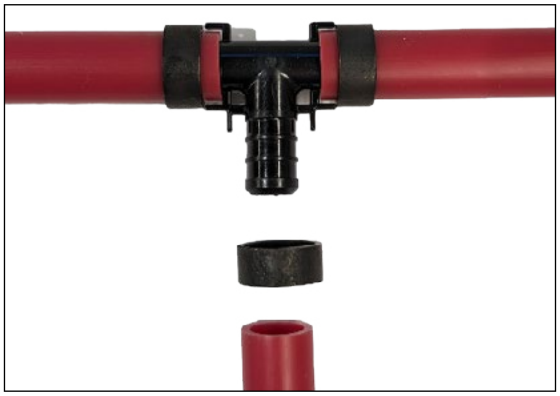


Figure 5.10 ASTM F2159 Plastic Insert Fittings with Copper Crimp Ring

ASTM F2098: Standard Specification for Stainless Steel Clamps for Securing SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) to Metal Insert and Plastic Insert Fittings

The stainless steel clamp is used with ASTM F1807 or ASTM F2159 insert fittings and in place of a copper crimp ring. The clamp is tightened onto PEX tubing using a ratcheting tool which only releases once a tight seal is achieved (see **Figure 5.11**).

Figure 5.11 ASTM F2098 Stainless Steel Clamps with ASTM F1807 Brass Insert Fittings

ASTM F3347: Standard Specification for Metal Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for use with SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

These types of fittings are inserted into the PEX tubing and use a stainless steel press sleeve that is compressed around the PEX tubing to produce a tight seal. ASTM F3347 fittings are produced from lead-free bronze (see **Figures 5.12** and **5.13**).

The fitting has a barbed or ribbed annular end which is inserted into the tubing. The sleeve is attached to the fitting and slides over the tubing as the fitting is inserted. A manual or electric press tool is used to compress the sleeve onto the tubing.

Figure 5.12 ASTM F3347 Metal Insert Tee with Stainless Steel Press Sleeve

Figure 5.13 ASTM F3347 Metal Insert Elbow with Stainless Steel Press Sleeve

ASTM F3348: Standard Specification for Plastic Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for use with SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

These types of fittings are inserted into the PEX tubing and use a stainless steel press sleeve that is compressed around the PEX tubing to produce a tight seal. ASTM F3348 fittings are produced from polymer (see **Figures 5.14**, **5.15**, and **5.16**).

The fitting has a barbed or ribbed annular end which is inserted into the tubing. The sleeve is attached to the fitting and slides over the tubing as the fitting is inserted. A manual or electric press tool is used to compress the sleeve onto the tubing.

Figure 5.14 ASTM F3348 Plastic Insert Fittings with Stainless Steel Press Sleeve

Figure 5.15 ASTM F3348 Plastic Insert Tee with Stainless Steel Press Sleeve

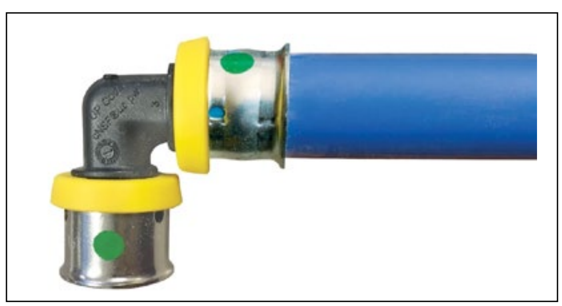


Figure 5.16 ASTM F3348 Plastic Insert Elbow with Stainless Steel Press Sleeve

ASSE 1061: Performance Requirements for Push-fit Fittings

These types of fittings use an interlocking mechanism to connect the PEX tubing to the fitting. The tubing is inserted or pushed into the fitting and locked into place with a fastening device that keeps it from being backed-out or disconnected. A support liner is inserted into the tubing and a fastening system with a locking component, such as a snap ring or twist collar, is used to ensure that the connection remains secure (see **Figures 5.17**, **5.18**, **5.19**, **5.20**, and **5.21**).

Push-fit fittings typically use an O-ring or gasket to form a tight seal on the exterior of the PEX tubing. ASSE 1061 fittings are produced from lead-free brass or polymer.

Figure 5.17 ASSE 1061 Brass Push-Fit Fitting

Figure 5.18 ASSE 1061 Polymer Push-Fit Fitting

Figure 5.19 ASSE 1061 Polymer Push-Fit Fitting

Figure 5.20 ASSE 1061 Polymer Push-Fit Fitting

Figure 5.21 ASSE 1061 Fittings in Brass and Polymer

Standard Specifications for Fittings

Each of these fitting systems are categorized in accordance with ASTM or ASSE specifications as follows, with the formal scopes of each of these standards copied verbatim from the specifications:

Note: ASTM Standard Titles and Scopes were extracted, with permission, from ASTM F877, ASTM F1807, ASTM F1960, ASTM F2080, ASTM F2098, ASTM 2159, ASTM F3347, and ASTM F3348, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standards may be purchased from ASTM International at www.astm.org.

ASTM F877: Standard Specification for Crosslinked Polyethylene (PEX) Hot- and Cold-Water Distribution Systems

This specification covers requirements, test methods, and marking requirements for system components when tested with nominal SDR9 crosslinked polyethylene (PEX) tubing as a system. Systems are intended for 100 psi (0.69 MPa) water service up to and including a maximum working temperature of 180°F (82°C). Requirements and test methods are included for materials, workmanship, dimensions, and tolerances, burst pressure, hydrostatic sustained pressure, excessive temperature and pressure, corrosion resistance, and thermocycling tests. The components covered by this specification are intended for use in, but not limited to, residential and commercial hot and cold potable water distribution systems or other applications such as municipal water service lines, radiant heating and cooling systems, hydronic distribution systems, snow and ice melting systems, geothermal ground loops, district heating, turf conditioning, compressed air distribution, and building services pipe.

ASTM F1807: Standard Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring, or Alternate Stainless Steel Clamps, for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR 9 Polyethylene of Raised Temperature (PE-RT) Tubing

This specification covers metal insert fittings and copper crimp rings, or alternate stainless steel clamps, for use with cross-linked polyethylene (PEX) tubing in Nominal Tubing Size (NTS) 3/8, 1/2, 5/8, 3/4, 1, 1 1/4, 1 1/2, and 2 nominal sizes that meet requirements for Specification ASTM F876 or Specification F3253 or for use with polyethylene of raised temperature (PE-RT) tubing in NTS 3/8, 1/2, 5/8, 3/4, 1, 1 1/4, 1 1/2, and 2 nominal sizes that meets the requirements of Specification F2623 or Specification F2769. These fittings are intended for use in 100 psi (689.5 kPa) cold- and hot-water distribution systems operating at temperatures up to, and including, 180°F (82°C).

ASTM F1960: Standard Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Crosslinked Polyethylene (PEX) Tubing and Polyethylene of Raised Temperature (PE-RT) Tubing

This specification covers cold expansion fittings and cross-linked (PEX) reinforcing rings for use with cross-linked polyethylene (PEX) plastic tubing in nominal tubing sizes of 3/8, 1/2, 5/8, 3/4, 1, 1 1/4, 1 1/2, 2, 2 1/2, and 3 that meet the requirements of Specification F876 or F3253 and for use with Polyethylene of Raised Temperature (PE-RT) pipe in nominal tubing sizes of 3/8, 1/2, 5/8, 3/4, 1, 1 1/4, 1 1/2, 2, 2 1/2, and 3 that meet the requirements of Specification F2769. These fittings are intended for use in 100 psi (690 kPa) cold- and hot-water distribution systems operating at temperatures up to and including 180 °F (82 °C). The system is comprised of a PEX reinforcing ring and a cold expansion fitting. Included are the requirements for materials, workmanship, dimensions, and markings to be used on the fitting components. The components covered by this specification are intended for use in residential and commercial, hot and cold, potable water distribution systems as well as sealed central heating, including under-floor-heating systems.

ASTM F2080: Standard Specification for Cold Expansion Fittings with Metal Compression Sleeves for Crosslinked Polyethylene (PEX) Pipe and SDR9 Polyethylene of Raised Temperature (PE-RT) Pipe

This specification covers cold-expansion fittings using metal compression-sleeves for use with crosslinked polyethylene (PEX) plastic pipe in 3/8, 1/2, 5/8, 3/4, 1, 1 1/4, 1 1/2, and 2 nominal diameters, meeting the requirements of Specification F876 or F3253, and for use with Polyethylene of Raised Temperature (PE-RT) pipe in 3/8, 1/2, 5/8, 3/4, 1, 1 1/4, nominal diameters meeting the requirements of Specification F2769, whereby the pipe is cold-expanded before fitting assembly. The components covered by this specification are intended for use in residential and commercial, hot and cold, potable water distribution systems or other applications such as municipal water service lines, building supply lines, radiant panel heating systems, hydronic baseboard heating systems, snow and ice melting systems, geothermal underground pipe systems and building services pipe with continuous operation at pressures up to and including 100 psi (690 kPa), and at temperatures up to and including 180 °F (82 °C).

ASTM F2098: Standard Specification for Stainless Steel Clamps for Securing SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) to Metal Insert and Plastic Insert Fittings

This specification covers stainless steel clamps for use with five sizes of insert fittings that comply with F1807 or F2159, and cross-linked polyethylene (PEX) plastic tubing that complies with F876 and for use with polyethylene of raised temperature (PE-RT) tubing that complies with Specification F2769. These clamps are intended as an alternative to the copper-alloy crimp-rings of Specifications F1807 or F2159 for use in 100 psi (689.5 kPa) cold- and hot-water distribution systems operating at temperatures up to and including 180°F (82°C). Included are requirements for materials, workmanship, dimensions, and marking of the stainless steel clamps; requirements for deforming the clamps; which apply to assemblies of PEX tubing and Specifications F1807 and F2159, insert fittings secured with deformed clamps per this specification.

ASTM F2159: Standard Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring, or Alternative Stainless Steel Clamps, for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

This specification establishes requirements for sulfone plastic insert fittings and copper crimp rings, or alternate stainless steel clamps for four sizes Nominal Tubing Sizes (NTS) (3/8, 1/2, 3/4, and 1) of cross-linked polyethylene (PEX) tubing that meet the requirements for Specification F876 or Specification F3253, or polyethylene of raised temperature (PE-RT) tubing that meet the requirements of Specification F2623 or Specification F2769. These fittings are intended for use in 100 psi (690 kPa) cold- and hot-water distribution systems operating at temperatures up to and including 180 °F (82 °C). Included are the requirements for material, molded part properties, performance, workmanship, dimensions, and markings to be used on the fittings and rings.

ASTM F3347: Standard Specification for Metal Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

This specification covers copper alloy metal press insert fittings with factory assembled stainless steel press sleeves incorporating 3 view holes and tool locator ring. These fittings are for use with cross-linked polyethylene (PEX) tubing in nominal sizes 5/16, 3/8, 1/2, 5/8, 3/4, 1, 1 1/4, 1 1/2, and 2 that meet the requirements for Specification F876 or F3253 and for use with polyethylene of raised temperature (PE-RT) tubing in nominal sizes 3/8, 1/2 , 3/4, 1, 1 1/4, 1 1/2, and 2 that meet the requirements of Specification F2769. These fittings are intended for use in 100 psi (689.5 kPa) hot and cold water distribution systems operating at temperatures up to, and including, 180 °F (82 °C). The requirements for materials, workmanship, dimensions, and markings to be used on the fittings and sleeves are also included.

ASTM F3348: Standard Specification for Plastic Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

This specification covers plastic press insert fittings with factory assembled stainless steel press sleeves incorporating 3 view holes and a tool locator ring. These fittings are for use with cross-linked polyethylene (PEX) tubing in nominal sizes 3/8, 1/2, 3/4, 1, 1 1/4, 1 1/2, and 2 that meet the requirements for Specification F876 or F3253 and for use with polyethylene of raised temperature (PE-RT) tubing in nominal sizes 3/8, 1/2, 3/4, 1, 1 1/4, 1 1/2, and 2 that meet the requirements of Specification F2769. These fittings are intended for use in 100 psi (690 kPa) cold- and hot-water distribution systems operating at temperatures up to and including 180 °F (82 °C). Included are the requirements for material, molded part properties, performance, workmanship, dimensions, and markings to be used on the fittings and sleeves.

ASSE Standard 1061 *Performance Requirements for Push-Fit Fittings*

This standard applies to push-fit fittings up to 2 in. that can be used with one or more of the following materials:

1. PEX tubing complying with ASTM F876 or CSA B137.5;
2. Type K, L and M copper tubing complying with ASTM B88;
3. CPVC tubing complying with ASTM D2846 or CSA B137.6; and
4. PE-RT tubing complying with ASTM F2769.

Push-fit fittings may be designed to be used with one or more types of tubing that conform to the dimensions as specified in their respective standard. This standard serves to supplement ASTM F877, ASTM D2846 and ASTM B88 in describing a test method for a specific type of push-fit fitting system to be used with PEX, Copper, CPVC and PE-RT tubing. This standard covers minimum temperature and pressure ratings, markings, and identification.

Other PEX Joining/Fitting Systems

Some PEX tubing manufacturers offer fitting systems for which ASTM standards have not yet been written. These systems are typically listed as meeting the performance requirements of ASTM F877 or CSA B137.5 for PEX systems, which is allowed by standards and model codes, but their fitting dimensions and materials are not specified in a standard published by ASTM, for example.

These fittings are typically available only through a single manufacturer and the components of the system may not interchange with similar-looking parts from a different manufacturer. When using these systems, users are cautioned not to mix components from different manufacturers, even if they appear the same.

Note: The content included in this Guide is based on the latest versions of standards as of the publication date. All referenced standards are subject to change.

PEX Plumbing System Layouts & Design

6

The unique properties of PEX tubing allow it to be configured in a variety of plumbing system designs applicable to both residential and commercial plumbing systems. This chapter describes three popular layout options: trunk and branch, parallel (i.e., home-run), and zoned (i.e., remote manifolds). When used as described in this chapter or in various combinations, these three layouts can be configured to optimally serve almost any type of residential or commercial plumbing application.

By carefully choosing the right system for the application, the designer can produce a plumbing system that balances cost, installation time, resilience, and performance, including timely delivery of hot water with minimal water waste.

The unique features of PEX tubing allow for a great deal of system design freedom that can increase the performance and savings associated with the plumbing system. In today's high-performance homes, many designers recognize that the plumbing system can be designed to provide hot or cold water faster with greatly reduced energy loss. PEX plumbing systems can be designed to enhance these features but, like any plumbing system, PEX systems perform best and cost less to install when planned during the home's design phase. Advanced planning allows maximum performance, while limiting the lengths of pipe and number of fittings used.

When considered early enough in the house planning stage, a few simple room layout considerations can greatly improve the performance of the plumbing system. By consulting the codes and local inspectors in advance, builders and plumbers can also avoid costly time delays due to code issues arising during construction.

Note: Installers are recommended to take advantage of the flexibility of PEX tubing and to install directional fittings such as 90-degree elbows only when necessary, such as within tight cavities. The use of sweeps, usually installed with snap-on bend supports described in **Chapter 3 *Material Properties***, will typically reduce material cost, installation time, and pressure drop in the system.

This chapter describes a process that provides the guidance and tools needed to successfully lay out a PEX plumbing system in nearly any building.

Part I: Select Plumbing Layout

This section describes three popular layout options: trunk and branch, parallel (i.e., home-run), and zoned (i.e., remote manifolds) and the pros and cons of each.

Trunk and Branch (T&B)

Trunk and branch (T&B) piping systems have been used by plumbers for water distribution systems for decades. Installation of PEX tubing can be performed in a similar manner using a main trunk line to supply various branch take-offs to specific outlets. Typically, the trunk line services numerous outlets while the branch line services generally one to three closely grouped outlets, such as in a bathroom. Installation of PEX tubing in the T&B design follows the general design requirements established in plumbing codes.

As with rigid piping systems, use of tee fittings allows for the connection of branch take-offs from the main trunk. PEX tubing is available in long coils, reducing or eliminating the number of couplings that are required. Unlike rigid pipe systems, many elbows can be eliminated by bending the tubing to change direction

Specific features and advantages of the PEX trunk and branch design include:

- Simple system design
- PEX tubing provides opportunities to reduce the number of fittings thanks to flexibility of the tubing and long coils
- T&B systems will deliver hot water quicker during sequential flows with adjacent fixtures
- T&B systems will generally supply one fixture at a higher pressure as compared to a parallel (home-run) system using smaller diameter tubing

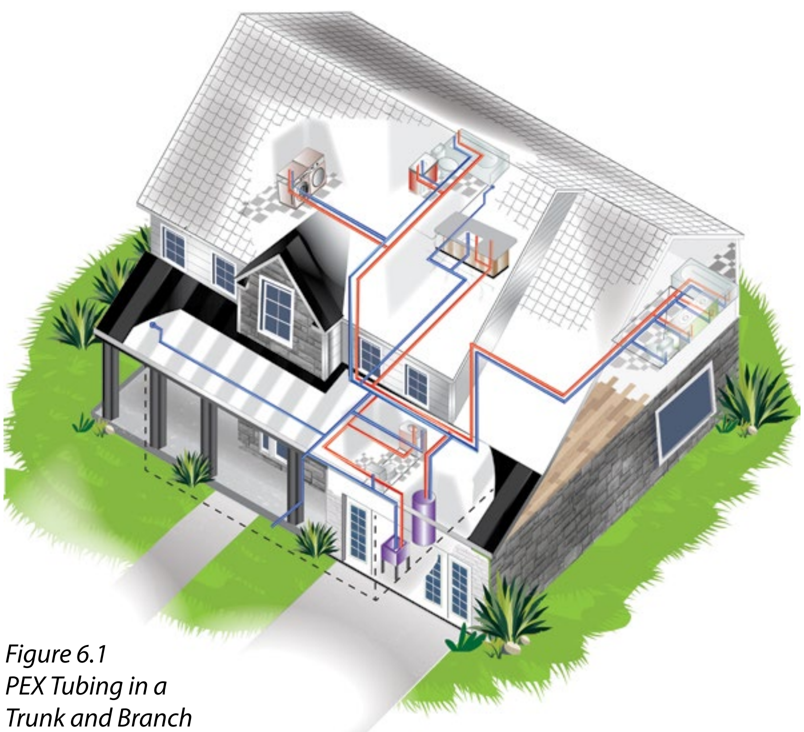


Figure 6.1
PEX Tubing in a Trunk and Branch System Design

Parallel (Home-run)

The unique features of PEX tubing make it ideal for use in centralized manifold-type system designs, commonly referred to as parallel or home-run plumbing systems. In this layout, each fixture is supplied with a dedicated line that runs directly from central hot- and cold-water manifolds. The hot water manifold should be located in close proximity to the hot water source to ensure fast and efficient delivery.

All outlets or fixtures are individually fed from a common manifold or two central manifolds (e.g., hot and cold). Because most, if not all, inline fittings are eliminated, pressure drop is minimized, potentially allowing the tubing size to be reduced for certain fixtures.

Depending on the hydraulic calculations and code allowance, nominal 3/8 tubing may be used for lower flow fixtures, with nominal 1/2 tubing recommended for longer lengths and higher flow fixtures. As demonstrated elsewhere in this Guide, nominal 3/8 PEX tubing has approximately 54% of the volume of nominal 1/2 tubing, so reducing tubing from 1/2 to 3/8 reduces the amount of water in a tube by 46%. This can allow for faster delivery of hot water with less wasted water.

The parallel system, sometimes referred to as "home-run" because of its similarity to home-run electrical wiring, often provides more consistent pressure when flowing water to multiple fixtures, since each fixture has its own dedicated supply line. Smaller diameter tubing also results in quicker delivery of hot water from the water heater because there is less volume of water to be flushed.

If the centralized manifolds are installed using valved outlets, it is not always required to install a second valve at the fixture (check local codes for specific requirements). An advantage of this system is the ability to shut off water for a specific fixture at the manifold without having to turn off water for the entire house at once.

Specific features and advantages of the PEX parallel design include:

- Smaller diameter tubing supplying each fixture
- Opportunity to eliminate most or all fittings between the manifold and the fixture
- Quicker delivery of hot and cold water to fixtures
- A more stable pressure to each fixture when operating simultaneous fixtures
- Ability to isolate individual fixtures from a central manifold

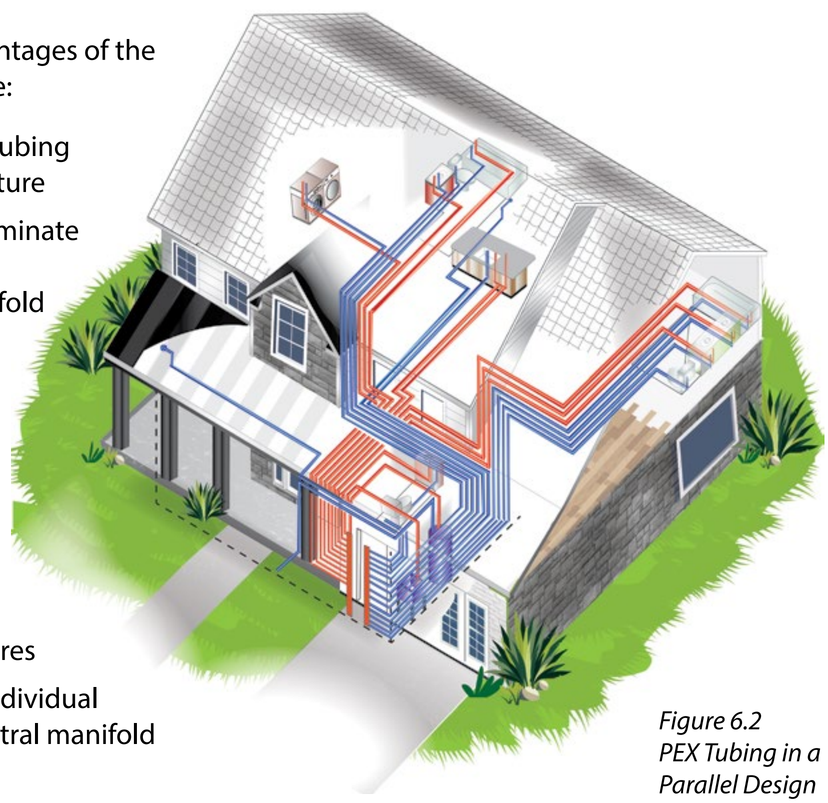


Figure 6.2
PEX Tubing in a Parallel Design

Zoned (Remote Manifolds / Multi-port Tees)

A third method for installing PEX systems combines elements of the first two systems and is typically referred to as a zoned system design. The basic approach to this system is running hot and cold trunk lines to locations in close proximity to multiple fixtures, such as a kitchen or bathroom group. At this point, a small manifold or multi-port tee is installed on each trunk line, and individual branch lines, typically 3/8 or 1/2 tubing, are then run to each fixture.

The remote manifolds/multi-port tees typically do not have valves, unlike the centralized manifolds used in parallel plumbing. These manifolds are available as flow-through or closed end. Manifolds with valves must be installed in accessible locations; manifolds without valves or multi-port tees may be installed in enclosed spaces such as within floors or walls.

The zoned system combines advantages of the Trunk and Branch layout and the Parallel layout and simplifies installation due to the reduced number of fittings and joints that are required. This layout also uses less tubing than parallel plumbing, with fewer penetrations through studs, joists, etc.

Specific features and advantages of the zoned plumbing layout include:

- Relatively simple system design conversion from rigid piping to flexible PEX tubing
- Opportunities to reduce the number of fittings installed
- Quicker hot water delivery during sequential flows
- Easier to implement hot-water recirculation than with parallel layouts
- Opportunity to have centrally located individual shutoffs at each bathroom group when manifolds are accessible

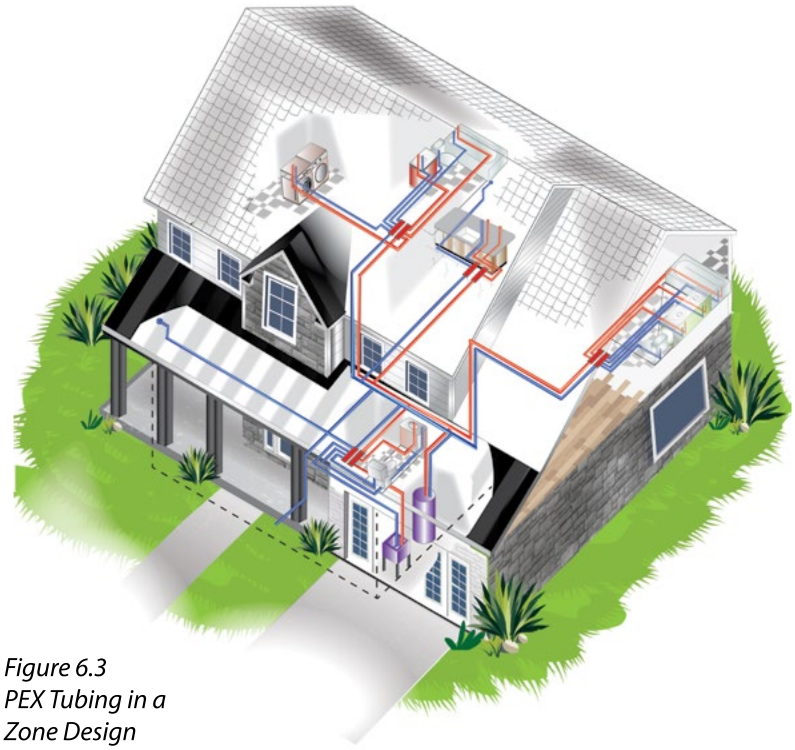


Figure 6.3
PEX Tubing in a Zone Design

Part II: Design Recommendations

Optimize Plumbing Designs (fixture layouts)

Some of the most substantial problems with modern plumbing system designs relate not to the piping itself, but to the design and layout of the building. The materials that are chosen for framing, the location of rooms, the location of the water heater/s, and the point at which the water service line or building supply line enters the building can all have a significant impact on the performance of a hot- and cold-water distribution system. Often, the design of the plumbing system is left until the end of the design process when the building layout is largely determined. This can result in a poorly performing and costly system. By observing a number of guidelines early in the design process, PEX tubing systems can be installed in ways that minimize costs, ease installation, and increase occupant satisfaction.

One key to optimizing the design of any plumbing system is to minimize pipe lengths from the water heater to the fixtures. While this may seem intuitive, it cannot be stressed enough. Within the building, short piping runs result in shorter wait-times for hot water, better water quality due to reduced stagnation, potentially higher pressure, faster installation time, and lower material costs. This can be accomplished by the builder or designer early in the planning stage using several basic design principles:

1. **Group fixtures together** – Grouping plumbing fixtures around a common location can result in saving time, materials, water, and the energy required to heat the water. This can be done between floors as well, such as in the case of stacked bathrooms. Where possible, avoid locating bathrooms long distances from the water heater.

2. **Centrally located distribution point** – Centrally located water heaters and incoming water supplies can significantly improve the performance of a plumbing system. Water heater locations are typically not given a lot of thought, resulting in locations selected for convenience or placed in the utility room, commonly far from the fixture groups. This approach often leads to excessively long plumbing runs along with the resultant increase in materials, installation time, and water and energy use. Whenever feasible, locate the water heater as close as possible to the mid-point of the fixture groupings to keep tubing runs short.

3. **Create spaces for bundled pipe runs** – Particularly applicable to parallel (home-run) layouts, simultaneous installation of multiple tubing runs will reduce installation time. The flexibility of PEX tubing, available in coils, enables the simultaneous installation of multiple plumbing lines running in the same direction using common holes and chases. By utilizing space in interior soffits, bulkheads, and chases for tubing bundles, installation time can be reduced. However, cold and hot water lines should be bundled separately (i.e., cold with cold, hot with hot) and installers should follow local codes for pipe insulation requirements, especially for hot-water lines.

4. **Use building elements that ease tubing installation** – Using building construction elements such as open web floor trusses can dramatically speed up the process of installing plumbing tubing. This can also speed up the process of installation of other mechanicals including ducting and wiring.

Select Tubing System Layout and Design

The next step for the designer, plumber, and builder is to select the most appropriate plumbing system layout (e.g., trunk and branch, parallel, zoned) and design for the home or building. The unique properties of PEX tubing allow it to be configured in a number of different designs. All have been shown to work well in residential, multi-family, and commercial applications and all are code compliant. The selection of a system layout and design is generally based on a combination of key factors such as material cost, labor time, ease of installation, system performance, and installer preference.

The challenge for a plumbing designer is to select the layout that balances the unique needs of the installer, owner, and builder. This section of the Guide and **Chapter 7 *Optimizing Design*** will provide comparisons of the three most prevalent PEX plumbing layouts: trunk and branch, parallel, and zoned, and the guidance to select between layouts.

Selecting among the three layout options often involves a balance of the key factors since each project, installer, and circumstance is different. Selecting the best system for your project can reduce installation costs, minimize installation time, and lead to more satisfied owners. As demonstrated in **Chapter 8 *Performance Data***, all three system layouts can supply sufficient flow and pressure to the fixtures.

To aid in the decision-making process, several tools are provided:

1. **General Rankings of the layouts for Key Factors** – **Table 6.1** will provide a place to start and demonstrate how the layouts compare to each other based on specific priorities.

2. **Example Layouts** – In **Chapter 7**, detailed designs of each layout are provided for four common residence types. By selecting the residence type that most closely resembles your project, you can see how the layouts compare for your building.

3. **Performance Testing** – The three layouts were compared and measured in comprehensive laboratory tests. By examining the test data shown in **Chapter 8**, you can identify differences in the systems' performance in varying scenarios (e.g., low or high incoming pressure).

4. **Industry Technical Support** – Manufacturers and organizations offer a range of resources to assist PEX users. Available support ranges from general information to technical assistance on specific projects. For example, PPI's **Plastic Pipe Design Calculator** www.plasticpipecalculator.com can be used to estimate pressure drop through plumbing systems of various diameters.

General Rankings of the Layouts

The general characteristics of the three major layout options are ranked in Table 6.1. Given the wide difference between building designs and preferences, they may not apply in every situation but are useful for general guidance as you design your building. The best way to use Table 6.1 is to establish the relative priority of key factors, and then use the rankings of system designs to provide a starting point for the system to be selected.

Table 6.1 General Rankings of the System Characteristics

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

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

[a] A fitting is the device that allows the PEX tubing to change direction or size (i.e., tees, elbows, reducers). A joint is the connection of the PEX tubing to a fitting (i.e., a tee fitting has three joints).

For example, if a user determines that their top three factors are Minimizing Fittings and Joints, Centralized Shut-off Valving, and Pressure Stability with Use of Multiple Fixtures, then, given the fact that the parallel system ranks at the top of all three, it is a logical place to start.

However, if your top factors give you three different best designs, the right choice is not as obvious. You will then need to consider other factors and further explore the detailed design of your building to make a choice. The example layouts earlier in this chapter may then be helpful in making a choice.

Since local labor costs vary and there is variation between the fitting and tubing costs offered by different manufacturers, cost has been omitted as a factor in Table 6.1. This table simply provides information on the amount of tubing and fittings needed. Since the balance between material and labor cost varies across the country, the determination of actual cost estimates and total cost comparison between system designs is left to the designer or installer.

Plan Pipe Routing, Manifold/Multi-port Tee, and Valve Locations

Once the system layout and design are selected, the final step in the design process is to plan pipe routing, manifold/multi-port tee sizes and locations, and valve locations. There are several guidelines that can simplify this process. Bear in mind that PEX tubing is available in continuous coils as well as straight lengths. Consult local codes for specific installation requirements for your project.

Guidelines for optimizing the design of a PEX plumbing system include:

- **Minimize fittings** – The flexibility of smaller diameter PEX tubing (e.g., ≤NTS 1) enables it to be easily installed around obstructions and through framing members. Use of sweeps to change direction (i.e., bending the pipe in a gentle sweep rather than using elbow fittings) can result in quicker installations, fewer fittings, and potentially less pressure drop.

- **Group fixtures together** – If using trunk and branch or zoned layouts, use common trunk lines to feed multiple fixture groups. For example, if two bathrooms are stacked, use a single trunk line to supply both bathrooms groups, rather than two trunk lines.
- **Minimize pipe lengths** – Though this may seem intuitive, attention to this detail should lead to more efficiently installed plumbing systems plus benefits such as shorter wait for hot water.
- **Select appropriate tubing diameters** – Codes do not require changing the diameter or sizes of distribution tubing when switching from one tubing material to another. Performance data generated by Home Innovations and detailed in **Chapter 8 *Performance Data*** explains that PEX tubing can replace copper tubing on a size-for-size basis. Refer to local codes and the "Pipe Sizing" section below for specific recommendations.

Taking a short amount of time to plan the tubing sizes needed to supply the proper flow rates at the required pressure will result in the use of tube sizes that deliver the required fixture flow rate without being oversized. Oversized plumbing system designs result in wasted energy and water, as well as reduced customer satisfaction with the plumbing system operation.

1. **Bundle pipe runs** – Applicable particularly to PEX plumbing runs where few fittings are installed, installation of multiple tubing runs at the same time will reduce installation time. The flexibility of PEX tubing and the long unbroken lengths that can be easily fed from coils enables the simultaneous installation of multiple plumbing lines running in the same direction using common holes through framing members such as joists.

2. **Plan for solid attachment of transition points** – The flexibility of PEX tubing also requires that the transition to threaded fittings or rigid piping be performed correctly. As with most piping materials, solid connection points and attachment points are necessary when threading on valves and transition fittings to other materials. For example, drop-ear elbows, which include several tabs with holes for fastening to braces and supports, are available for installation of tub outlets and shower heads.

3. **Use color coding** – PEX tubing is often available in different colors. Using dedicated colors for hot, cold, and reclaimed water, where applicable, can be helpful for installers, owners, and future retrofits. However, it is not necessary to utilize PEX of different colors and this is not a requirement in any model code.

4. **Plan manifold locations** – Before selecting and locating manifolds, determine whether valves will be placed at end-points (e.g., at fixtures) or on central manifolds. Some jurisdictions require valves at all fixtures while others allow them to be located on central manifolds. In some cases, the homeowner, architect, or building owner may express a preference for the location of shut-off valves.

If valved manifolds are used, they must be situated to allow easy access and not concealed behind drywall, for example. This can be accomplished by placing them behind access panels or in open areas such as in basements, laundry rooms, mechanical rooms, or garages where no freezing potential exists. Just as with an electrical breaker panel, it is important to label each valve on the manifold to ensure easy identification of the distribution lines.

If manifolds without valves are used and local codes allow, the manifolds may be enclosed within walls or floors, similar to any other fitting such as a tee or elbow.

Pipe Sizing

Selecting appropriate pipe sizes or diameters can be a multi-faceted challenge. In many cases, the prevailing plumbing code dictates minimum pipe diameter based on predicted demand or flow rates, but some of those sizing tables are based on outdated expectations of fixture demands and unrealistic simultaneous usage. Current research has resulted in updated pipe sizing methods for certain types of construction, such as IAPMO's **Water Demand Calculator** (WDC), and further research will continue to update pipe sizing tables. This section discusses several aspects of pipe sizing for both residential and commercial design.

Oversized piping results in wasted energy and water since it takes longer to flush larger hot water lines to get hot water to fixtures. This can also lead to reduced customer satisfaction with the plumbing system. Oversized piping can result in stagnant water in which disinfectants such as chlorine decay, creating the possibility of growth of opportunistic pathogens such as Legionella. Oversized piping also reduces the velocity of water within the pipes, with the potential to allow greater biofilm growth[1]. Finally, oversized piping wastes material and increases installation costs.

Undersized piping can result in excessive water velocities that could lead to erosion corrosion in metallic components or a higher probability of surge pressures and water hammer as a result of fast-closing valves. Undersized piping can also lead to excessive pressure drop and insufficient pressure at distal outlets. See **Table 6.2** for **Flow Velocity** through all diameters of PEX tubing and **Tables 6.3** and **6.4** for **Pressure Drop** of water through PEX tubing at 60°F (16°C) and 125°F (52°C), respectively.

High water velocities can also result in excessive surge pressures that can damage other plumbing system components and create audible water hammer when a fast-acting valve closes. Plastic pipe materials such as PEX, which is inherently more flexible than metallic materials and therefore able to absorb instantaneous surge pressures, will help to reduce surge pressures and water hammer (see **Chapter 3 *Material Properties***).

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

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

The Plastic Pipe Institute's **Plastic Pipe Design Calculator** can be used to select optimal pipe diameters to manage pressure drop and velocity. www.plasticpipecalculator.com.

1 *Impact of Premise Plumbing Design, Velocity, and Operational Factors on Microbial Activity During Stagnation in Pipes,* P. Gurian, S. Samuel, N. Yadav, M. Krieger, R. Singh, T. Bartrand, 2025

Domestic Hot Water Recirculation (DHWR)

Since 2003, chlorine resistance testing according to ASTM Test Method F2023 is a mandatory requirement for all PEX tubing intended for potable water applications as per tubing standards ASTM F876 and CSA B137.5. Continuous recirculation, timed recirculation, and traditional domestic (i.e., intermittent) conditions are evaluated.

This test procedure is designed to extrapolate the life expectancy of a plumbing pipe when used at a hot-water temperature of 140°F (60°C) and a pressure of 80 psig (0.55 MPa), considered to be the normal operating limits of domestic hot-water plumbing systems. ASTM F2023 allows test laboratories to use reverse osmosis-purified water with a free chlorine concentration of 4 ppm (4 mg/L) and pH of 6.8, resulting in an ORP of 825 mV or higher. This represents a very aggressive water quality which gives conservative results in terms of service life of the pipe.

Note: Continuous recirculation of hot chlorinated water through PEX tubing at temperatures above 140°F (60°C) is beyond the intended application of the standard chlorine ratings as defined in those standards listed above. See **PPI TN-53 *Guide to Chlorine Resistance Ratings of PEX Pipe and Tubing*** for more information.

When selecting PEX tubing for a domestic hot water recirculation system (DHWR), ensure the tubing has the appropriate level of chlorine resistance for the application. This can be verified through the PEX Material Designation Code (e.g., PEX 5106) and by contacting the tubing manufacturer. See **Chapter 3 *Material Properties*** for details about chlorine resistance.

Where possible, it is recommended to utilize **intermittent recirculation systems**, such as circulating pumps on timers or activated by demand sensors, and to not run recirculation systems continuously (i.e., 24/7). This will help to save energy and comply with energy codes.

It is recommended that designers size tubing to achieve velocities that will deliver domestic hot water to distal points of the plumbing system and return to the source with a temperature drop of not more than 10°F (5.6°C), in accordance with ASPE *Plumbing Design Handbook Volume Two*. Pipe insulation is sometimes needed to help achieve consistent hot water temperatures throughout a domestic hot water recirculation (DHWR) piping loop for the purposes of faster delivery of hot water to distal points, as well as energy conservation.

Maintaining hot water temperatures between 125°F and 135°F (51°C to 57°C) will prevent the growth of pathogens (e.g., *Legionella*) while minimizing the risk of scalding and preventing excessive energy loss due to excessive water temperatures. However, the IAPMO Uniform Plumbing Code, Appendix N states that scalding ("second degree burn") can occur in as little as 18 seconds when skin is exposed to 130°F (54°C) water. Installation of appropriate mixing devices is recommended to reduce outlet water temperatures to reduce the risk of scalding.

For the return piping of domestic hot water recirculation (DHWR) systems, according to **IAPMO IS-31(2023)**, the return piping flow velocity shall not exceed **2 feet per second** (0.6 m/s) for PEX tubing. This maximum flow velocity through return lines can be accommodated by controlling the flow rate via correct adjustment of DHWR circulation pumps (i.e., do not oversize pumps) or by increasing the diameter of the pipe return legs to reduce the flow velocity (e.g., increase from 1/2 to 3/4 tubing). See **Table 6.2** which shows the flow rate/volume per each nominal diameter of PEX tubing at a 2 ft/sec flow velocity.

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

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

Other Design Considerations

If a pressure reducing valve (PRV) is installed in a plumbing system, an expansion tank or other form of thermal expansion relief is recommended. Consult the local code and the Authority Having Jurisdiction (AHJ).

Finally, for commercial plumbing systems, designers are recommended to review the following industry publications:

- ASPE Engineered Plumbing Design II
- ASPE Plumbing Engineering Design Handbook, Volume One: Fundamentals of Plumbing Engineering
- ASPE Plumbing Engineering Design Handbook, Volume Two: Plumbing Systems
- ASPE Engineering Methodologies to Reduce the Risk of Legionella in Premise Plumbing Systems
- ASHRAE Guideline 12 *Managing the Risk of Legionellosis Associated with Building Water Systems*
- ASHRAE 188 Legionellosis: *Risk Management for Building Water Systems*
- ASHRAE 514 *Risk Management for Building Water Systems: Physical, Chemical and Microbial Hazards*
- IAPMO Uniform Plumbing Code (UPC) Appendix N *Impact of Water Temperature on the Potential for Scalding and Legionella Growth*
- IAPMO Z1403 Water Demand Calculator

Part III: Flow Velocity and Pressure Drop Tables

The following tables provide detailed design information about sizing PEX tubing based on flow velocities and pressure drop:

- **Table 6.3 *Flow Velocity in PEX Tubing***
- **Table 6.4 *Pressure Drop through PEX Tubing with 60°F (16°C) Water***
- **Table 6.5 *Pressure Drop through PEX Tubing with 125°F (52°C) Water***

The information in these tables was developed from the **PPI Plastic Pipe Design Calculator** which is a free online tool available at www.plasticpipe.org.

Notes to Tables 6.3, 6.4 and 6.5:

- All Flow Rates shown in this Guide are in US gallons (3.78 l) per minute (GPM).
- Values in red represent flow velocities above 10 fps (3.0 m/s) which are not recommended for PEX.
- Values in blue represent transition flow rates between laminar and turbulent flow for which precise pressure drop values cannot be calculated.

Table 6.3 Flow Velocity in PEX Tubing

Flow Rate	Flow Velocity ft/sec									
GPM	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
0.5	1.67	0.91	0.45	0.27	0.18	0.13	0.08	0.05	0.04	0.02
0.75	2.50	1.36	0.68	0.41	0.28	0.20	0.12	0.08	0.05	0.03
1.0	3.33	1.81	0.91	0.55	0.37	0.26	0.15	0.10	0.07	0.04
1.5	5.00	2.72	1.36	0.82	0.55	0.40	0.23	0.15	0.11	0.06
2.0	6.67	3.62	1.81	1.10	0.74	0.53	0.31	0.20	0.14	0.08
2.5	8.34	4.53	2.27	1.37	0.92	0.66	0.38	0.25	0.18	0.10
3.0	10.0	5.43	2.72	1.65	1.10	0.79	0.46	0.30	0.21	0.12
3.5	11.7	6.34	3.18	1.92	1.29	0.92	0.54	0.35	0.25	0.14
4.0	13.3	7.24	3.63	2.20	1.47	1.06	0.62	0.40	0.28	0.16
4.5		8.15	4.08	2.47	1.65	1.19	0.69	0.45	0.32	0.18
5.0		9.05	4.54	2.75	1.84	1.32	0.77	0.51	0.36	0.20
6.0		10.9	5.44	3.30	2.21	1.58	0.92	0.61	0.43	0.24
7.0		12.7	6.35	3.85	2.57	1.85	1.08	0.71	0.50	0.28
8.0			7.26	4.40	2.94	2.11	1.23	0.81	0.57	0.33
9.0			8.17	4.95	3.31	2.38	1.39	0.91	0.64	0.37
10.0			9.07	5.50	3.68	2.64	1.54	1.01	0.71	0.41
11.0			9.98	6.05	4.04	2.90	1.69	1.11	0.78	0.45
12.0			10.9	6.60	4.41	3.17	1.85	1.21	0.85	0.49
13.0			11.8	7.15	4.78	3.43	2.00	1.31	0.92	0.53
14.0				7.70	5.15	3.70	2.16	1.41	0.99	0.57

Table 6.3 Flow Velocity in PEX Tubing (Continued)

Flow Rate	Flow Velocity ft/sec									
GPM	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
15.0				8.25	5.52	3.96	2.31	1.52	1.07	0.61
16.0				8.80	5.88	4.22	2.46	1.62	1.14	0.65
17.0				9.35	6.25	4.49	2.62	1.72	1.21	0.69
18.0				9.90	6.62	4.75	2.77	1.82	1.28	0.73
19.0				10.4	6.99	5.02	2.92	1.92	1.35	0.77
20.0				11.0	7.35	5.28	3.08	2.02	1.42	0.81
25.0					9.19	6.60	3.85	2.53	1.78	1.02
30.0					11.0	7.92	4.62	3.03	2.13	1.22
35.0					12.9	9.24	5.39	3.54	2.49	1.42
40.0						10.6	6.16	4.04	2.84	1.63
45.0						11.9	6.93	4.55	3.20	1.83
50.0							7.70	5.05	3.55	2.03
55.0							8.47	5.56	3.91	2.24
60.0							9.24	6.06	4.26	2.44
65.0							10.0	6.57	4.62	2.64
70.0							10.8	7.07	4.97	2.85
75.0							11.5	7.58	5.33	3.05
80.0								8.08	5.68	3.25
85.0								8.59	6.04	3.46
90.0								9.09	6.39	3.66
95.0								9.60	6.75	3.86
100.0								10.1	7.10	4.07
110.0								11.1	7.81	4.47
120.0									8.52	4.88
130.0									9.23	5.29
140.0									9.95	5.69
150.0									10.7	6.10
160.0									11.4	6.51
170.0										6.92
180.0										7.32
190.0										7.73
200.0										8.14
220.0										8.95
240.0										9.76
260.0										10.6
280.0										11.4
300.0										12.2

Values in red represent flow velocities above 10 fps (3.0 m/s) which are not recommended for PEX.

Table 6.4 Pressure Drop through PEX Tubing with 60°F (16°C) Water

Flow Rate	psi/100 ft of Pipe									
GPM	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
0.5	1.0-2.6	0.3-0.6	0.08-0.1	0.03	0.01	0.01	0.00	0.00	0.00	0.00
0.75	5.15	1.22	0.1-0.2	0.05-0.1	0.02	0.01	0.00	0.00	0.00	0.00
1.0	8.46	1.99	0.39	0.08-0.12	0.05	0.01	0.00	0.00	0.00	0.00
1.5	17.1	4.02	0.78	0.24	0.10	0.05	0.00	0.00	0.00	0.00
2.0	28.3	6.63	1.29	0.39	0.15	0.07	0.00	0.00	0.00	0.00
2.5	42.0	9.79	1.90	0.58	0.22	0.10	0.03	0.00	0.00	0.00
3.0	57.9	13.5	2.61	0.79	0.31	0.14	0.04	0.01	0.00	0.00
3.5	76.1	17.7	3.41	1.04	0.40	0.18	0.05	0.02	0.01	0.00
4.0	96.5	22.4	4.31	1.31	0.50	0.23	0.06	0.02	0.01	0.00
4.5		27.6	5.30	1.61	0.62	0.28	0.08	0.03	0.01	0.00
5.0		33.2	6.38	1.94	0.74	0.34	0.09	0.03	0.02	0.00
6.0		45.9	8.80	2.67	1.02	0.47	0.13	0.05	0.02	0.01
7.0			11.6	3.50	1.34	0.61	0.17	0.06	0.03	0.01
8.0			14.7	4.43	1.70	0.77	0.21	0.08	0.03	0.01
9.0			18.1	5.45	2.09	0.95	0.26	0.10	0.04	0.01
10.0			21.8	6.57	2.52	1.14	0.32	0.12	0.05	0.01
11.0			25.8	7.78	2.98	1.35	0.37	0.14	0.06	0.02
12.0			30.2	9.08	3.47	1.57	0.44	0.16	0.07	0.02
13.0			34.8	10.5	4.00	1.81	0.50	0.18	0.08	0.02
14.0				11.9	4.56	2.07	0.57	0.21	0.09	0.02
15.0				13.5	5.16	2.34	0.65	0.24	0.10	0.03
16.0				15.2	5.79	2.62	0.72	0.26	0.11	0.03
17.0				16.9	6.44	2.92	0.80	0.29	0.13	0.03
18.0				18.7	7.14	3.23	0.89	0.33	0.14	0.04
19.0				20.6	7.86	3.55	0.98	0.36	0.16	0.04
20.0				22.6	8.61	3.89	1.07	0.39	0.17	0.05
25.0					12.8	5.79	1.59	0.58	0.25	0.07
30.0					17.8	8.03	2.20	0.80	0.35	0.09
35.0					23.5	10.6	2.90	1.06	0.46	0.12
40.0						13.4	3.68	1.34	0.58	0.15
45.0						16.6	4.55	1.66	0.71	0.19
50.0							5.50	2.00	0.86	0.23
55.0							6.52	2.37	1.02	0.27
60.0							7.63	2.77	1.19	0.31
65.0							8.81	3.20	1.38	0.36
70.0							10.1	3.66	1.57	0.41
75.0							11.4	4.14	1.78	0.47
80.0								4.65	2.00	0.52
85.0								5.18	2.23	0.58

Table 6.4 Pressure Drop through PEX Tubing with 60°F (16°C) Water (Continued)

Flow Rate	psi/100 ft of Pipe									
GPM	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
90.0								5.75	2.47	0.65
95.0								6.34	2.72	0.71
100.0								6.95	2.98	0.78
110.0								8.26	3.54	0.93
120.0									4.14	1.08
130.0									4.78	1.25
140.0									5.47	1.43
150.0									6.19	1.62
160.0									6.96	1.82
170.0										2.03
180.0										2.25
190.0										2.48
200.0										2.72
220.0										3.23
240.0										3.79
260.0										4.38
280.0										5.01
300.0										5.67

Values in red represent flow velocities above 10 fps (3.0 m/s) which are not recommended for PEX. Values in blue represent transition flow rates between laminar and turbulent flow for which precise pressure drop values cannot be calculated.

Table 6.5 Pressure Drop through PEX Tubing with 125°F (52°C) Water

Flow Rate	psi/100 ft of Pipe									
GPM	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
0.5	2.06	0.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.75	4.18	0.98	0.19	0.06	0.02	0.00	0.00	0.00	0.00	0.00
1.0	6.91	1.62	0.31	0.10	0.04	0.02	0.00	0.00	0.00	0.00
1.5	14.1	3.29	0.64	0.19	0.07	0.03	0.01	0.00	0.00	0.00
2.0	23.6	5.46	1.05	0.32	0.12	0.06	0.02	0.01	0.00	0.00
2.5	35.1	8.11	1.56	0.47	0.18	0.08	0.02	0.01	0.00	0.00
3.0	48.7	11.2	2.15	0.65	0.25	0.11	0.03	0.01	0.01	0.00
3.5	64.2	14.8	2.82	0.85	0.33	0.15	0.04	0.02	0.01	0.00
4.0	81.7	18.8	3.58	1.08	0.41	0.19	0.05	0.02	0.01	0.00
4.5		23.2	4.41	1.33	0.51	0.23	0.06	0.02	0.01	0.00
5.0		28.0	5.32	1.60	0.61	0.28	0.08	0.03	0.01	0.00
6.0		38.9	7.37	2.22	0.85	0.38	0.11	0.04	0.02	0.00
7.0		51.3	9.71	2.92	1.11	0.50	0.14	0.05	0.02	0.01
8.0			12.3	3.70	1.41	0.64	0.18	0.06	0.03	0.01
9.0			15.3	4.57	1.74	0.79	0.22	0.08	0.03	0.01
10.0			18.4	5.52	2.10	0.95	0.26	0.10	0.04	0.01
11.0			21.9	6.55	2.49	1.13	0.31	0.11	0.05	0.01
12.0			25.6	7.66	2.91	1.32	0.36	0.13	0.06	0.02
13.0			29.6	8.85	3.36	1.52	0.42	0.15	0.07	0.02
14.0				10.1	3.84	1.73	0.48	0.17	0.08	0.02
15.0				11.5	4.35	1.96	0.54	0.20	0.08	0.02
16.0				12.9	4.88	2.20	0.60	0.22	0.10	0.03
17.0				14.4	5.45	2.45	0.67	0.25	0.11	0.03
18.0				15.9	6.04	2.72	0.75	0.27	0.12	0.03
19.0				17.6	6.66	3.00	0.82	0.30	0.13	0.03
20.0				19.3	7.30	3.29	0.90	0.33	0.14	0.04
25.0					10.9	4.91	1.34	0.49	0.21	0.06
30.0					15.2	6.83	1.86	0.68	0.29	0.08
35.0					20.1	9.04	2.46	0.89	0.38	0.10
40.0						11.5	3.13	1.14	0.49	0.13
45.0						14.3	3.88	1.40	0.60	0.16
50.0							4.69	1.70	0.73	0.19
55.0							5.58	2.02	0.87	0.23
60.0							6.53	2.36	1.01	0.26
65.0							7.56	2.73	1.17	0.31
70.0							8.65	3.12	1.34	0.35
75.0							9.81	3.54	1.52	0.40
80.0								3.98	1.70	0.44
85.0								4.45	1.90	0.50

Table 6.5 Pressure Drop through PEX Tubing with 125°F (52°C) Water (Continued)

Flow Rate GPM	psi/100 ft of Pipe									
	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
90.0								4.93	2.11	0.55
95.0								5.45	2.33	0.61
100.0								5.98	2.55	0.67
110.0								7.12	3.04	0.79
120.0									3.56	0.93
130.0									4.12	1.07
140.0									4.71	1.22
150.0									5.35	1.39
160.0									6.02	1.56
170.0										1.74
180.0										1.93
190.0										2.14
200.0										2.34
220.0										2.79
240.0										3.27
260.0										3.79
280.0										4.34
300.0										4.92

Values in red represent flow velocities above 10 fps (3.0 m/s) which are not recommended for PEX. Values in blue represent transition flow rates between laminar and turbulent flow for which precise pressure drop values cannot be calculated.

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

To compare the actual pressure drop and flow rate performance of plumbing systems constructed in the same design using both PEX and Type L copper tubing, laboratory testing was performed on identical configurations of PEX and copper trunk and branch (T&B) plumbing systems serving standard residential plumbing fixtures supplied at source pressures of 40, 60, and 80 psi, with lengths of 60 and 100-feet of pipe to the furthest fixture. The measured flow rate at each plumbing fixture was virtually identical for both piping systems, except for minor differences in the water closet fill rate.

Even though PEX tubing has a slightly smaller inside diameter than copper tubing of the same nominal dimension, both tubing systems satisfied the farthest fixture demand, even with multiple fixtures flowing. **Table 6.6** compares the two piping systems with a minimum source pressure of 40 psi and a maximum tubing length of 100 ft, the most demanding scenario in the test. Results of flow tests using higher pressures were consistent.

This testing demonstrates that in a typical single-family residential plumbing system, both PEX and copper piping systems will deliver sufficient volumetric flow rates and pressures to the plumbing fixtures when using the same nominal size tubing. Details of this testing as well as additional test configurations are published in the NAHB-RC report "Fixture Flow Rate Comparison – Crosslinked Polyethylene (PEX) Piping and Copper Tubing" available on the PPI website.

Table 6.6 Flow Performance Data, PEX and Copper, 100' Maximum Length, 40 psi Main Source Pressure

Unit of Measure	Source						Farthest Test Fixture (Shower)							
	System Flow GPM		Cold Supply GPM		Hot Supply GPM		Hot Water Flow GPM		Hot Water Pressure psi		Cold Water Flow GPM		Cold Water Pressure psi	
System Type	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper
T&B 100' Main Pressure									34.0	33.5			35.2	34.6
TF	2.2	2.1	.5	.7	1.7	1.5	1.7	1.5	31.6	32.5	.2	.5	35.1	34.4
TF + Lav	3.5	3.6	1.6	1.7	1.9	1.9	1.7	1.5	31.2	32.1	.2	.5	34.2	34.1
TF + WC	5.7	6.2	4.0	4.8	1.6	1.4	1.7	1.5	31.9	32.9	.2	.5	29.5	32.3
TF + Kit	3.5	3.7	1.3	1.9	2.2	1.7	1.7	1.5	31.3	32.3	.2	.5	35.0	34.2
TF + Sh2	4.2	4.3	1.3	1.7	2.8	2.6	1.7	1.5	30.6	31.7	.2	.5	34.9	34.2
TF + Sh2+Kit	5.6	5.7	2.2	2.5	3.4	3.2	1.7	1.5	30.3	31.5	.2	.5	34.7	34.0
TF + Sh2+Kit+Lav	7.0	7.1	3.5	3.7	3.5	3.5	1.7	1.5	30.1	31.1	.2	.5	33.4	33.6
TF+Sh2+Kit+Lav+WC	10.0	10.9	5.8	6.9	4.2	4.0	1.7	1.5	28.6	30.9	.2	.5	29.3	31.5

GPM=Gallons Per Minute, psi=pounds per square foot, TF=Test Shower Fixture, Lav=Lavatory (sink), WC=Water Closet, Kit= Kitchen, Sh2=Shower 2

7 Optimizing PEX Plumbing Designs

This chapter focuses on optimizing plumbing system designs for the use of PEX systems. It provides example plumbing system designs utilizing the three main layout options described in **Chapter 6 *Layouts & Design*** (trunk & branch, parallel, zoned) for four common types of residential and multi-family structures:

- **The Colonial:** 2,000 square feet house, unfinished basement plus two levels, 4 bedrooms, 2 full baths, 1 half bath (see **Figure 7.1**)
- **The Ranch:** 1,300 square feet, one story, 3 bedrooms, 2 full baths
- **The Townhouse:** 1,000 square, three levels, 2 bedrooms, 1 full bath, 1 half bath
- **The Condo:** 1,200 square feet, one level, 2 bedrooms, 2 full baths

While many commercial buildings are unique structures and require a specific hot- and cold-water plumbing design based on fixtures, flows, locations, distance to water heaters, customer expectations, and the applicable plumbing codes, certain commercial plumbing designs (e.g., apartments, hotels) may be modeled based on the guidance provided in these four design examples. For such structures, plumbing engineers can follow the principles provided in **Chapter 6** and this chapter.

Chapter 8 Performance Data provides performance measurements for each type of system, with regards to the flow and residual pressure, as well as the time-to-wait for hot water in each of the plumbing layouts.

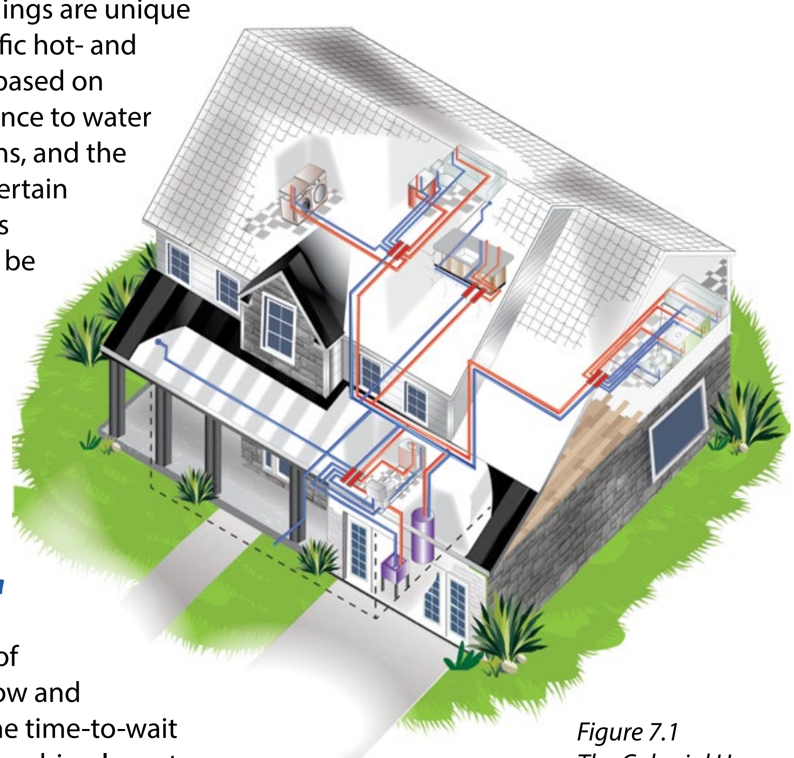


Figure 7.1
The Colonial House

Example Layouts

The following plumbing system layouts were based on simulated Computer-Aided Design (CAD) designs matching the architectural scale of each of the four housing types. These CAD designs provide hot- and cold-water distribution piping designs. The length of tubing for both hot- and cold-water supply and quantities of fittings and joints are shown for each design to provide a comparison of material use and labor required. You can choose the residential design that most closely resembles your project to help select the PEX plumbing system that is optimal for each project. In these designs, only a few common structural obstructions are accounted for; therefore, these piping layouts represent idealized pipe runs with minimal fittings. Actual construction with more structural obstructions may require additional tubing and changes of direction to bypass them.

Table 7.1 outlines the number and type of fixtures for each residence type.

Table 7.1 Fixture Count for Each Residence Type

Fixture	Colonial	Ranch	Townhouse	Condominium
Kitchen Sink	1	1	1	1
Dishwasher	1	1	1	1
Lavatory	4	3	2	3
Water Closet	3	2	2	2
Shower/Tub	3	3	1	3
Clothes Washer	1	1	1	1
Utility Sink	1	0	0	0
Hose Bibbs	2	2	2	0
Total	**16**	**13**	**10**	**11**

Colonial Layout

The Colonial house layout has approximately **2,000** square feet of floor area and an unfinished basement. The water service line enters the house under the basement slab. The water heater is located near the service line in the basement. The first floor has a living room, dining room, kitchen, family room, and a powder room. The second floor has four bedrooms, two full baths, and clothes washer.

Table 7.2 provides the Fixture Summary for the Colonial house.

Table 7.2 Fixture Summary for the Colonial House

Level	Kitchen Sink	Dish-washer	Lava-tory	Water Closet	Shower / Tub	Clothes Washer	Utility Sink	Hose Bibs	Total
Basement	0	0	0	0	0	0	1	0	**1**
First Floor	1	1	1	1	0	0	0	2	**6**
Second Floor	0	0	3	2	3	1	0	0	**9**
Total	**1**	**1**	**4**	**3**	**3**	**1**	**1**	**2**	**16**

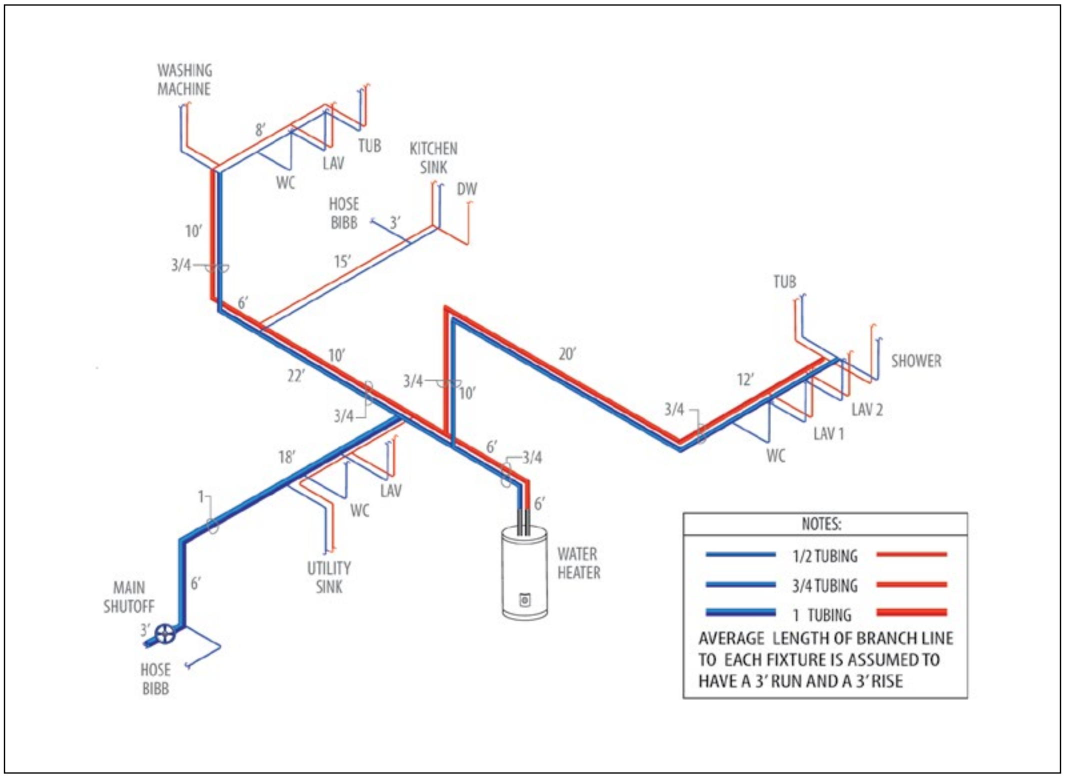


Figure 7.2 Trunk and Branch Isometric Riser for the Colonial House

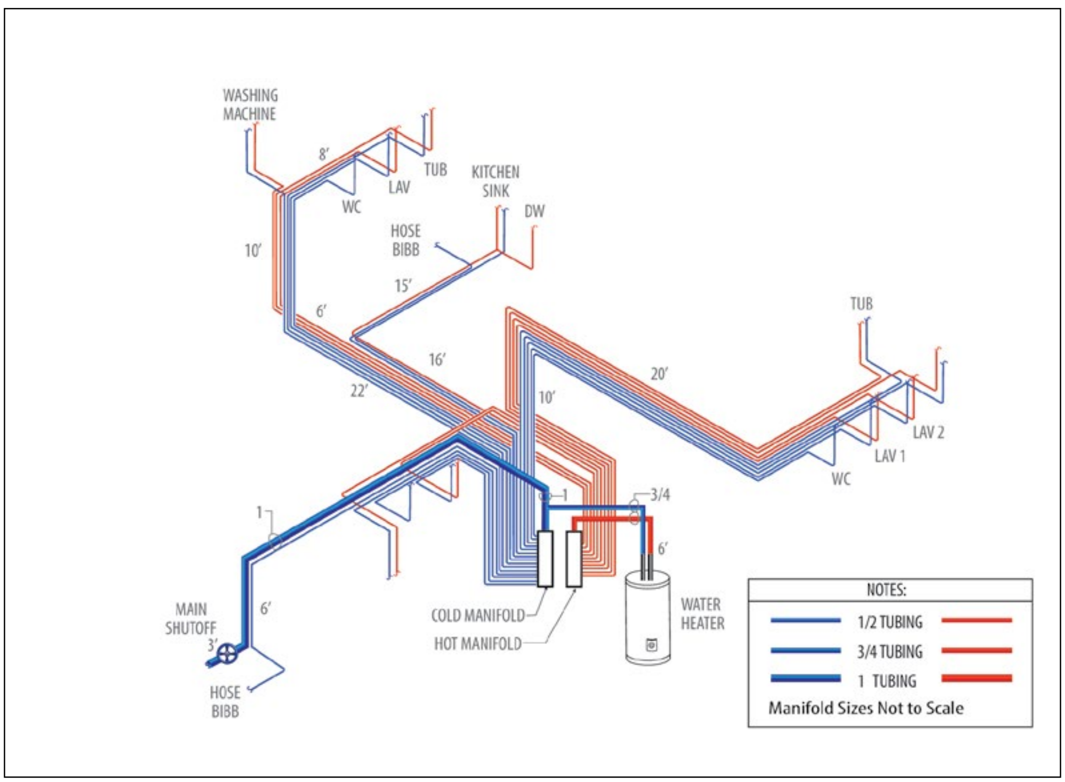


Figure 7.3 Parallel Isometric Riser for the Colonial House

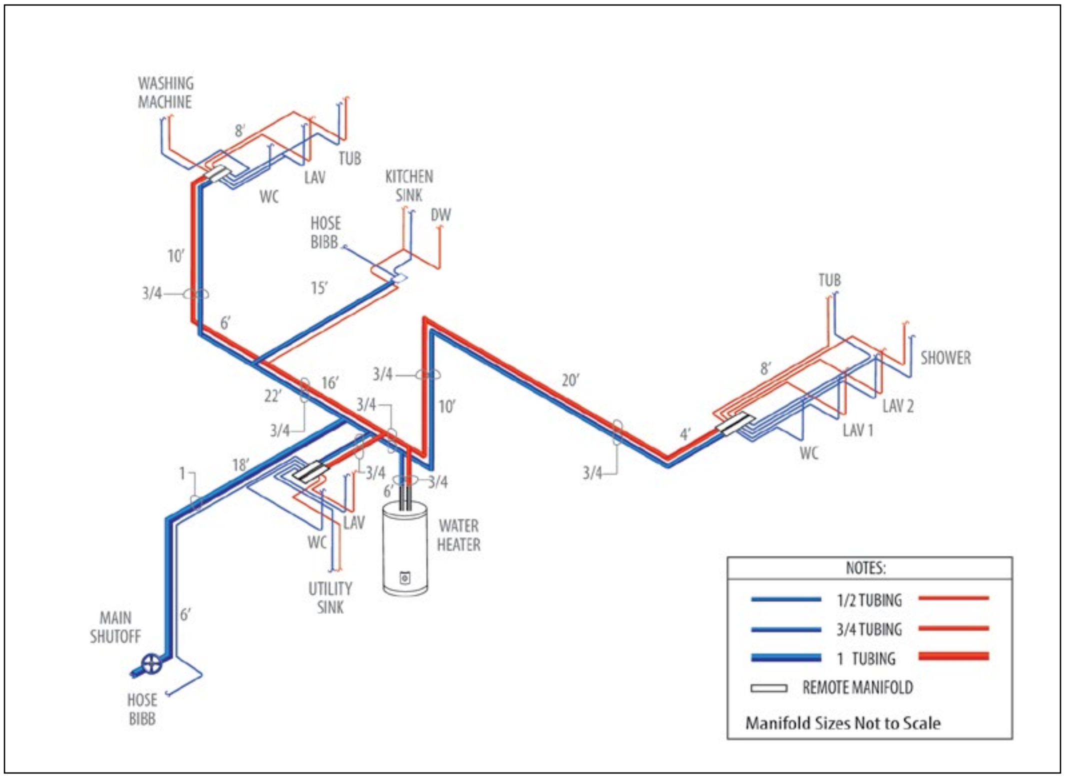


Figure 7.4 Zone Isometric Riser for the Colonial House

Table 7.3 provides the Material Summary for PEX tubing, fittings, and joints for each of the three plumbing layouts for the Colonial house.

Table 7.3 Material Summary for the Colonial House

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

In homes and buildings with a large separation between fixture groups (e.g., bathrooms), the trunk and branch design uses the least amount of total tubing but the most fittings and joints. In this example, the T&B design uses **395** feet of tubing, **35** fittings and **123** joints. The parallel system uses the most tubing (**1,087** feet or 2.75 times more than T&B) and the least amount of fittings (**11**) and joints (**75**). While the parallel system uses more tubing, it is all smaller diameter, which is easier to handle and install, particularly around obstructions and bends. The zoned system strikes a balance with **472** feet of tubing, **28** fittings, and **109** joints.

An appropriate balance between labor and material costs as well as the relative performance of the systems is important when deciding on a system layout for a particular house or building.

Ranch Layout

The Ranch house has approximately **1,300** square feet of one-story floor area slab-on-grade. The water service line enters the house under the slab. The one-story floor plan includes a great room, a kitchen, a dining room, three bedrooms, and two full baths. The water heater and clothes washer are located in the utility room.

Table 7.4 provides the Fixture Summary for the Ranch house.

Table 7.4 Fixture Summary for the Ranch House

Level	Kitchen Sink	Dish-washer	Lava-tory	Water Closet	Shower / Tub	Clothes Washer	Utility Sink	Hose Bibs	Total
Main Floor	1	1	3	2	3	1	0	2	**13**

See **Figure 7.5** for the trunk and branch, **Figure 7.6** for parallel, and **Figure 7.7** for zoned plumbing layouts for the Ranch house.

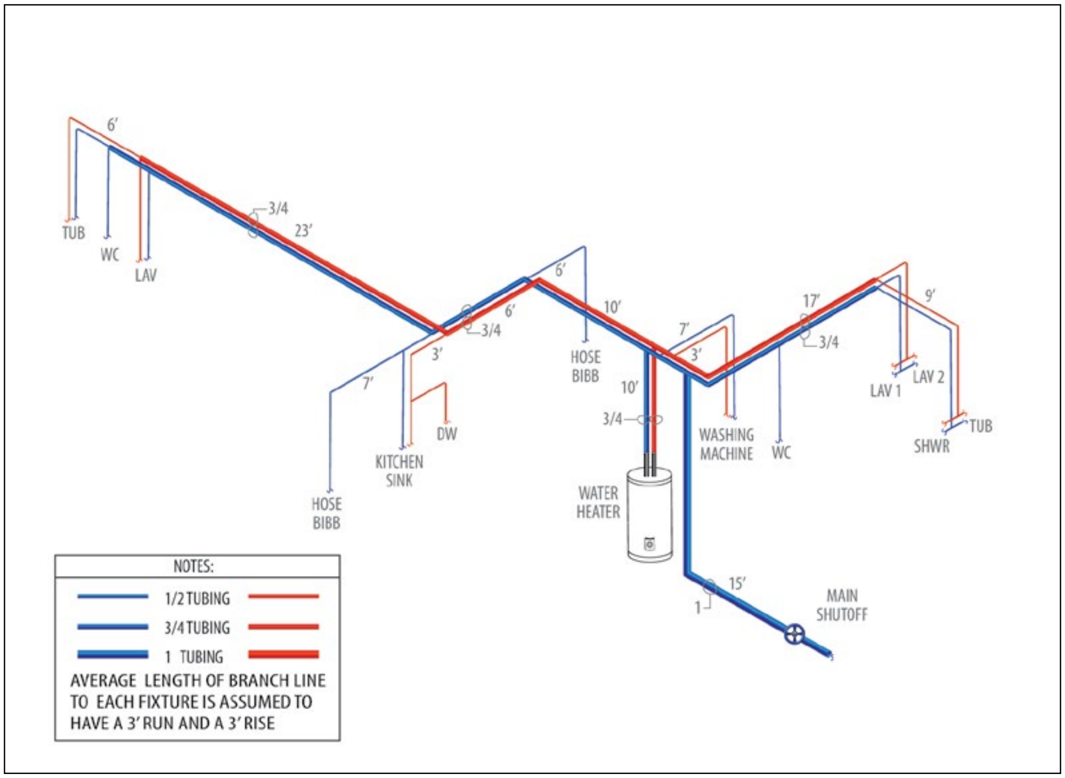


Figure 7.5 Trunk and Branch Isometric Riser for the Ranch House

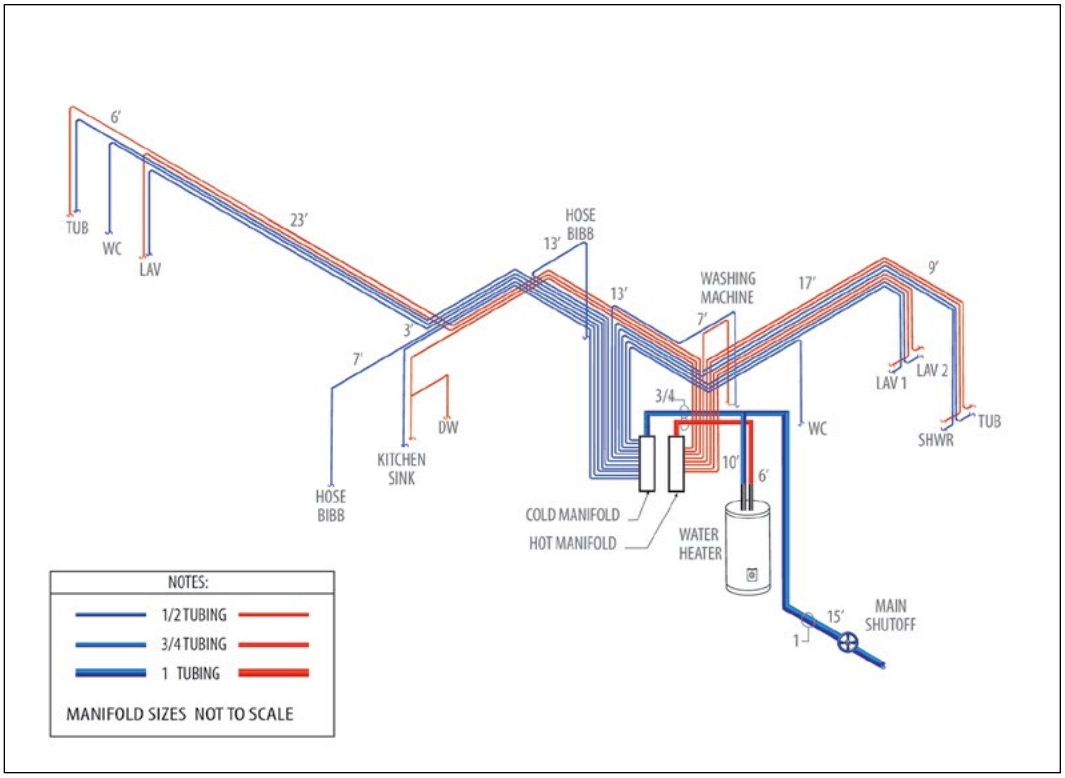


Figure 7.6 Parallel Isometric Riser for the Ranch House

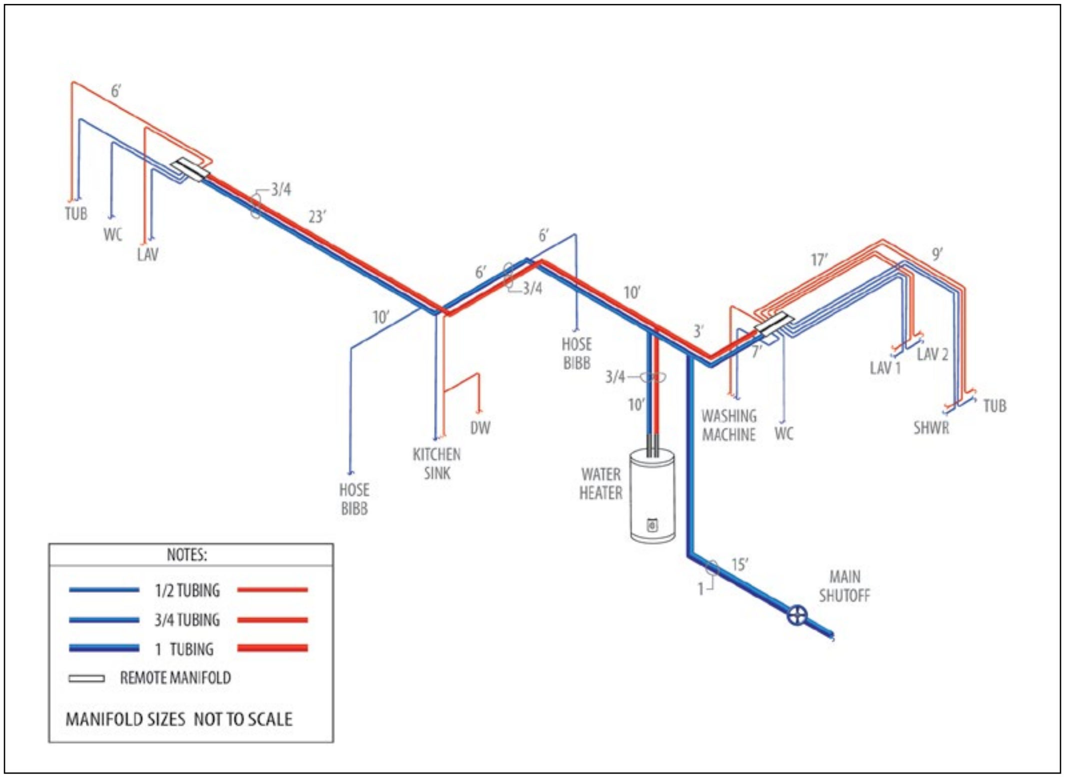


Figure 7.7 Zone Isometric Riser for the Ranch House

Table 7.5 provides the Material Summary for PEX tubing, fittings, and joints for each of the three plumbing layouts for the Ranch house.

Table 7.5 Material Summary for the Ranch House

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

In homes and buildings with a large separation between fixture groups (e.g., bathrooms, kitchens), the trunk and branch design uses the least amount of total tubing, but the most fittings and joints. In this example, the T&B design uses **365** feet of tubing, **25** fittings and **92** joints. The parallel system uses the most total tubing (**752** feet or 2 times more than T&B) and the least amount of fittings (**7**) and joints (**60**). While the parallel system uses the most tubing, it is all smaller diameters, which is easier to handle and install, particularly around obstructions and bends. The zoned system strikes a balance with **498** feet of tubing, **12** fittings, and **74** joints.

An appropriate balance between labor and material costs as well as the relative performance of the systems is important when deciding on a system layout for a particular house or building.

Townhouse Layout

The Townhouse has two stories and is approximately **1,000** square feet of floor area. The water service line enters the house under the first floor's slab. The first floor has a living room, kitchen, dining room, and a powder room. The second floor has two bedrooms and one full bath. The water heater and clothes washer are located on the first floor.

Table 7.6 provides the Fixture Summary for the Townhouse.

Table 7.6 Fixture Summary for the Townhouse

Level	Kitchen Sink	Dish-washer	Lava-tory	Water Closet	Shower / Tub	Clothes Washer	Utility Sink	Hose Bibs	Total
First Floor	1	1	1	1	0	1	0	2	**7**
Second Floor	0	0	1	1	1	0	0	0	**3**
Total	**1**	**1**	**2**	**2**	**1**	**1**	**0**	**2**	**10**

See **Figure 7.8** for the trunk and branch, **Figure 7.9** for parallel, and **Figure 7.10** for zoned plumbing layouts for the Townhouse.

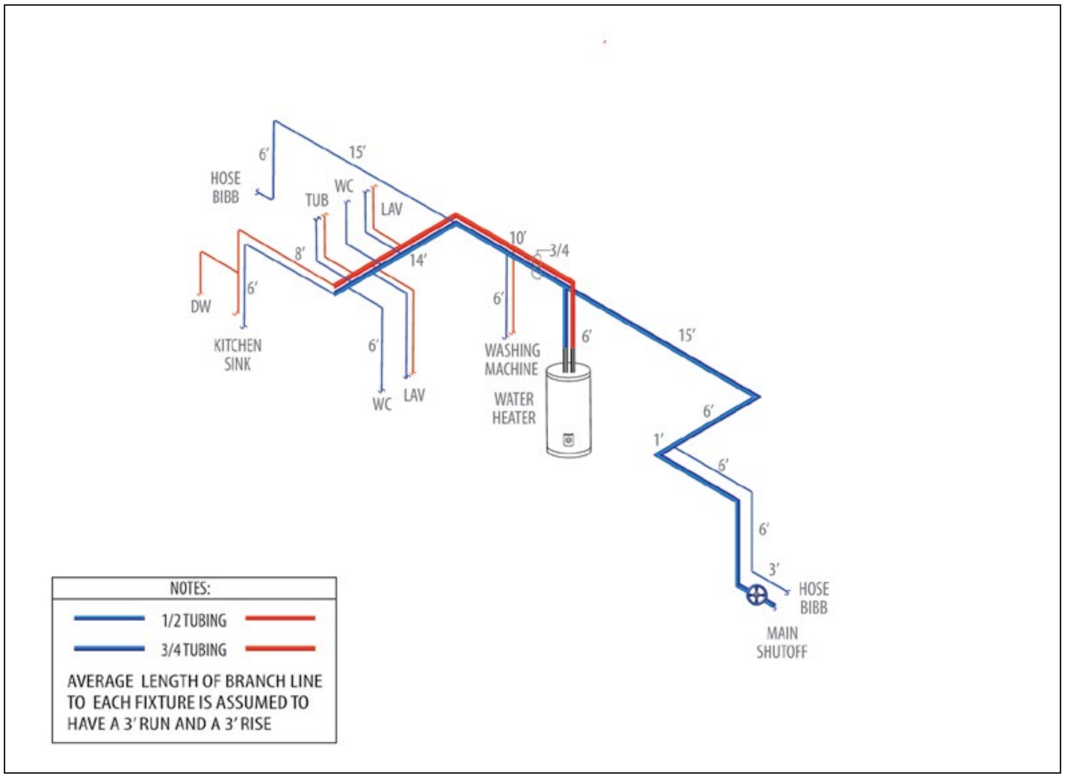


Figure 7.8 Trunk and Branch Isometric Riser for the Townhouse

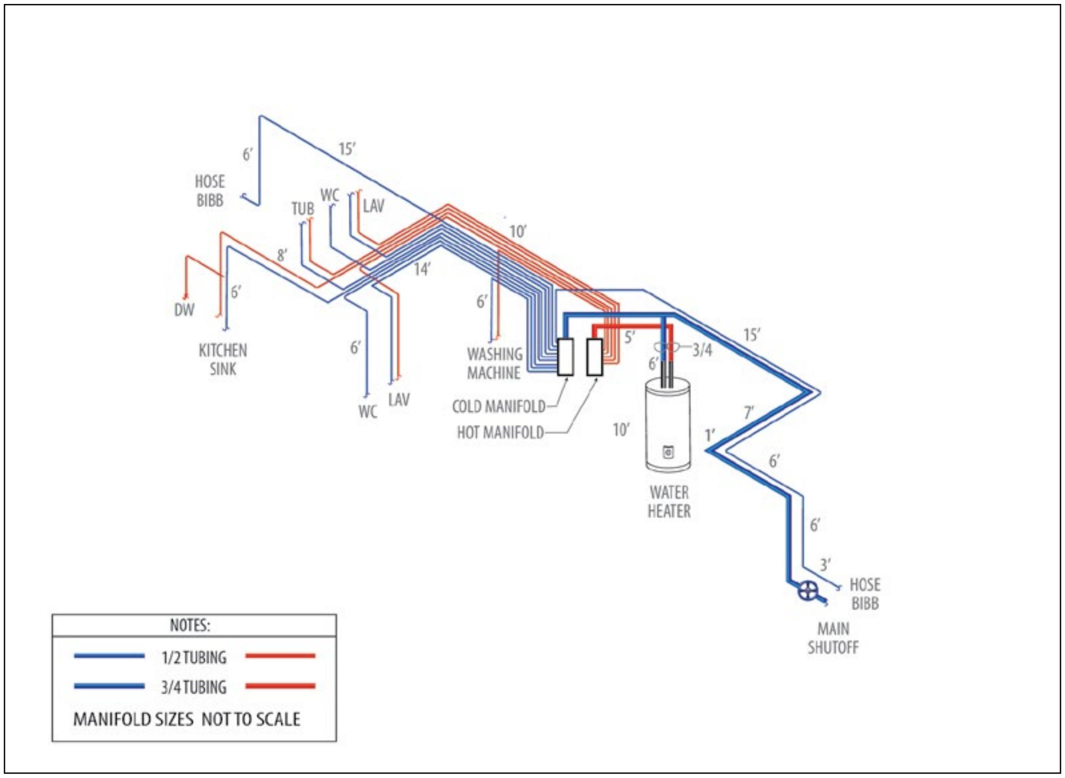


Figure 7.9 Parallel Isometric Riser for the Townhouse

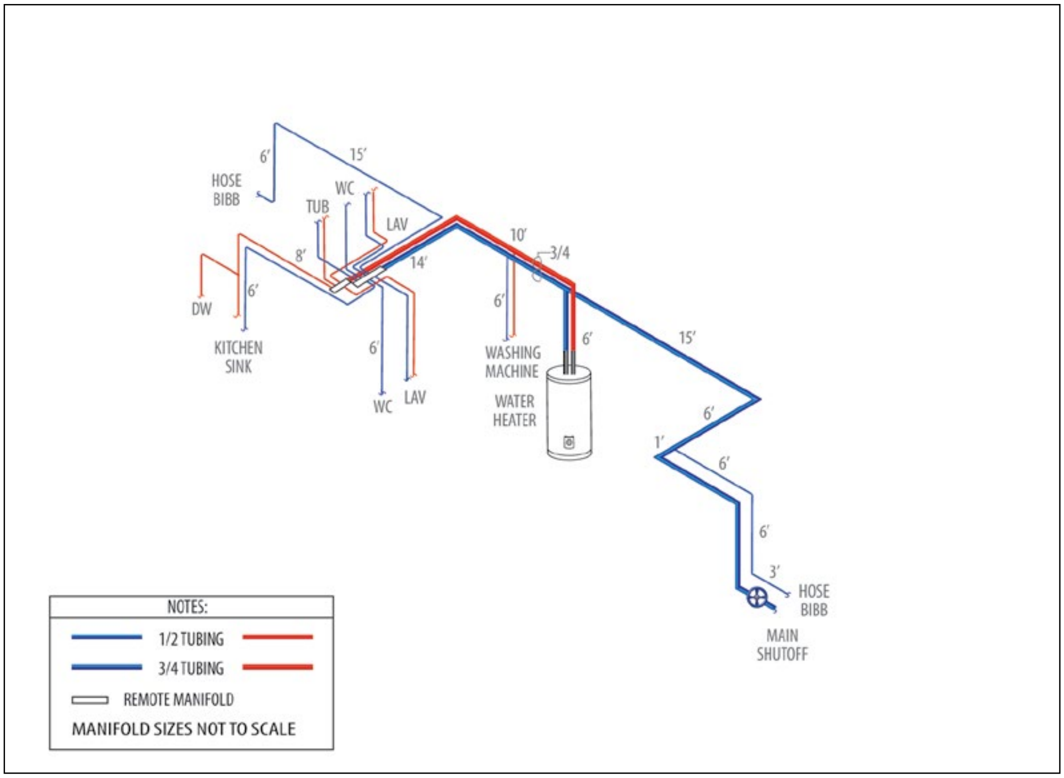


Figure 7.10 Zone Isometric Riser for the Townhouse

Table 7.7 provides the Material Summary for PEX tubing, fittings, and joints for each of the three plumbing layouts for the Townhouse.

Table 7.7 Material Summary for the Townhouse

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

In compact house designs such as townhomes, the differences between the trunk and branch and zone systems are primarily in reduced fittings and joints for the zone system. In this example, the T&B design uses **226** feet of tubing, **22** fittings and **74** joints. The parallel system uses considerably more tubing, **438** feet or 1.9 times more than T&B, with **10** fittings and **54** joints. While the parallel system uses more tubing, all of it is smaller diameter, which is easier to handle and install, particularly around obstructions and bends. The zoned system strikes a balance with **241** feet of tubing, **12** fittings, and **57** joints.

An appropriate balance between labor and material costs as well as the relative performance of the systems is important when deciding on a system layout for a particular house or building.

Condominium Layout

The Condominium has approximately **1,200** square feet of floor area on one level. This layout is also applicable to large apartments and hotel rooms. It has a living room, kitchen, dining room, two bedrooms, and two full baths. The clothes washer is located in the unit. The condominium building has a central plant for water heating; therefore, there is no water heater located in the unit.

Table 7.8 provides the Fixture Summary for the Condominium.

Table 7.8 Fixture Summary for the Condominium

Level	Kitchen Sink	Dish-washer	Lava-tory	Water Closet	Shower / Tub	Clothes Washer	Utility Sink	Hose Bibs	Total
Main Floor	1	1	3	2	3	1	0	0	**11**

See **Figure 7.11** for the trunk and branch, **Figure 7.12** for parallel, and **Figure 7.13** for zoned plumbing layouts for the Condominium.

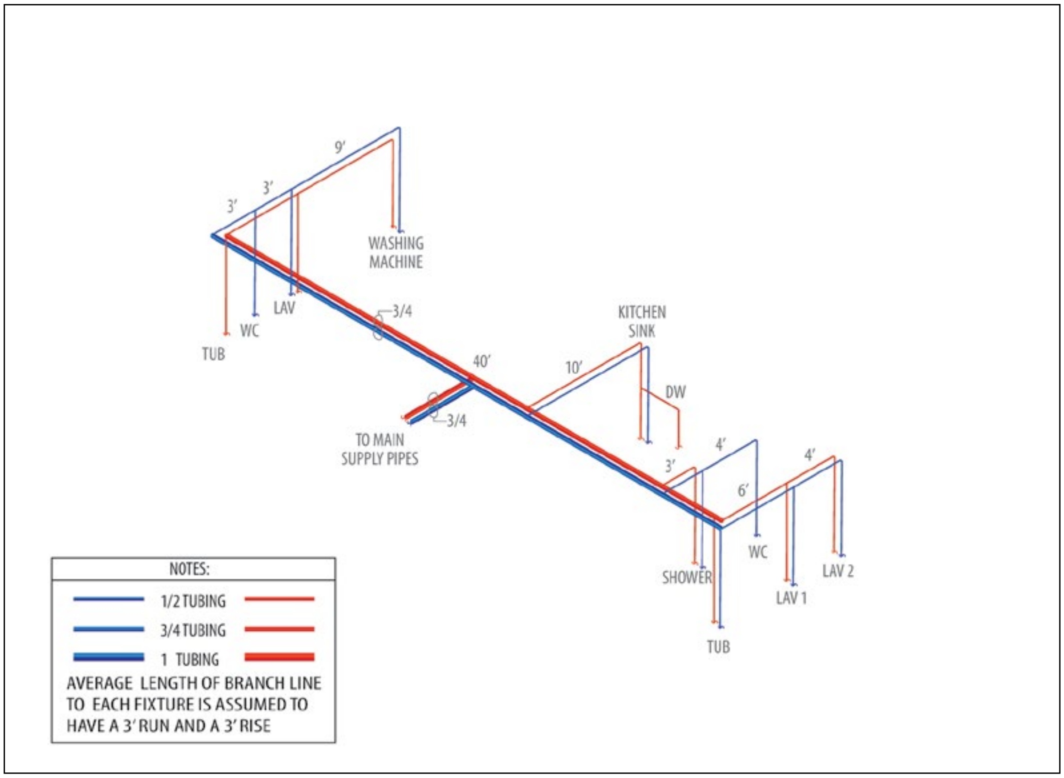


Figure 7.11 Trunk and Branch Isometric Riser for the Condominium

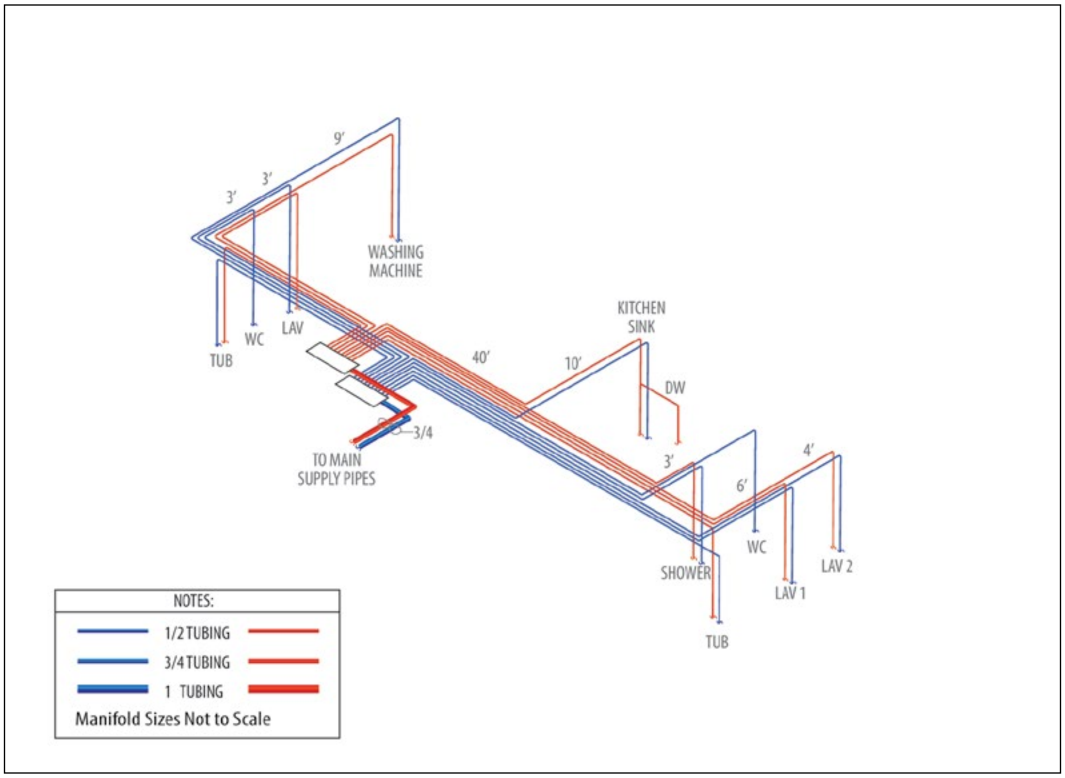


Figure 7.12 Parallel Isometric Riser for the Condominium

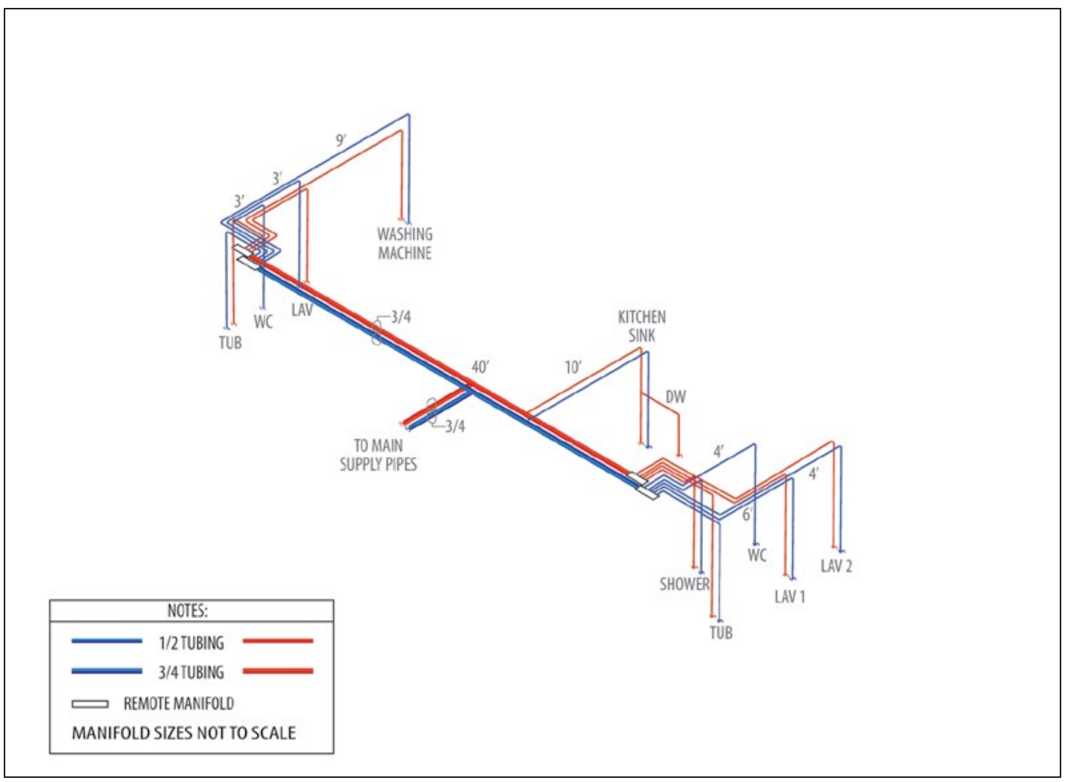


Figure 7.13 Zone Isometric Riser for the Condominium

Table 7.9 provides the Material Summary for PEX tubing, fittings, and joints for each of the three plumbing layouts for the Condominium.

Table 7.9 Material Summary for the Condominium

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

In this type of structure, a trunk and branch system uses the most tees, which increases the number of joints, whereas the zone system uses fewer fittings, resulting in fewer joints. In this example, the T&B system uses **314** feet, **17** fittings and **72** joints. The parallel system uses **557** feet of tubing (1.8 times more than T&B), **3** fittings and **48** joints. While the parallel system uses more tubing, it is all smaller diameter, which is easier to handle and install, particularly around obstructions and bends. The zoned system strikes a balance with **317** feet of tubing, **5** fittings, and **56** joints.

An appropriate balance between labor and material costs as well as the relative performance of the systems is important when deciding on a system layout for a particular house or building.

8 Performance Data

Following the introduction of PEX plumbing systems in North America in the 1980s and the rapid growth of its usage in the 1990s, a significant amount of research on the performance of PEX plumbing systems was conducted in the early 2000s with the objectives of determining the most efficient and effective plumbing designs for residential and light commercial applications.

For the reference of plumbing engineers and designers, installers, builders, and inspectors, this chapter is intended to present and summarize the foundational research which demonstrates the high levels of performance from various PEX plumbing designs and their suitability in distribution systems in a wide range of building types.

This chapter includes laboratory performance data on three common PEX plumbing layouts: trunk and branch, parallel, and zoned (i.e., remote manifold) – and provides both objective and subjective ratings of each of these designs for various type of residential and light commercial applications while considering numerous criteria.

System Performance Comparison

Each of the three PEX plumbing layouts described in this guide can be installed in most homes and buildings, meeting the performance demands of the system, codes, and customer expectations. The different layouts and combinations thereof offer opportunities to optimize the performance of the plumbing system, reduce the installed cost, and increase overall customer satisfaction and acceptance.

To quantify the differences between PEX plumbing system designs, each system was tested in the laboratory to provide a similar set of conditions under which the systems are typically installed and operated. Actual residential plumbing fixtures, piping layouts with fittings, and elevation changes were included in these empirical tests.

This provided a consistent comparison between the performance of the three layouts, as well as an indication of the minimum performance characteristics of each system. PEX tubing was installed in each of the three layouts - trunk and branch, parallel, and zoned - with overall results showing that:

- All systems had similar flow characteristics at each of the fixtures when flowing independently

- All system designs responded in a similar manner to simultaneous flow events (more than one fixture flowing at once)
- Minor differences in the actual measured flow and pressure at a test fixture emerged when simultaneous flow events occurred

Test System Design and Set-up

Plumbing fixtures were installed in a laboratory setting to provide actual flow and pressure data during operation of the fixtures. The test system was constructed and reconfigured for each type of PEX plumbing design, including the standard trunk and branch (T&B), the parallel (HR), and the zoned system using remote manifolds (RM).

A primary Test Fixture (TF), represented by a tub/shower unit, was installed and instrumented to measure flow rate and flow pressure on the hot and cold lines, as well as mixed water temperature. **Figure 8.1** shows the laboratory system diagram for the T&B system. Other test system designs are shown in **Appendix A**.

The Test Fixture was positioned to be the farthest fixture from the water source and was operated in shower mode during all tests. The operating performance of this test fixture represents the "worst case" scenario of the full system, since all other fixtures were closer to the source. **Figure 8.2** shows the laboratory set-up configured with the fixtures and the T&B system design with 100-foot distance to the TF. **Figure 8.3** shows the TF with the sensors for pressure and flow installed.

The data provides assurance that the PEX plumbing system design is capable of supplying the required flow rates during operation of the fixtures. In addition, the test results provide assurance that the plumbing system design will supply adequate flow and pressure to a remote test fixture while other fixtures are operated simultaneously.

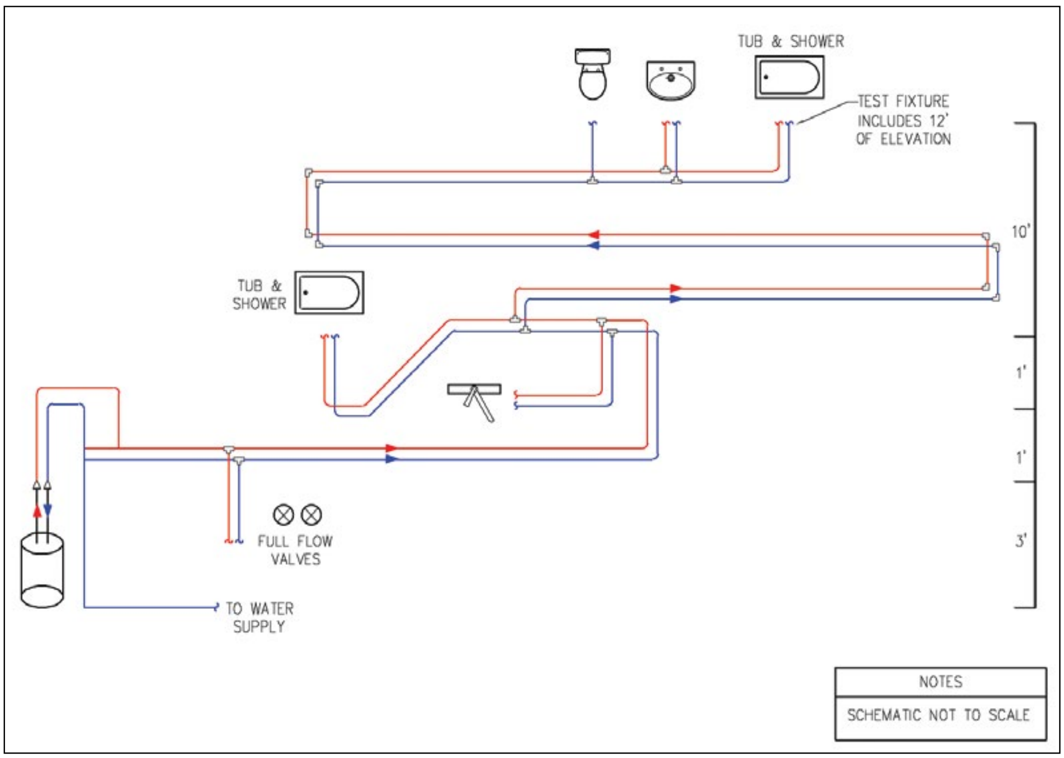


Figure 8.1 Fixture Layout for Laboratory Testing

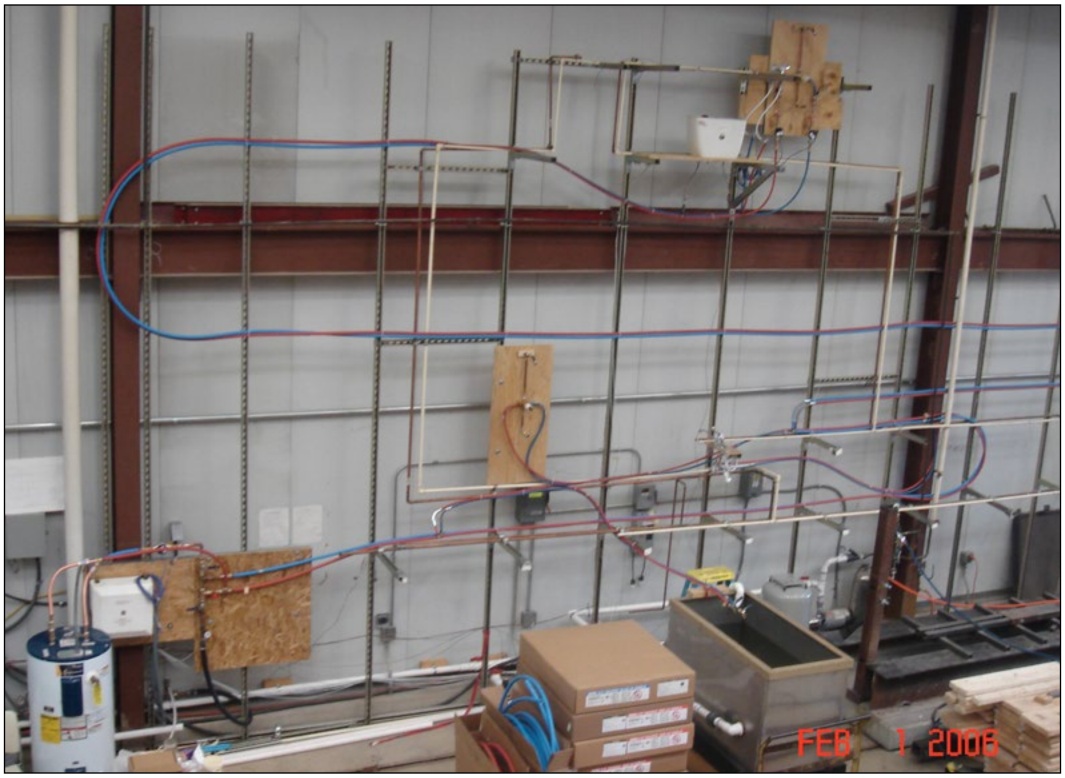


Figure 8.2 Laboratory Test Set-up with Hot Water Tank for T&B System

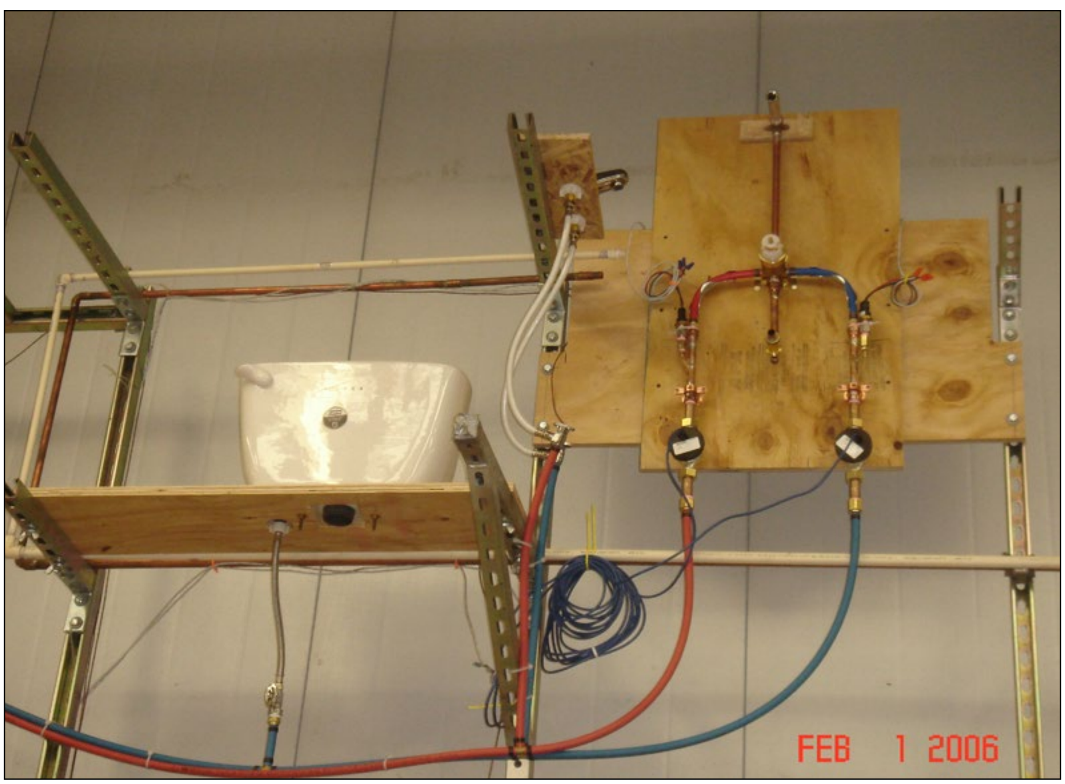


Figure 8.3 The Test Fixture (Shower) with Flow and Pressure Sensors Installed

Table 8.1 shows the set of plumbing fixtures installed to represent specific residential outlets. These fixtures were connected to each of the three different PEX plumbing configurations. Tests included using 100-foot and 60-foot total distances of pipe run to the farthest test fixture. The piping runs to the other fixtures were run in lengths that matched the type of piping system installed (i.e., if the HR system was being tested, all fixtures are plumbed with the HR system).

Table 8.1 Plumbing Fixtures Installed in the Test Plumbing System

Fixture	Length from Source (feet)	Elevation Above Source	Operation During Test
Tub/Shower TF	60 or 100	15	Full-On Shower
Lavatory	60 or 100	15	Intermittent
Water Closet (tank type)	55 or 95	15	Intermittent
Kitchen Faucet	Less than 40	5	Intermittent
Tub/Shower 2	Less than 40	6	Intermittent

Diagrams of all the test piping arrangements are shown in **Appendix A**.

Two sets of tests were performed for each plumbing system. One test recorded pressure and flow data at the test fixture while other fixtures were operated. A second set of tests was performed to measure the length of time it took for hot water to reach the test fixture. This test began after the piping was stabilized to the incoming water temperature.

Plumbing System Pressure and Flow Test Results

For all pressure and flow tests, the farthest shower Test Fixture (TF) was operated in the shower "full-on" mode. The flow pressure and flow rates for each of the hot- and cold-water supplies to the TF were recorded. During the operation of the TF, other simultaneous flows were added as described in **Table 8.2**. For this, the TF flow and pressure data were recorded as well as the total hot- and cold-water supply to the other fixtures and the pressure at the base of the riser.

Table 8.2 Pressure and Flow Test Regime

Test No.	Fixtures Operated	Nomenclature
1	Test Fixture (TF)	TF
2	TF and Lavatory	TF+Lav
3	TF and Water Closet	TF+WC
4	TF and Kitchen Faucet (mid-position)	TF+Kit
5	TF and 2nd Shower (full-on)	TF+Sh2
6	No. 5 and Kitchen	TF+Sh2+Kit
7	No. 6 and Lavatory	TF+Sh2+Kit+Lav
8	No. 7 and Water Closet	TF+Sh2+Kit+Lav+WC

Flow and pressure measurements were recorded for each of the tests and are recorded in **Table 8.3**. Each system was tested at three different static pressures measured at the base of the riser: 40, 60, and 80 psi. **Table 8.3** shows the results of the TF flowing with no simultaneous fixtures operating.

Table 8.3 TF Flow and Pressure Data for Each System

System Type, Distance to TF, Riser Pressure	Riser Pressure psi	TF Hot Valve Flow GPM	TF Hot Valve Pressure psi	TF Cold Valve Flow GPM	TF Cold Valve Pressure psi
T&B, 100', 40 psi	40.0	1.7	31.6	0.2	35.1
Zoned, 100', 40 psi	40.0	1.7	31.6	0.2	35.0
Parallel, 100', 40 psi	40.0	1.7	29.3	0.2	35.0
T&B, 100', 60 psi	60.0	2.2	50.0	0.3	55.2
Zoned, 100', 60 psi	60.0	2.2	49.7	0.3	54.9
Parallel, 100', 60 psi	60.0	2.1	46.4	0.3	54.8
T&B, 100', 80 psi	80.0	2.6	68.7	0.3	75.1
Zoned, 100', 80 psi	80.0	2.6	68.7	0.3	75.1
Parallel, 100', 80 psi	80.0	2.5	63.6	0.3	75.0
T&B, 60', 40 psi	40.0	1.8	32.0	0.2	35.1
Zoned, 60', 40 psi	40.0	1.8	32.1	0.2	35.0
Parallel, 60', 40 psi	40.0	1.7	30.8	0.2	35.0
T&B, 60', 60 psi	60.0	2.2	50.8	0.3	54.9
Zoned, 60', 60 psi	60.0	2.2	50.6	0.3	55.0
Parallel, 60', 60 psi	60.0	2.2	48.8	0.3	54.9
T&B, 60', 80 psi	80.0	2.6	69.9	0.3	75.2
Zoned, 60', 80 psi	80.0	2.6	70.2	0.3	75.1
Parallel, 60', 80 psi	80.0	2.5	66.9	0.3	75.1

Note 1: **T&B** = Trunk and Branch;
Note 2: Systems installed at either 100' or 60' to TF
Note 3: Nominal Pressures of 40, 60, and 80 psi are static pressures

The performance data for each of the three plumbing layouts shows very similar performance for both the 100-foot distance and the 60-foot distance to the Test Fixture. At 100 feet from the source, the TF flow rate on the hot side of the valve was the primary flow and was 1.5 GPM (US gallons per minute) at a low pressure of 40 psi (static). The flow rate at the valve increased to 2.4 GPM for the 60-foot distance with a riser pressure of 80 psi (static).

Once the baseline flow performance was verified for the TF, additional tests were performed adding simultaneous flows in conjunction with the TF flowing. The performance measure of the system capability to supply the farthest fixture is the flow and pressure data at the TF. **Table 8.4** shows the performance data for the 100-foot tests with a source pressure of 40 psi.

Table 8.4 Simultaneous Flow Performance Data – 100′ Maximum Length, 40 psi Source Pressure

Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	GPM	GPM	GPM	psi	GPM	psi	GPM	psi
Trunk and Branch 100′ 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.2
TF	2.1	0.5	1.6	40.0	1.7	31.6	0.2	35.1
TF+Lav	3.5	1.6	1.9	40.0	1.7	31.2	0.2	34.2
TF+WC	5.5	3.9	1.6	40.0	1.7	31.9	0.2	29.5
TF+Kit	3.5	1.3	2.2	40.0	1.7	31.3	0.2	35.0
TF+Sh2	4.2	1.3	2.9	40.0	1.7	30.6	0.2	34.9
TF+Sh2+Kit	5.6	2.2	3.4	40.0	1.7	30.3	0.2	34.7
TF+Sh2+Kit+Lav	7.0	3.5	3.5	40.0	1.7	30.1	0.2	33.4
TF+Sh2+Kit+Lav+WC	10.2	5.9	4.3	40.0	1.7	28.6	0.2	29.3
Zone 100′ 40 psi Static	0.0	0.0	0.0	40.0	0.0	33.9	0.0	35.2
TF	2.1	0.4	1.7	40.0	1.7	31.6	0.2	35.0
TF+Lav	3.5	1.4	2.1	40.0	1.7	31.1	0.2	34.6
TF+WC	5.5	3.9	1.6	40.0	1.8	32.0	0.2	31.8
TF+Kit	3.5	1.3	2.2	40.0	1.7	31.3	0.2	34.9
TF+Sh2	4.2	1.5	2.7	40.0	1.7	30.6	0.2	34.9
TF+Sh2+Kit	5.6	2.4	3.2	40.0	1.7	30.5	0.2	34.7
TF+Sh2+Kit+Lav	7.0	3.6	3.4	40.0	1.7	30.0	0.2	34.0
TF+Sh2+Kit+Lav+WC	10.2	6.2	4.0	40.0	1.7	29.8	0.2	30.8
Parallel 100′ 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.2
TF	2.1	0.4	1.7	40.0	1.7	29.3	0.2	35.0
TF+Lav	3.5	1.2	2.3	40.0	1.7	29.2	0.2	35.0
TF+WC	5.5	3.7	1.8	40.0	1.7	29.4	0.2	35.0
TF+Kit	3.5	1.2	2.3	40.0	1.7	29.0	0.2	35.0
TF+Sh2	4.2	1.5	2.8	40.0	1.7	28.6	0.2	35.0
TF+Sh2+Kit	5.6	2.3	3.3	40.0	1.7	28.6	0.2	34.9
TF+Sh2+Kit+Lav	7.0	3.3	3.7	40.0	1.7	28.4	0.2	34.8
TF+Sh2+Kit+Lav+WC	10.2	6.3	3.9	40.0	1.7	28.7	0.2	34.6

TF = Test Shower Fixture, 15′ elevation; **Lav** = Lavatory, both valves open, 15′ elevation; **WC** = Water Closet, tank type, 15′ elevation; **Kit** = Kitchen, mid-position, 4′ elevation; **Sh2** = 2nd Shower, full open valve, 6′ elevation

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

Table 8.5 Simultaneous Flow Performance Data – 60′ Maximum Length, 40 psi Source Pressure

Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower) Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	GPM	GPM	GPM	psi	GPM	psi	GPM	psi
Trunk and Branch 60′ 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.1	0.0	35.2
TF	2.1	0.4	1.7	40.0	1.8	32.0	0.2	35.1
TF+Lav	3.5	1.4	2.1	40.0	1.7	31.6	0.2	34.5
TF+WC	5.5	3.9	1.7	40.0	1.8	32.1	0.2	31.2
TF+Kit	3.5	1.3	2.2	40.0	1.7	31.7	0.2	35.0
TF+Sh2	4.2	1.4	2.8	40.0	1.7	30.9	0.2	34.9
TF+Sh2+Kit	5.6	2.2	3.4	40.0	1.7	30.5	0.2	34.7
TF+Sh2+Kit+Lav	7.0	2.9	3.5	40.0	1.7	30.4	0.2	33.7
TF+Sh2+Kit+Lav+WC	10.2	6.0	4.2	40.0	1.7	29.2	0.2	30.0
Zone 60′ 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.2
TF	2.1	0.3	1.7	40.0	1.8	32.1	0.2	35.0
TF+Lav	3.5	1.3	2.2	40.0	1.7	31.7	0.2	34.8
TF+WC	5.5	3.9	1.6	40.0	1.8	32.3	0.2	33.1
TF+Kit	3.5	1.1	2.4	40.0	1.7	31.7	0.2	35.0
TF+Sh2	4.2	1.4	2.8	40.0	1.7	31.1	0.2	34.9
TF+Sh2+Kit	5.6	2.3	3.3	40.0	1.7	30.7	0.2	34.8
TF+Sh2+Kit+Lav	7.0	3.4	3.6	40.0	1.7	30.4	0.2	34.3
TF+Sh2+Kit+Lav+WC	10.2	6.2	4.0	40.0	1.7	30.4	0.2	32.0
Parallel 60′ 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.1
TF	2.1	0.4	1.7	40.0	1.7	30.8	0.2	35.0
TF+Lav	3.5	1.2	2.3	40.0	1.7	30.7	0.2	34.9
TF+WC	5.5	3.9	1.6	40.0	1.7	31.6	0.2	34.8
TF+Kit	3.5	1.4	2.2	40.0	1.7	30.6	0.2	34.9
TF+Sh2	4.2	1.4	2.8	40.0	1.7	30.2	0.2	34.9
TF+Sh2+Kit	5.6	2.3	3.3	40.0	1.7	30.0	0.2	34.8
TF+Sh2+Kit+Lav	7.0	3.3	3.7	40.0	1.7	29.8	0.2	34.8
TF+Sh2+Kit+Lav+WC	10.2	6.5	3.7	40.0	1.7	30.3	0.2	34.5

TF = Test Shower Fixture, 15′ elevation; **Lav** = Lavatory, both valves open, 15′ elevation;
WC = Water Closet, tank type, 15′ elevation; **Kit** = Kitchen, mid-position, 4′ elevation;
Sh2 = 2nd Shower, full open valve, 6′ elevation

The system performance with simultaneous flows was very similar to the previous 100- foot test but with slightly lower pressure drops. A static pressure of 40 psi is considered to be a minimum supply pressure. A summary of the results for the simultaneous flow system performance at 60 and 80 psi source static pressure is shown in **Appendix A**.

Comparing the flow pressure and flow rate is a good way to determine the performance of a plumbing system. The limitation is that the pressure at the base of the riser is dependent on the size of the service line, meter, and water utility supply pressure. In order to describe and compare the performance of each type of system, the pressure drop from the base of the riser to the farthest outlet (including elevation losses) can be evaluated.

Figures 8.4 and **8.5** show the comparison of pressure drop based on various outlets in the system flowing with the resultant pressure drop at the farthest fixture. Both figures indicate that the parallel system, while having a higher pressure drop to the TF, has a more consistent pressure drop during simultaneous flow. The other systems, based on the trunk line feeding branch lines, continued to show increasing pressure drop as more fixtures were added to the system. In fact, when the full set of fixtures was operating simultaneously, the trunk and branch system pressure drop exceeded that of the parallel and the zone configurations. (The zone system is highly dependent on the system design, i.e., the location of the manifolds and the number of fixtures connected to the manifold).

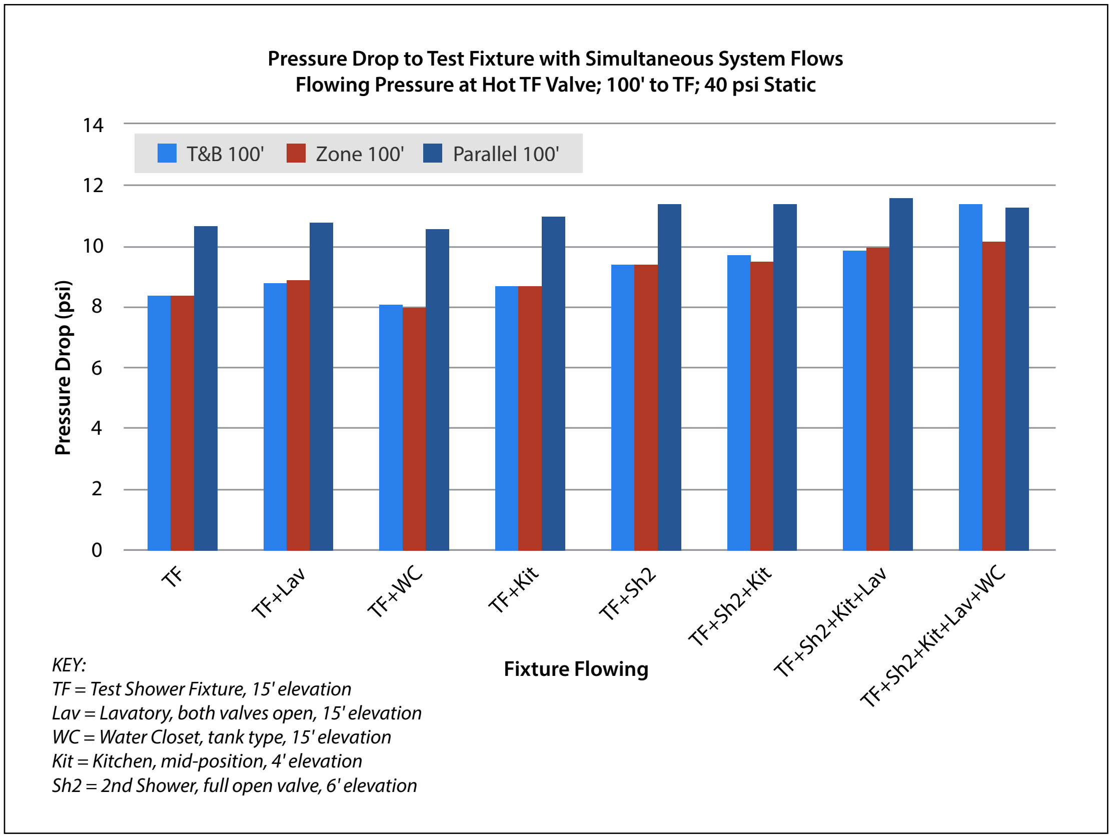


Figure 8.4 Pressure Drop Comparison, 100 ft. Distance to TF

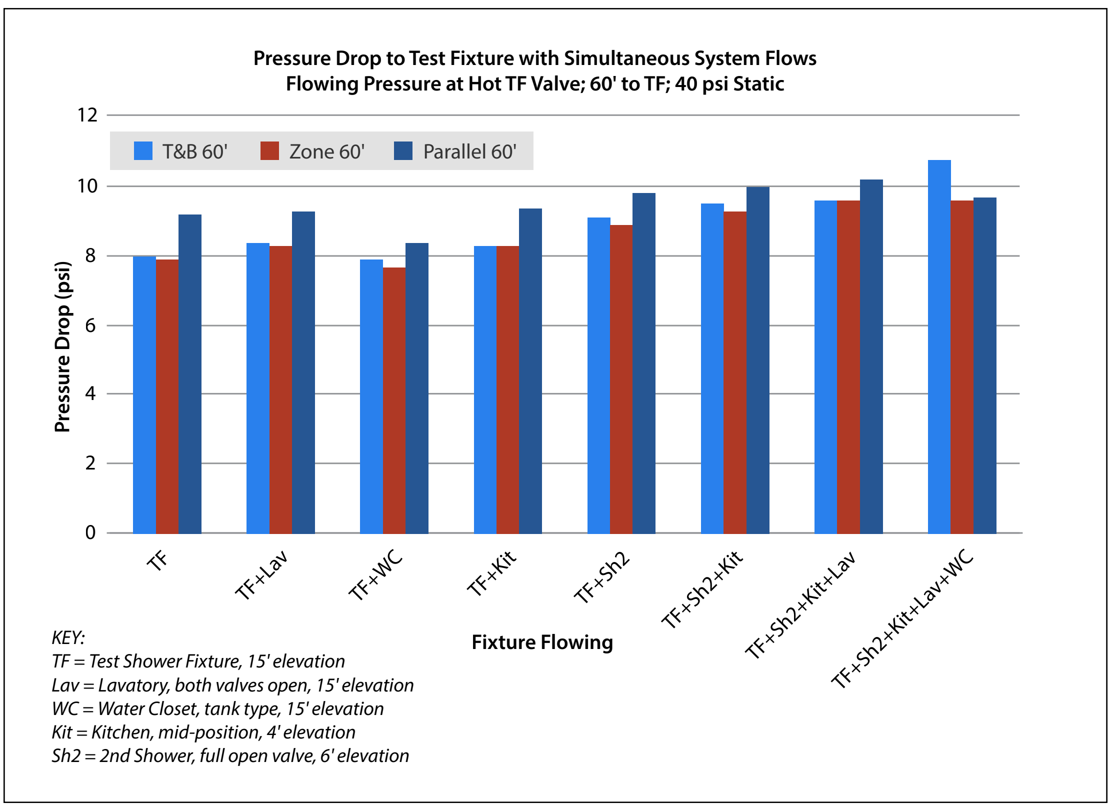


Figure 8.5 Pressure Drop Comparison, 60 ft. Distance to TF

Wait Time for Hot Water

A significant benefit of PEX piping systems is the opportunity to reduce water and energy waste by reducing the amount of time to deliver hot water from the water heater to the outlets.

Though hard to definitively quantify, there are indications that hundreds of gallons of water per year are wasted while waiting for hot water to reach outlet.

Tests were also performed on each of the three PEX system designs to compare the time it takes for hot water to be delivered to the test fixture (TF). **Figure 8.6** shows the results of delivering hot water to the shower fixture after the pipes were flushed with cold (city) water. The results were normalized to keep the flow rates and temperature from the hot water tank constant for all systems.

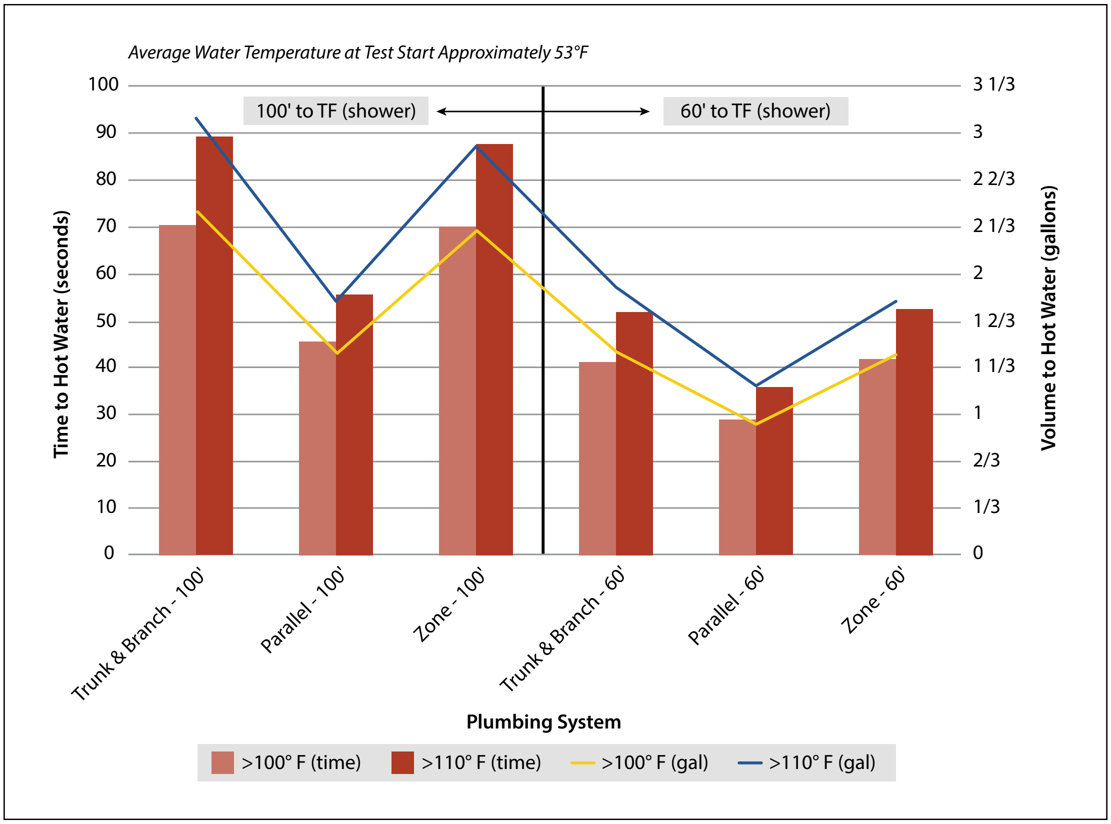


Figure 8.6 Comparison of Hot Water Delivery Time

Water and time savings of between 30% and 40% were identified based on this analysis of the parallel system over either the trunk and branch or zone system designs.

Test Summary

A summary of the performance characteristics of each system is shown in **Table 8.6**. The data indicates:

- Trunk and branch systems and zoned systems will supply a single fixture at a higher residual pressure than parallel systems, which utilize a dedicated supply line of smaller tubing
- Parallel (i.e., home-run) systems will supply more stable pressure to each fixture when operating simultaneous fixtures
- Parallel systems will deliver hot water to outlets quicker due to the smaller tubing
- Trunk and branch systems and zoned systems will deliver hot water quicker during sequential flows, because the trunk line is already charged with hot water when the second fixture is opened
- All three system designs will supply sufficient flow and pressure to fixtures even when the base riser (i.e., source) pressure is just 40 psi and the length to the farthest outlet is 100 feet

Table 8.6 Performance Summary, 100′ Maximum Distance

System	Test Fixture Only		Test Fixture With Simultaneous		Test Fixture Only	
	Flow Rate Hot GPM	Pressure Hot psi	Flow Rate Hot GPM	Pressure Hot psi	Time to > 100°F Hot Water sec	Time to > 110°F Hot Water sec
40 psi Static Pressure						
T&B - 100′	1.7	31.6	1.7	28.6		
Zone - 100′	1.7	31.6	1.7	29.8		
Parallel - 100′	1.7	29.3	1.7	28.7		
60 psi Static Pressure					**from 53°F**	
T&B - 100′	2.2	50.0	2.1	44.4	71.9	90.9
Zone - 100′	2.2	49.7	2.1	46.3	71.6	89.3
Parallel - 100′	2.1	46.4	2.1	45.6	46.3	56.8
80 psi Static Pressure						
T&B - 100′	2.6	68.7	2.4	61.6		
Zone - 100′	2.6	68.7	2.5	63.0		
Parallel - 100′	2.6	63.6	2.4	62.0		

Installation of PEX Plumbing Systems

9

Limitations on Use and Applications of Crosslinked Polyethylene (PEX)

This chapter begins with a list of DOs and DO NOTs and then provides many important installation details for various types of PEX plumbing systems.

- DO store fittings in protective packaging so that they do not get nicked, dented, or otherwise damaged during transportation and storage.
- DO store fittings in containers that are free of oil, grease, lubricants, solder flux, or other chemicals and away from corrosive atmospheres (e.g., ammonia). Refer to **PPI TR-19 *Chemical Resistance of Plastic Piping Materials*** for chemical compatibility of pipe and fitting materials.
- DO NOT use PEX systems in applications outside of the manufacturer's recommended installation practices (e.g., beyond approved temperature or pressure ratings).
- DO NOT use tubing with gouges, cuts, cracks, abrasions, evidence of chemical attack, or other defects, or tubing that has been crushed or kinked. See manufacturer's instructions for dealing with damaged tubing before or during installation.
- DO NOT store or use PEX tubing or fittings where it will be exposed to direct or reflected sunlight.
- DO NOT allow PEX tubing or plastic fittings to come in contact with the construction materials listed below (this list is not all-inclusive):
  - Pipe thread sealing compounds (e.g., "pipe dope")
  - Solder Flux
  - Open flame
  - Fire wall penetration sealing compounds. *Exception: water soluble, gypsum-based caulking or other sealants approved by the PEX tube manufacturer. Consult PEX manufacturer for an approved list.*
  - Petroleum-based materials or sealants such as kerosene, benzene, gasoline, ABS/PVC/CPVC primer and solvent cements, fuel oils, cutting oils, asphaltic paint, and asphaltic road materials, acetone, toluene, and/or xylene or any other solvents. Consult your tubing manufacturer if you have questions about these or any other materials not listed.

- DO NOT install PEX tubing in heavily contaminated soil or other heavily contaminated environments.
- DO NOT use PEX systems in swimming pool, spa or hot tub piping systems unless approved by the system manufacturer.

PEX Tubing Installation Practices

Preparation

Review all limitations and guidance provided by local codes and regulations, as well as by the PEX system manufacturer (i.e., tubing, fittings, valves, fasteners, tools), prior to beginning installation.

Storage & Handling

PEX tubing is typically supplied in continuous coils of 100 ft, 300 ft, 500 ft or more. Coils are easy to transport and handle, and reduce the number of couplings used during installation, reducing installation time and potentially, the pressure drop through fittings. PEX tubing may also be supplied in straight lengths (a.k.a. "sticks") of 10 ft or 20 ft length which some installers prefer to avoid having to straighten the tubing.

Straight lengths may be more difficult to transport and store and may require additional fittings (e.g., couplings) due to their shorter lengths. **Using coils maximizes the benefits and flexibility of using PEX**.

Like most plastics, the long-term performance of PEX will be affected by ultraviolet (UV) radiation from sunlight. Although most PEX tubing has good UV resistance (see **Chapter 3 *Material Properties***), PEX tubing should not be stored outdoors where it is exposed to the sun, or interior locations (i.e., indoors) directly exposed to sunlight (see **Figure 9.1**).

PEX tubing should not be installed outdoors, unless buried in earth or properly protected from UV exposure, either direct or indirect. Indirect (diffused) and reflected sunlight also emit UV energy.

If PEX will be exposed to sunlight continuously after installation, such as in an unfinished basement, installers should cover the pipe with a UV-blocking sleeve or pipe insulation that is approved by the PEX manufacturer.

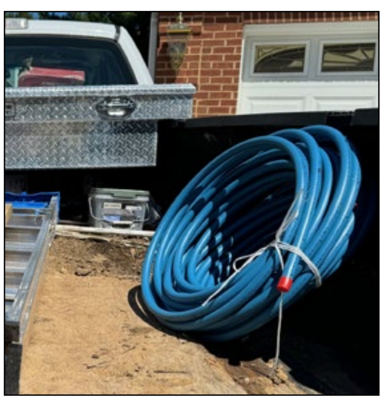


Figure 9.1 PEX Tubing Stored Outdoors

Figure 9.2 Sharp Objects Can Damage PEX

Figure 9.3 Objects that Can Damage PEX

Each PEX tubing manufacturer publishes the maximum recommended UV exposure time limit based on the UV resistance as determined in accordance with ASTM Test Method F2657 and the requirements published in ASTM F876. Central Arizona is used as the basis of the exposure time limits, as it represents the worst-case known North American location for UV energy.

PEX tubing and fittings shall be stored in a way to protect them from mechanical damage (cuts, puncture, nicks, dents, etc.; see **Figure 9.2**). PEX should be stored in original packaging or similar protection for cleanliness. Inspect all tubing and fittings before installation and do not use components that are damaged or suspected of damage or that have been exposed to excessive sunlight.

When transporting or installing, do not drag PEX tubing over rough terrain, rocks, sharp masonry or metals or any surface that can cut, puncture, or damage the tubing wall (see **Figure 9.3**).

Do not crush or kink the tubing during handling or installation.

Bending & Flexibility

Crosslinked polyethylene remains a flexible material even at temperatures well below freezing. In fact, PEX tubing remains flexible and can still be bent at temperatures as low as -40°F (-40°C).

The flexibility and low stiffness of PEX allows it to be bent gently around obstructions and installed as one continuous run without fittings, if desired. Slight changes in direction are made easily by cold-bending the tubing by hand; snap-on bend supports can hold the tubing in 90-degree sweeps in place of elbow fittings (see **Figure 9.4**).

Minimizing joints and connections can result in quicker installations, less potential for leaks at fittings, and less resistance by reducing pressure drop through fittings. Bend supports should be used to facilitate rigid bends and to alleviate stress on PEX joints when bends are needed in close proximity to such joints.

The free (unsupported) bending radius for PEX tubing, measured at the mid-point of the bend, shall be not less (i.e., no tighter than) than six times the actual outside diameter of the tubing, unless otherwise specified by the PEX manufacturer (see **Figure 9.5**).

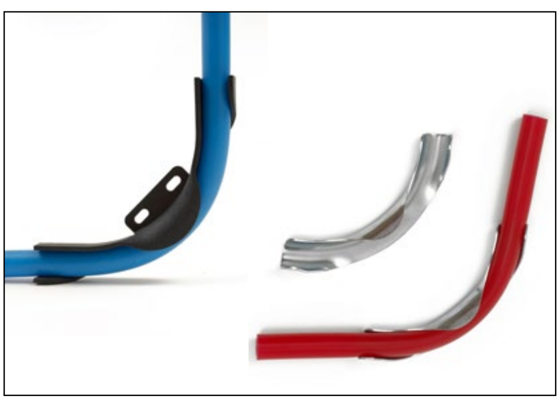


Figure 9.4 Plastic and Metal PEX Bend Supports

Figure 9.5 Tubing at its Minimum Bend Radius

Refer to **Table 9.1** for a list of bend radii based on tubing diameter and allowed minimum bend radius.

Note: For certain types of PEX tubing in coils, when bending the tubing **against** the coil direction, the minimum bending radius is three times the "6 times Bend Radius" given in **Table 9.1** (e.g., 1/2 tubing = 3.8 x 3 = 11.4 inches).

Despite this excellent flexibility, elbows may still be necessary in certain confined spaces (see **Figure 9.6**).

Table 9.1 Minimum Bend Radii of PEX Tubing

Nominal Tubing Size	Tubing OD (Actual) in.	6 times Bend Radius in.
3/8	0.500	3.0
1/2	0.625	3.8
3/4	0.875	5.3
1	1.125	6.8
1 1/4	1.375	8.3
1 1/2	1.625	9.8
2	2.125	12.8
2 1/2	2.625	15.8
3	3.125	18.8
4	4.125	24.8

Figure 9.6 Elbow Fittings in a Confined Joist Cavity

Fasteners & Supports

Horizontal runs of PEX tubing in nominal diameters up to 1 should be supported at intervals not to exceed 32 inches (80 cm) or as per local code. For most wood-frame construction, the joists can serve as the supports (see **Figure 9.7**).

For nominal diameters 1 1/4 and larger, horizontal PEX should be supported at intervals not to exceed 48 inches (120 cm) or as per local code.

Vertical tubing shall be supported each story height and at midstory, with a maximum of 60 inches (150 cm) between supports, or per local code.

Pipe support channel, typically manufactured of galvanized steel in a round or u-shape and supplied in lengths slightly less than 10 ft or 20 ft, can be used to support PEX tubing in between fittings to reduce hanger spacing and to hold the tubing straight, without drooping (see **Figure 9.8**). Be sure to use a pipe support channel that is approved by the tubing manufacturer (see **Figures 9.9** and **9.10**).

PEX tubing installed horizontally in a pipe support channel can use the following hanger spacing:

- Nominal 3/4 PEX and smaller – 6 ft (183 cm)
- Nominal 1 PEX – 8 ft (244 cm)
- Nominal PEX 1 1/4 and larger – 10 ft (305 cm)

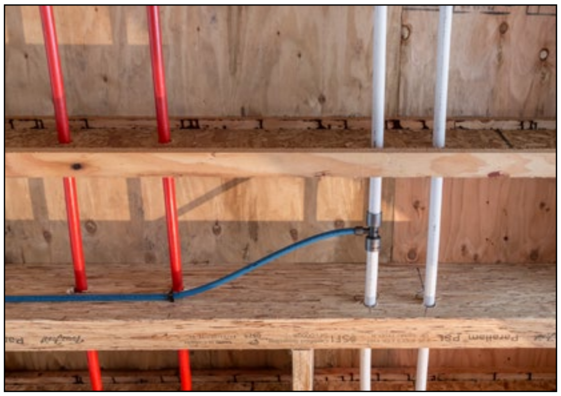


Figure 9.7 Wood Joists Serving as Horizontal Supports for PEX Tubing

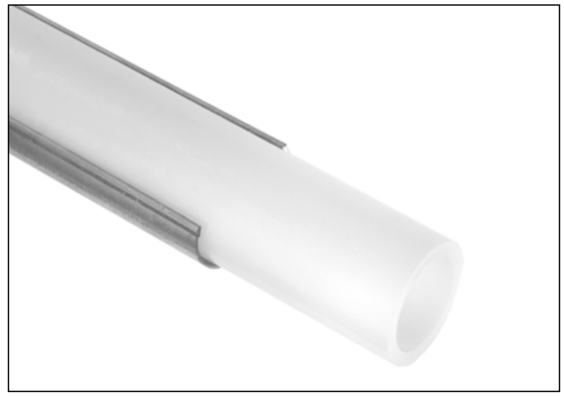
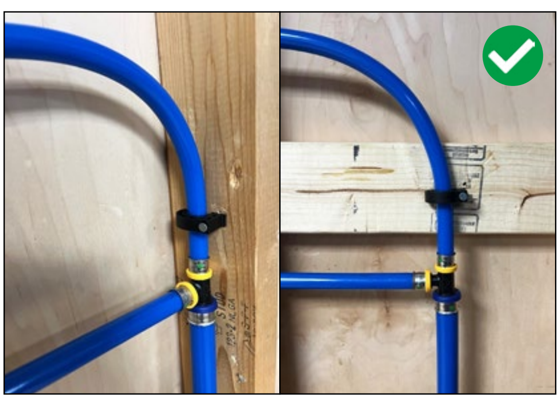


Figure 9.8 Pipe Support Channel

Figure 9.9 Pipe Support Channel

Figure 9.10 Pipe Support Channel

Tubing and fittings shall be installed without placing stress on joints or connections. Stress on connections may occur when tubing is not properly fastened at changes of direction and has the potential to cause leaks at fittings. See **Figures 9.11** and **9.12** for both recommended and incorrect fastening locations, respectively.



Figures 9.11a & 9.11b RECOMMENDED Fastening Locations to Minimize Stress on Joints

Figures 9.12a & 9.12b INCORRECT Fastening Locations that will Cause Excessive Stress on Joints at Fittings

Table 9.2 Recommended Minimum Hole Diameters for PEX tubing

Nominal Tubing Size	Minimum Hole Diameter
3/8	0.750 in. (3/4 in.) / 19 mm
1/2	0.875 in. (7/8 in.) / 22 mm
3/4	1.125 in. (1 1/8 in.) / 29 mm
1	1.375 in. (1 3/8 in.) / 35 mm
1 1/4	1.625 in. (1 5/8 in.) / 41 mm
1 1/2	1.875 in. (1 7/8 in.) / 48 mm
2	2.375 in. (2 3/8 in.) / 60 mm
2 1/2	2.875 in. (2 7/8 in.) / 73 mm
3	3.375 in. (3 3/8 in.) / 86 mm
4	4.375 in. (4 3/8 in.) / 111 mm
6	6.375 in. (6 3/8 in.) / 162 mm

Figure 9.13 PEX tubing Installed in Wood Studs

Protection

When passing through wood studs, joists, and beams, drill the hole a minimum of 1/4 inch (6 mm) larger than the outside diameter of the tubing (not the nominal diameter) to allow for slight movement (see **Table 9.2**). Tubing supports are not needed in wood (see **Figure 9.13**).

When passing through studs, joists, and beams of metal, concrete or masonry, use approved plastic pipe isolators, brackets, or hangers to prevent scratching of the tubing as it moves against sharp surfaces (see **Figure 9.14**).

Tubing supports should allow free tubing movement to accommodate thermal expansion and contraction (see **Figure 9.15a**). Do not use supports that pinch or cut the tubing (see **Figure 9.15b**).

Inspect all supports prior to installation to ensure that sharp edges do not exist that can damage the tubing.

Protect tubing from nail or screw damage where appropriate through the use of nailing plates/stud guards (see **Figure 9.16**) per local codes and manufacturer's guidelines.

Figure 9.14 Plastic Pipe Isolators, Brackets, and Hangers

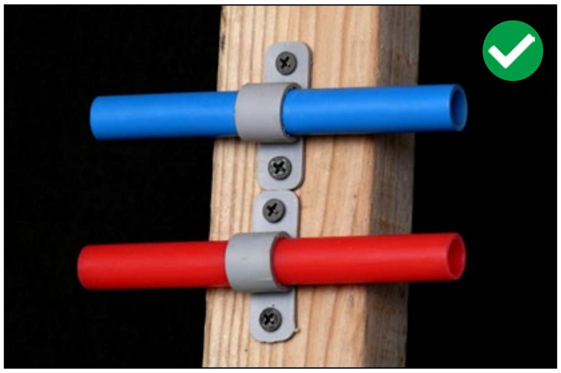


Figure 9.15a Tubing Supports that Allow Free Tubing Movement

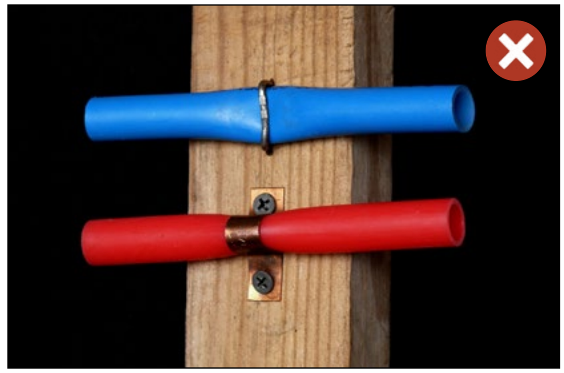


Figure 9.15b Tubing Supports that Do Not Allow Free Tubing Movement

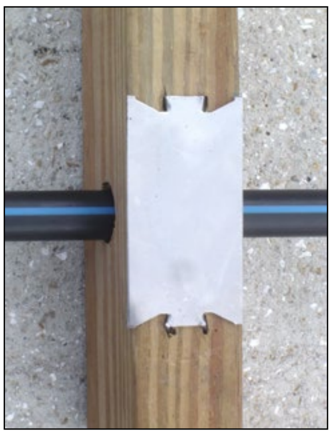


Figure 9.16 Nailing Plate Installed on Wood Stud to Protect PEX Tubing

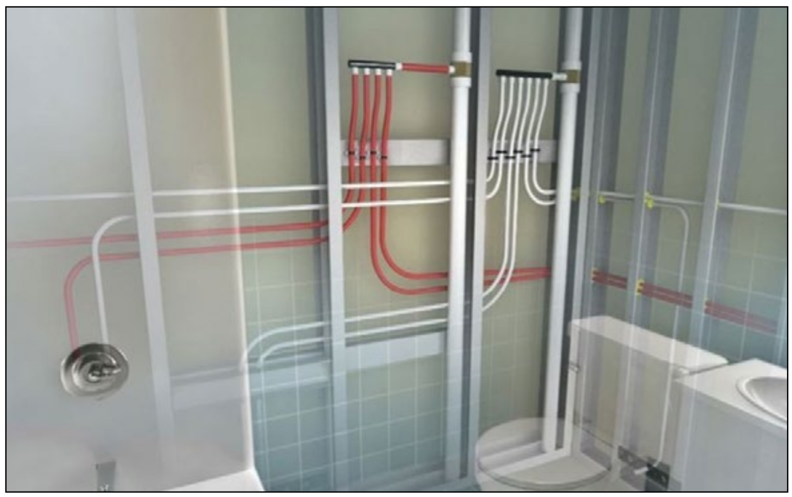


Figure 9.17 Properly Installed PEX Plumbing System within a Bathroom

Summary

A correctly installed PEX plumbing system is protected from damage, takes advantage of the material flexibility to avoid unnecessary use of fittings, is restricted from movement to prevent noise, and delivers long-term reliability (see **Figure 9.17**).

Protection from Artificial Lighting

Artificial light is primarily used for illumination of indoor living and work areas. Apart from visible light, many forms of artificial light also produce some ultraviolet (UV) light in their spectra. PEX tubing may be adversely affected by UV emissions from artificial light sources over decades of operation, and while different artificial light sources emit different levels of UV radiation, UV must be considered where PEX tubing is installed near all artificial light sources.

While it is difficult to address all types of artificial light and all installations from the perspective of possible impacts of artificial light on PEX, fluorescent lights, either tubular versions or single-envelope compact fluorescent lights (CFLs) are of most concern in residential and commercial applications as these lights have the highest component of UV emissions. Other types of lights, such as incandescent or LED lights, are of less concern.

UV irradiance and its harmful effects diminish with distance, so setback distance is a critical consideration. **PPI TN-72 *Potential Effects of Artificial Lighting on Crosslinked Polyethylene (PEX) Pipe and Tubing and Recommended Installation Practices*** explains that minimum setback distances of 36 inches (91 cm) for residential and light commercial applications (see **Figure 9.18**) and 30 feet (9.1 m) for industrial/ manufacturing, warehousing, and large commercial applications (see **Figure 9.19**) are considered reasonable for all types of artificial light sources.

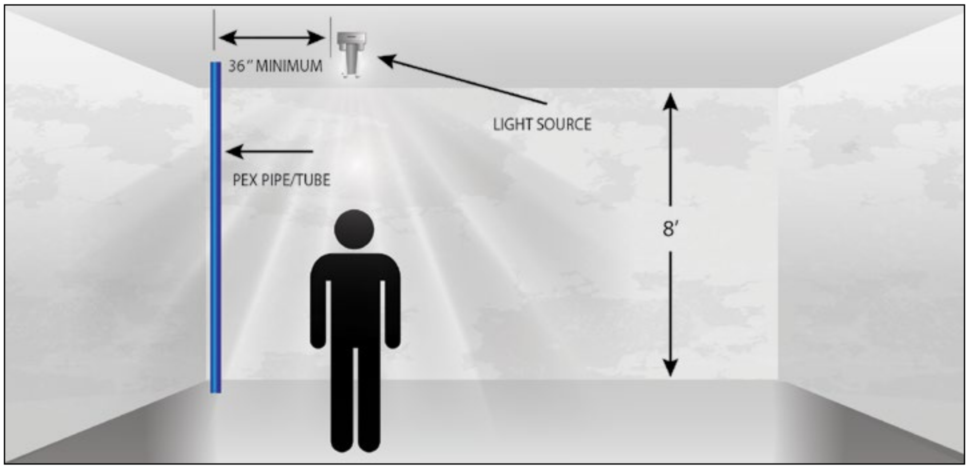


Figure 9.18 Recommended Setback Distance between Artificial Light Source (non-LED) in a Typical Residential Or Light Commercial Setting

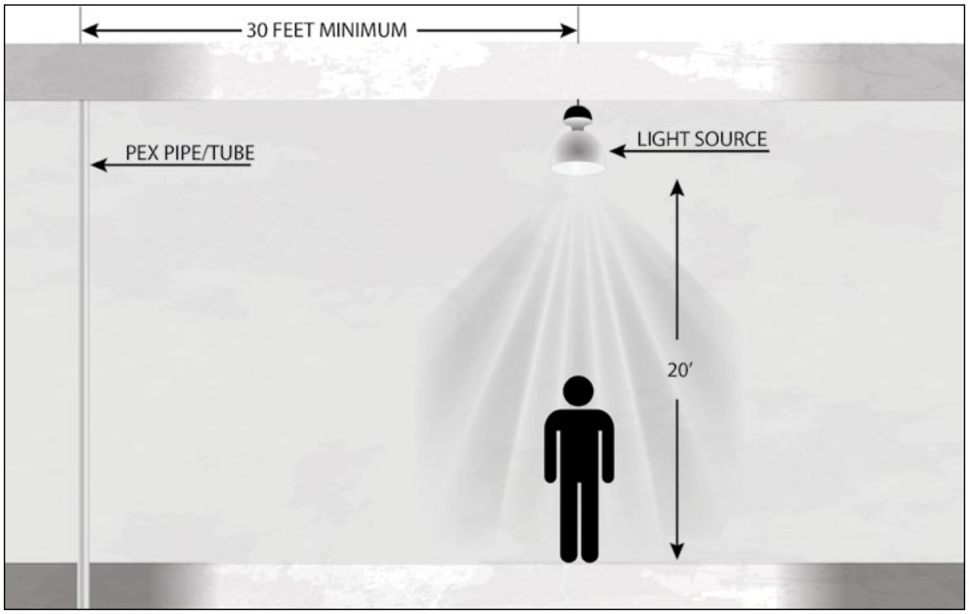


Figure 9.19 Recommended Setback Distance between Artificial Light Source (non-LED) in a Typical Industrial Setting

Recessed Lighting

Recessed lighting fixtures are typically classed as insulation contact (IC-rated) or no insulation contact (non-IC-rated). Light fixtures that are evaluated to the UL 1598 standard for an IC-rating may have exterior temperatures as high as 194°F (90°C) and recessed light fixtures that are not IC-rated may have surface temperatures as high as 300°F (150°C). It is imperative that plastic pipes be protected from exposure to these temperatures.

PEX tubing will not melt at 194°F. However, frequently repeated or long-term exposure to air or surface temperatures above 180°F (82°C) may have negative effects, potentially leading to premature tubing failure. It is recommended that, even with IC-rated recessed light fixtures, the tubing installer should ensure that adequate spacing exists so that the surface temperature of the PEX is kept to 180°F or less when lights are in operation and the environment surrounding the pipes represents a typical situation of the building when occupied (e.g., after construction is complete and the space is heated) (see **Figure 9.20**).

If the available air space is not sufficient to ensure that the surface temperature of the tubing is 180°F or less, then the PEX installer should protect the pipe with adequate thickness of insulation of a type that is approved by the tubing manufacturer and recommended by the insulation manufacturer for that type of installation, to ensure that the surface temperature of the pipe is 180°F or less when lights are in operation and the environment surrounding the pipes represents a typical situation of the building when occupied (e.g., after construction is complete and the space is heated) (see **Figure 9.21**).

CAUTION: If any plumbing supply pipe is installed too closely to a hot light fixture, the ambient heat from the fixture may increase the temperature of the water within the pipe, potentially delivering a short burst of excessively hot water to a user of the plumbing system when a valve is opened, for example, and potentially scalding the user. This is a potentially dangerous situation, regardless of which type of plumbing pipe material (e.g., plastic, metal) is used.

See **PPI TN-56 *Installation of Plastic Pressure Piping Materials Near Insulation Contact-Rated and Non-IC-Rated Recessed Lighting Fixtures*** for more information.

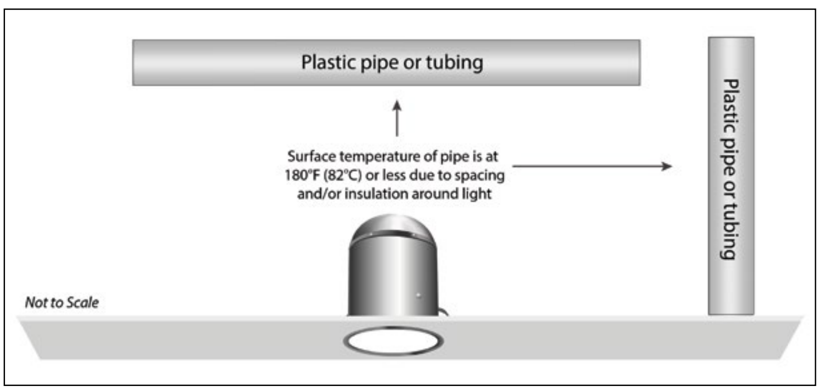


Figure 9.20 Protecting PEX Tubing against Excessive Air Temperature with Distance

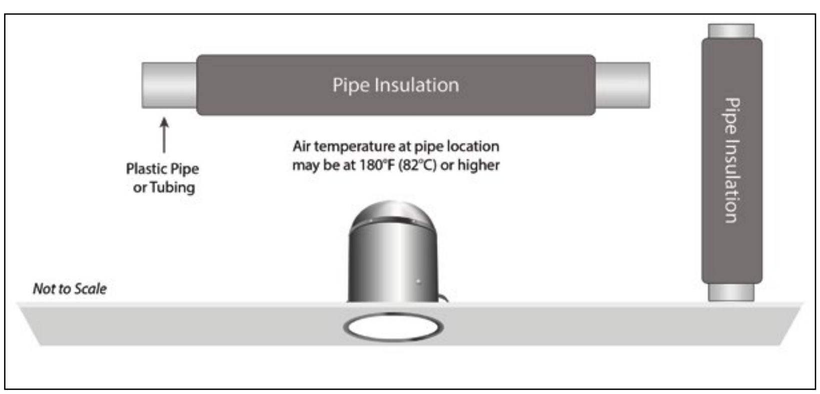


Figure 9.21 Protecting PEX Tubing against Excessive Air Temperature with Approved Insulation

Protection from Excessive Temperatures

If PEX tubing is installed too closely to an external source of heat (e.g., combustion water heater flue pipe), frequently repeated or long-term exposure to air or surface temperatures above 180°F (82°C) may have negative effects, potentially leading to premature tubing failure. It is recommended that the tubing installer should ensure that adequate spacing exists so that the surface temperature of the PEX tubing is kept to 180°F (82°C) or less when equipment is in operation and the environment surrounding the tubing represents a typical situation of the building when occupied (e.g. after construction is complete and the space is heated) (see **Figure 9.20**).

If the available air space is not sufficient to ensure that the surface temperature of the tubing is 180°F (82°C) or less, then the tubing installer should protect it with adequate thickness of insulation of a type that is approved by the tubing manufacturer for use with the specific type of PEX and recommended by the insulation manufacturer for that type of installation to ensure that the surface temperature of the PEX is 180°F or less when equipment is in operation and the environment surrounding the tubing represents a typical situation of the building when occupied (e.g. after construction is complete and the space is heated) (see **Figure 9.21**).

CAUTION: If any plumbing supply pipe is installed too close to a hot appliance, the ambient heat from the device may increase the temperature of the water within the pipe, potentially delivering a short burst of excessively hot water to a user of the plumbing system when a valve is opened, for example, and potentially scalding the user. This is a potentially dangerous situation, regardless of which type of plumbing pipe material (e.g., plastic, metal) is used.

Do not install PEX tubing where the pressure/temperature rating of the tubing could be exceeded.

Cutting PEX Tubing

For all types of PEX connections, it is important to have a clean, square cut at the end of the tubing without burrs or shavings to prevent the risk of leakage at fittings and connections (see **Figure 9.22**).

Use only a PEX tubing cutter that is intended for this purpose and approved by the tubing manufacturer (see **Figure 9.23**).

Figure 9.22 PEX Tubing with Clean Square Ends

Figure 9.23 Typical PEX Tubing Cutter

Linear (Longitudinal) Expansion & Contraction

The typical rate of linear or longitudinal expansion of PEX tubing is 1.1 inch per 10°F per 100 ft. length. For example, a 100 ft. long section of PEX tubing which undergoes a temperature increase from 70°F to 120°F (a 50°F temperature increase) will see linear expansion of 1.1 x 5 = 5.5 inches.

For nominal tubing size (NTS) of 1 and smaller, temperature changes in typical plumbing systems are usually accommodated by the tubing's flexibility and its ability to bend to accommodate expansion and contraction. During installation, do not pull tubing tightly, as this can cause excessive tensile force on fittings and connections when tubing cools and contracts due to a colder operating temperature.

It is recommended to allow 1/8 inch of slack per ft. of installed tubing (0.3 cm slack per 30 cm length) to allow for contraction when tubing cools (see **Figure 9.24**). When the tubing gets warmer, it will simply expand within the available space. PEX tubing should not be rigidly anchored to allow for free longitudinal movement of the tubing to accommodate thermal expansion.

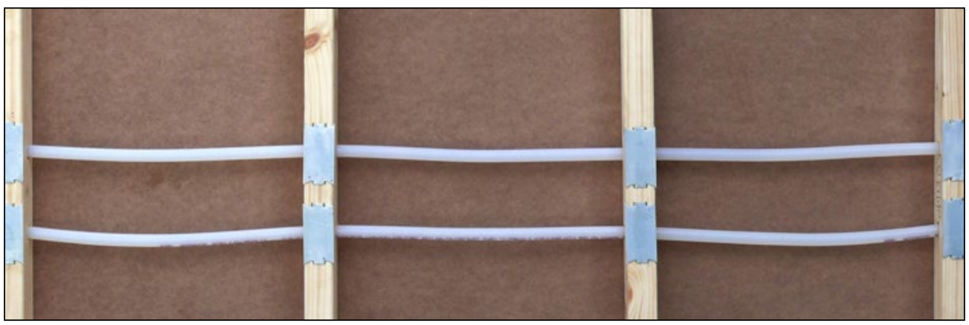


Figure 9.24 PEX Tubing Installed with 1/8 inch Slack Per Foot

Expansion loops and offsets (see **Figure 9.25**) can also be used to accommodate high rates of tubing expansion and contraction when needed. When creating expansion loops, be sure to follow minimum tubing bend radius, measured at the mid-point of the bend, per **Table 9.1**, and for both expansion loops and offsets, fasten tubing appropriately to prevent unwanted movement that could result in noise. Refer to the PEX tubing manufacturer's installation instructions for more detailed information on thermal expansion and contraction compensation techniques.

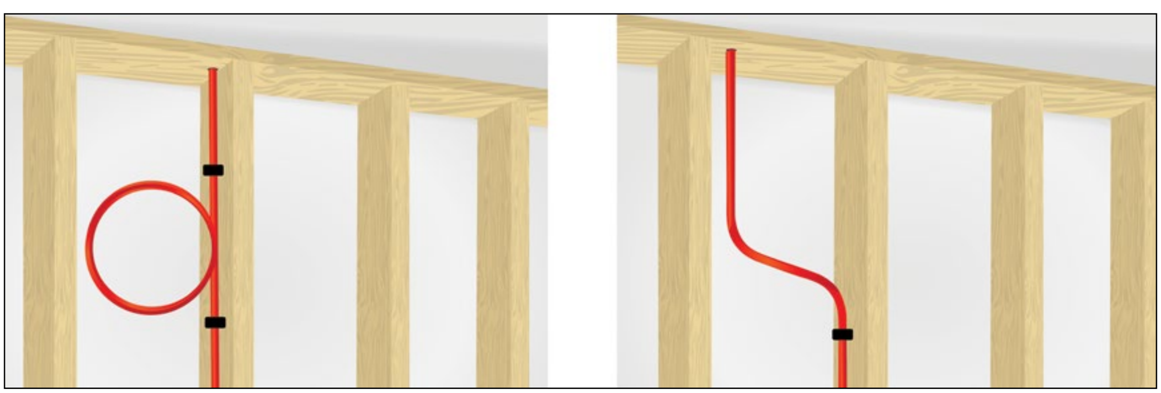


Figure 9.25 PEX Illustration of Thermal Expansion Loop (left) and Offset (right)

Larger PEX diameters (e.g., nominal tubing size 1 or larger) are not as flexible, so when installed as hot-water lines, expansion loops, arms, or legs may be needed to accommodate longitudinal thermal expansion, depending on the installation type and the expected temperature changes (see **Figure 9.26** and **Figure 9.27** for illustrations of an expansion arm and loop, respectively).

The **ASHRAE Handbook – Fundamentals** Ch. 22 *Pipe Design*, the **PPI Plastic Pipe Design Calculator**, and PEX tubing manufacturers' instructions can assist with calculations for thermal expansion and contraction and design of expansion arms and loops. www.plasticpipecalculator.com.

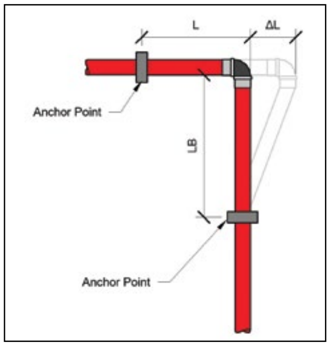


Figure 9.26 Expansion Arm Using One Elbow and Two Anchors

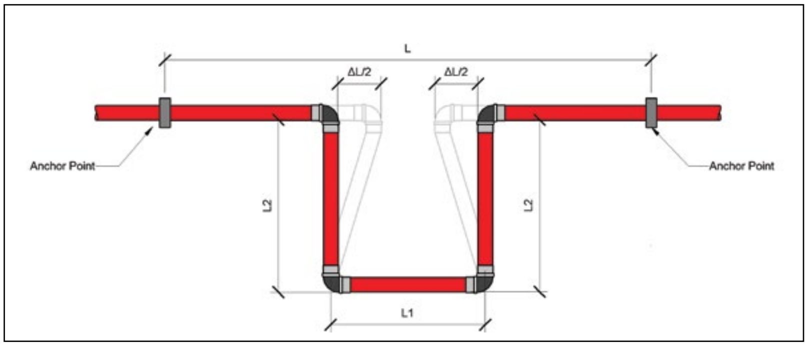


Figure 9.27 PEX Expansion Loop Using Four Elbows and Two Anchors

Installation Under Slabs

PEX tubing is recommended for hot- and cold-water distribution piping under slabs in most applications.

Laying and Supporting Tubing under Slab

For slab-on-grade installations, PEX tubing shall be completely buried by a suitable, easily compacted, backfill material such as sand or pea gravel, such that the tubing cannot come in contact with rebar, reinforcing wire mesh, or tensioning cables in the slab, or the slab itself (see **Figure 9.28**). Other soil materials without rocks or sharp edges may also be allowed, based on local building practices.

Figure 9.28 PEX Installed in Ground Below a Future Slab

Unless required by local code, it is not required to sleeve PEX tubing over its entire length where it lies beneath a slab, but tubing must be protected against abrasion with the slab by using a non-metallic sleeve or guide (e.g., PVC bend guides, PE sleeving) where it passes through and emerges from the slab (see **Figure 9.29** and **Figure 9.30**). This will serve to protect the PEX tubing from accidental damage as the slab is poured, leveled, and smoothed and from subsequent framing and construction work.

Figure 9.29 PVC Bend Guide for Protecting PEX when Emerging from a Slab

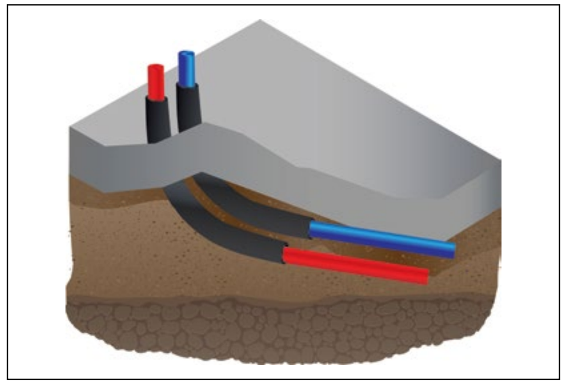


Figure 9.30 PEX Tubing Protected with Sleeving when Emerging from a Slab

PEX tubing emerging from a slab may need support to keep it vertical and prevent it from falling back onto the slab. To support the tubing in these cases, PEX can be carefully tied to a vertical piece of re-bar, wood stakes, or a rigid drainpipe for support. Some manufacturers also provide special guides for this purpose (see **Figure 9.31**).

Local codes may require insulation of PEX tubing under slabs. Follow the tubing manufacturer's recommendations for approved insulation materials.

Figure 9.31 PEX Tubing Held Vertically when Emerging from a Slab Using Special Guides

Termiticides or Pesticides

If termiticides or pesticides are applied to the soil or structure, all ends of the tubing must be closed or capped to prevent entry of chemicals into the pipe. Also, it is important to ensure that no pooling or puddling of the termiticide or pesticide occurs in the spacing between any sleeving and PEX tubing at the slab penetration. This spacing should be filled with sealants that are compatible with PEX. Please reference **PPI TN-39 *Recommended Practices Regarding Application of Pesticides and Termiticides Near PEX Tubing*** for additional information.

Protection of Tubing and Fittings from UV Exposure after the Pour

Due to the nature of slab-on-grade installations, tubing and fittings might be exposed to sunlight for unspecified periods of time before or after a slab is poured and before the structure is framed and enclosed. To prevent damage from excessive UV exposure, PEX tubing and fittings that are exposed above the slab must be wrapped with an opaque covering such as black polyethylene bags or sheeting immediately after the pouring of the slab, per manufacturer's instructions. This covering should extend down to the surface of the slab to protect the entire tubing surface above the slab from excessive UV exposure. For specific limitations on UV exposure, consult the PEX tube manufacturer.

It is recommended to not wrap tubing in duct tape for protection from sunlight or any other reason. Check with the tubing manufacturer for proper methods of protection from sunlight in these locations.

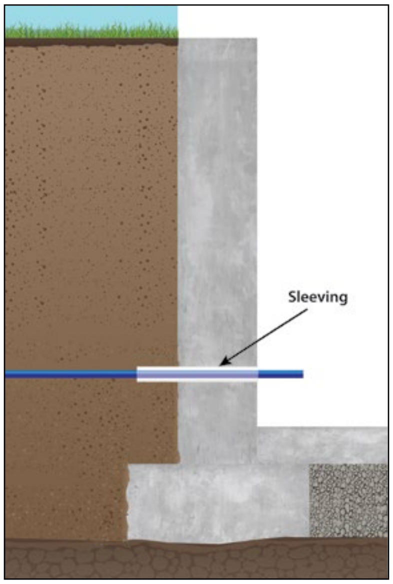


Figure 9.32 PEX Tubing Protected Against Pinching or Shearing at a Foundation Wall Penetration

Penetrating Foundation or Basement Walls

When PEX tubing passes through a basement or foundation wall, it must be protected by a rigid sleeve that spans the distance from within the wall out to the undisturbed soil in the pipe trench (see **Figure 9.32**). The purpose of this protective sleeve is to prevent pinching or shearing of the PEX tubing at the wall in the event there is settlement in the backfill around the wall.

At the point where the sleeve terminates inside the foundation or wall, the space between the PEX and the sleeve should be sealed with an approved caulking material to prevent leakage into the building.

Note: Petroleum-based caulks or sealants should not come in direct contact with PEX. Contact the tubing manufacturer for approved sealant and caulking materials.

Spray Foam Insulation

The spray polyurethane foam (SPF) curing reaction is exothermic, which means that heat is generated during the foam reaction. The heat of reaction is highly dependent on the SPF formulation and is also based upon the overall intended application or lift (i.e., layer) thickness installed. Peak temperature within the layer of foam typically occurs within 5 to 15 minutes of application, followed by gradual cooling.

The installation of spray polyurethane foam insulation on or around PEX tubing is typically acceptable when allowed by the pipe and fitting manufacturer and when the SPF installer strictly follows the recommendations of **PPI TN-69 *Recommendations When Applying Spray Polyurethane Foam Insulation On and Around Plastic Pressure Pipes & Fittings***, as well as the installation recommendations published by the Spray Polyurethane Foam Alliance (SPFA). www.sprayfoam.org.

To avoid excessive temperatures, Do Not encase PEX tubing and fittings in a single pass of SPF (see **Figure 9.33**).

SPFA recommends that when there are plastic pipes in a wall, ceiling, or floor cavity, the SPF installer should apply the first layer of foam until it just barely touches or encases the tubing, but keeping portions of the tubing exposed (see **Figure 9.34**).

SPF installers should let the first layer of foam cure for a sufficient amount of time while the heat is released and the tubing remains partially exposed. Typically, this is when the surface of the SPF has cooled to approximately 100°F (38°C). Then, they may apply the second layer or lift. This way, the tubing is never in the middle of a thick layer of foam insulation during curing. If tubing is installed at different depths, installers should continue this process for each depth of tubing.

Incorrect Installation

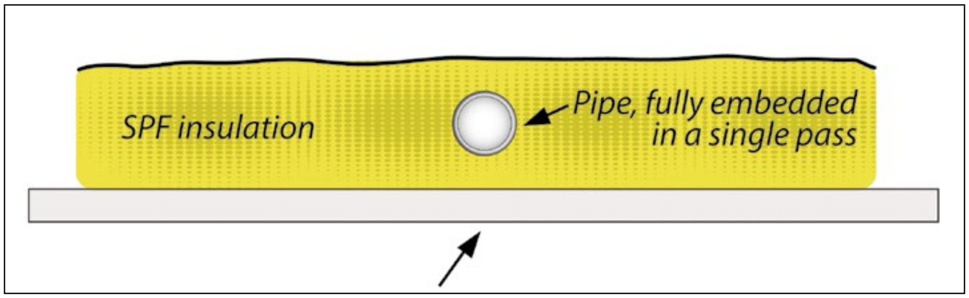


Figure 9.33 Incorrect Procedure for Installing SPF Insulation in a Single Pass, Potentially Damaging PEX Tubing and Fittings

Correct Installation

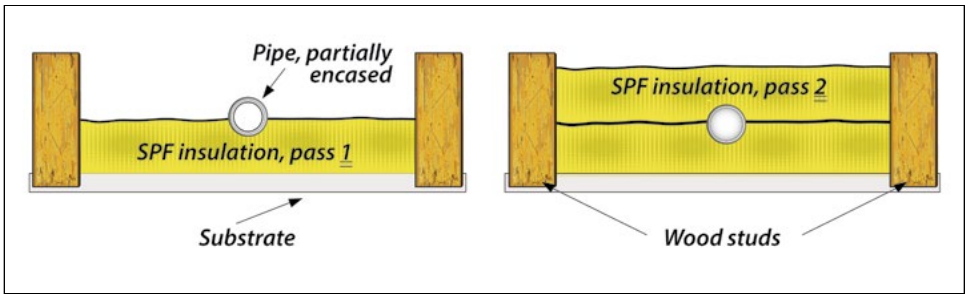


Figure 9.34 Correct Procedure for Installing SPF Insulation in Multiple Steps to Protect PEX Tubing

Protection of Polymer Fittings

Certain polymer fitting materials (e.g., polysulfone or PSU, polyphenlysulfone or PPSU) may be incompatible with spray foam insulation and might have chemical-compatibility issues if the fittings are encased directly in SPF (see **Figure 9.35**). Direct encasement of polymer fittings in spray foam is not recommended.

It is strongly recommended to completely wrap polymer fittings in aluminum foil, linerless tape, or other approved protective methods to provide a chemical barrier prior to foam application. Metallic fittings should be considered an alternative in situations where this protection is not possible.

When using polymer fittings, consult the fitting manufacturer to confirm chemical compatibility and the appropriate use of any protective materials.

Figure 9.35 Incorrect Placement of Spray Foam Insulation Directly on Polymer Fitting

Connection to Water Heaters and Other Heat Sources

When connecting PEX tubing to storage-type water heaters (oil, gas), the tubing must be kept at least six (6) inches (15 cm) away from the exhaust or flue pipe to prevent overheating. Flexible metal water heater connectors of at least 18 inches (457 mm) in length may be used to allow PEX tubing to be positioned away from flue pipes. This recommendation (18-inch metal connector) also applies to electric storage-type water heaters.

Per **PPI Recommendation H** ***Recommendation on Direct Connection of Plastic Piping Materials to Tankless Water Heaters for Domestic (i.e., residential) Applications***, PEX tubing may be connected directly to tankless or instantaneous water heaters which are intended for domestic (i.e., residential) applications, unless prohibited by local plumbing code or the specific water heater manufacturer.

For any type of water heater (e.g., storage tank, tankless, heat pump, indirect storage tank), if the inlet or outlet water piping connection positions the piping so that it might be exposed to sources of heat (e.g., vent or exhaust heat) other than the water being discharged by the water heater, the installer should use an appropriate metallic connector of sufficient length to separate the PEX tubing from the heat source so that it is not exposed to temperatures in excess of 180°F (82°C).

Connection/Transition to Other Piping Materials

PEX manufacturers offer a wide variety of transition fittings to allow direct connection of PEX tubing to copper, chlorinated polyvinyl chloride (CPVC), polybutylene (PB), polypropylene (PP), steel, or other piping materials. These fittings may transition PEX to other piping materials via tapered threads, flanges, press connections, push-fit fittings, solvent cement, or soldering (see **Figure 9.36** for examples of PEX transition fittings).

In most cases, the transition fitting should be attached to the other material (e.g., copper, steel, CPVC) before the connection to PEX is made. Be sure to solder copper transition fittings onto copper tubing first and allow them to cool before connecting to PEX tubing, because the high heat of soldering (e.g., greater than 180°F) may damage the PEX tubing and its connection.

Be sure to prevent contact with solder flux or ABS, PVC, or CPVC primer and solvent cement with plastic fittings (see **Figure 9.37**).

Push-fit fittings per ASSE 1061 are available to adapt PEX to other tubing materials directly (see **Figures 9.38**, **9.39**, and **9.40** for examples of PEX transition fittings).

Figure 9.36 Examples of PEX Transition Fittings for Sweat, Press, and Threaded Connections

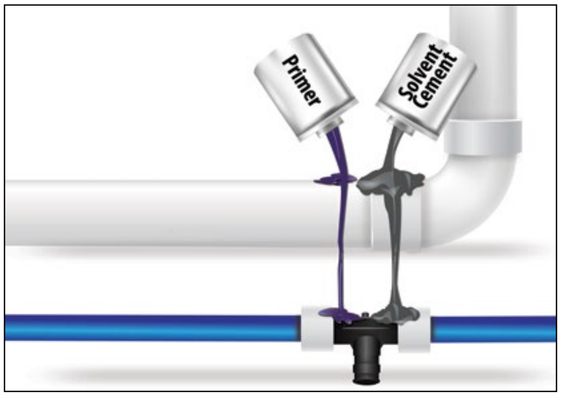


Figure 9.37 Prevent Contact with ABS, PVC, or CPVC Primer and Solvent Cement with Plastic Fittings

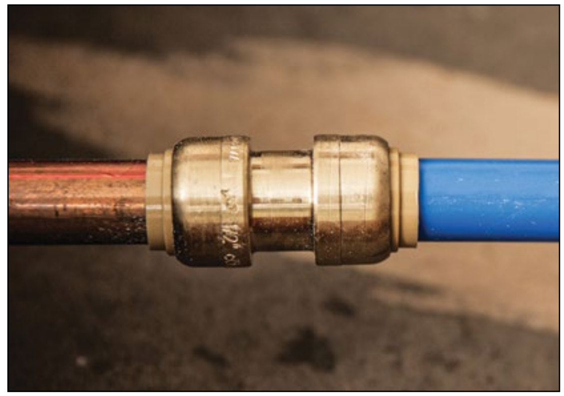


Figure 9.38 Push-Fit PEX Transition Fitting to Copper

Figure 9.39 Push-Fit PEX Transition Fitting to CPVC

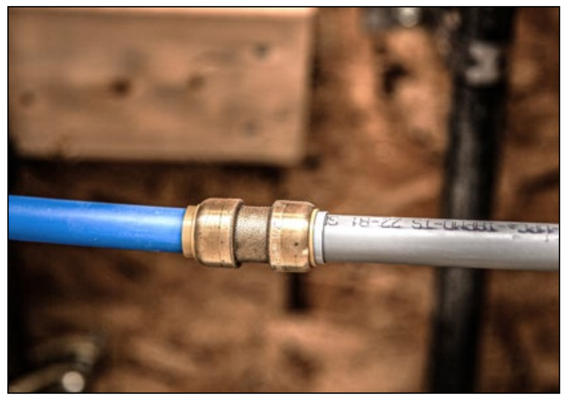


Figure 9.40 Push-Fit PEX Transition Fitting to PB

Do not use standard female plastic tapered (NPT) threaded fittings with metallic male tapered threaded fittings, since this may split the plastic female fitting. However, female plastic tapered (NPT) threaded fittings with metal reinforcements (e.g., a brass liner) may be connected to metallic male tapered threaded fittings when approved by the fitting manufacturer for that purpose.

Connections to Basin or Toilet Valves

Several options are available for supplying a basin or toilet valve below a sink or toilet with PEX tubing within the wall.

- PEX tubing may be run continuously to the exposed valve supported by a fastener on a nearby stud within the wall for rigidity (see **Figures 9.41**, **9.42** and **9.43**).
- A 90-degree support with a mounting plate may be used for this purpose (see **Figure 9.44**).
- Push-fit valves produced according to ASSE 1061 and intended for direct connection to PEX tubing may be used.
- PEX tubing may transition to a copper stub ell within the wall (see **Figure 9.45**) so that only the copper stub is visible in the room. In these cases, a standard solder, push-fit, or compression valve may be attached to the copper stub.

Figure 9.41 PEX Tubing Run Through the Wall to a Plumbing Fixture

Figure 9.42 PEX Tubing Run Through the Wall to a Plumbing Fixture

Figure 9.43 PEX Tubing Run Through the Wall to a Plumbing Fixture

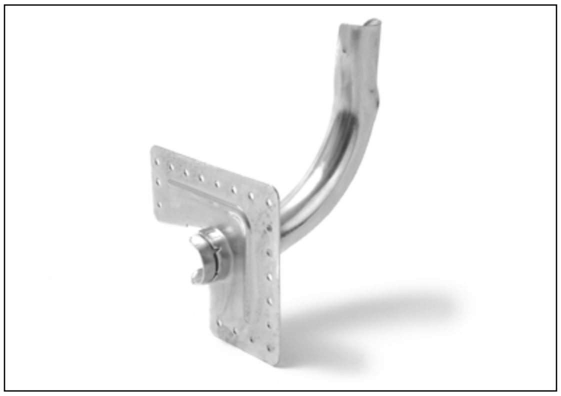


Figure 9.44 90-Degree PEX Support with Mounting Plate

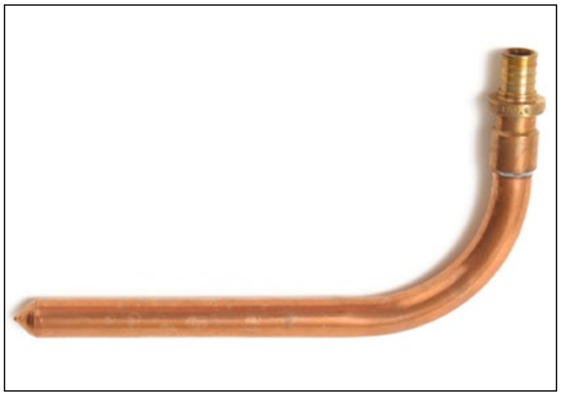


Figure 9.45 PEX/Copper Stub Ell

Hose Bibbs/Wall Hydrants/Sillcocks

PEX tubing may be used to supply hose bibbs, wall hydrants, and sillcocks and may be connected to standard hose bibbs by using a PEX transition fitting (see **Figure 9.46**. Several hose bibb manufacturers produce their assemblies with PEX connections as part of the assembly.

Hose bibbs should be protected from freezing using insulation (see **Figure 9.47**). Hose bibbs shall be anchored to prevent strain on PEX tubing and shall be supported with appropriate brackets and shall not be supported by PEX tubing alone.

Figure 9.46 PEX Connected to a Hose Bibb/Wall Hydrant

Figure 9.47 Insulated Hydrant to Prevent Freezing

Shower Valves

PEX tubing may be connected directly to shower valves using adapter fittings provided by the tubing manufacturer or using a shower valve with built-in PEX tubing connections (see **Figure 9.48**).

It is recommended to use PEX tubing for the hot- and cold-water supply lines to shower valves and for the supply line from the shower valve to the shower head or body sprays. However, it is not recommended to use PEX tubing for the connection from the valve to a tub valve/outlet, due to the potential for imbalanced flow to tub valves, which may prevent proper action of the valve (see **Figure 9.49**).

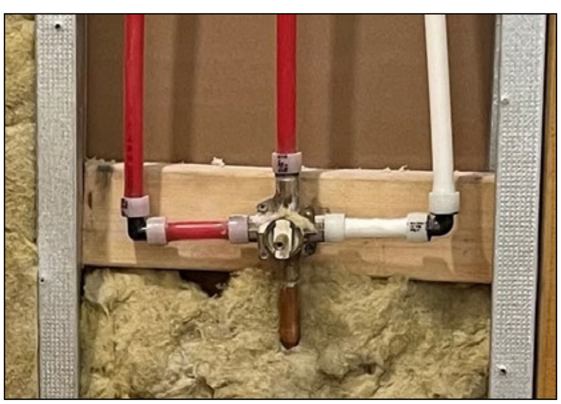


Figure 9.48 PEX Tubing Connected to a Shower Valve in 3 Locations

Figure 9.49 PEX Tubing Connected to a Shower Valve in 3 Locations

Other Valves

Many styles of valves may be used with PEX tubing systems, including ball valves which are manufactured directly with PEX connections on one or both ends (see **Figure 9.50**). When required by local code or regulations, thermostatic mixing valves (see **Figure 9.51**) and pressure regulating valves (see **Figure 9.52**) are also available with integrated PEX connections. Transition fittings may also be used to connect PEX tubing to standard threaded, solder, plastic, or flanged valves.

Figure 9.50 Ball Valve with F1960 PEX Connections

Figure 9.51 Thermostatic Mixing Valve with F1807 PEX Connections

Figure 9.52 Pressure Reducing Valve with F1960 PEX Connections

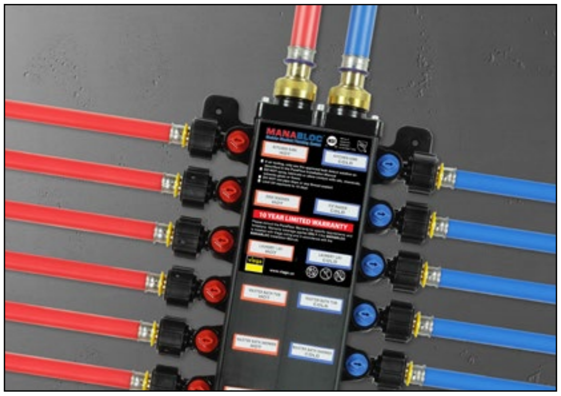


Figure 9.53 Integrated Hot- and Cold-Water Manifold Assembly

Parallel Piping (Home-run) Manifold Installations

As described in **Chapter 6 *Layouts & Design***, in a parallel or "home-run" plumbing system all outlets to fixtures are individually fed from a common manifold or two central manifolds serving hot and cold fixtures (see **Figure 9.53**). The hot water manifold should be located in close proximity to the hot water source (e.g., water heater) to minimize wait time for hot water to fixtures, ensuring efficient delivery and water conservation.

- Manifolds can be installed in a horizontal or vertical position (see **Figure 9.54**)
- In larger installations, with multiple water heaters, use a manifold at each water heater for the fixtures served by the water heater
- Tubing should be run continuously and as directly as possible between manifold and fixture locations
- Approved fittings may be used to repair kinked or damaged PEX distribution lines or to add additional length to a distribution line that was mistakenly cut too short during installation
- Tubing shall not be pulled tight. Leave slack to allow for expansion and contraction

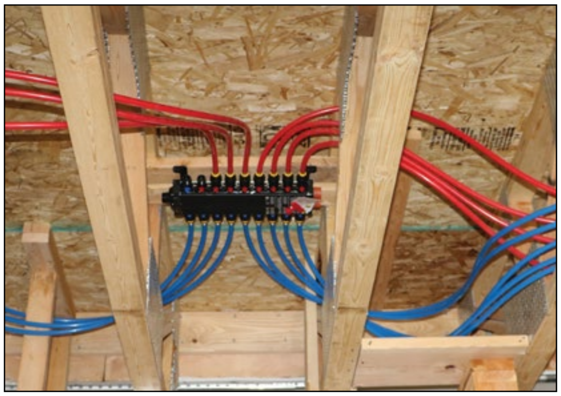


Figure 9.54 Hot- and Cold-Water Manifolds Installed Horizontally Below a Floor

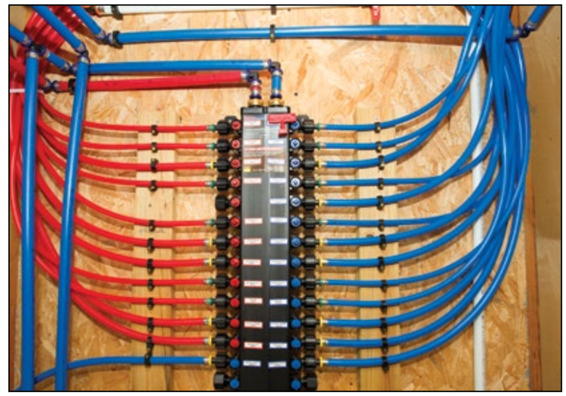


Figure 9.55 Hot- and Cold-Water Runs Labelled

- Install tubing cautiously to avoid bending, kinking, or abrasion
- Leave excess tubing at the beginning and end of runs for connection to fixtures and the manifolds
- When running lines to a group of fixtures, they may be bundled together but must be bundled loosely enough to allow individual tubing movement. Plastic ties may be used. Hot and cold lines may be bundled together but some jurisdictions do not permit this practice. Be sure to check with the local authority
- Do not use tape when bundling tubing, as it may restrict movement of tubing runs and cause chemical compatibility problems
- When bundled lines pass through conventional structural members, cut a hole at the centerline of the member. Consult the applicable code for maximum allowable hole size
- Identify and mark all lines at the manifold (see **Figure 9.55**)
- Manifolds with valves shall be accessible and protected from freezing and exposure to sunlight
- Individual fixture shutoff valves may be installed at the manifold if permitted by the local authority. If installed, they shall be identified as to the fixture being supplied

Retrofit Installations

PEX tubing is ideal for retrofit applications and may be used to repair or replace lead, galvanized steel, copper, polybutylene, or other piping materials. The flexibility of the product and continuous lengths allow for easier installation in existing walls and structures than traditional rigid piping systems. In some cases, existing pipes may even be downsized to smaller diameter PEX tubing, when flow calculations indicate that original pipes are larger than needed. This may help to improve water quality by reducing exposure to older metal pipes and by reducing water stagnation with smaller pipes.

Several varieties of fitting adapters are available for simple transition between piping systems, such as solder, threaded, and polybutylene adapters. Consult the manufacturer for available product offerings. The use of PEX in retrofit applications should follow the same installation instructions described in this guide, as well as local codes.

Thawing Frozen PEX Tubing Systems

Although PEX tubing has been shown to be freeze-break resistant (see **Chapter 3 *Material Properties***), PEX tubing systems should not be intentionally subjected to freezing.

For frozen tubing that is accessible, the following methods of safely thawing it may be used:

- Pour warm or hot water over the affected portion of the frozen tubing
- Apply hot air to the outside of the tubing using a hot air gun or hair dryer to heat frozen areas. Ensure that the temperature of the tubing does not exceed 180°F (82°C); ice should thaw long before this temperature is reached
- Wrap a warm moist towel around frozen tubing to thaw ice
- Use a temporary space heater to warm the general area around the frozen tubing

Thawing inaccessible frozen tubing can be performed using available hot water injection equipment which sprays hot water into an open end of a tube through a nozzle which is designed to propel itself forward through the tube until it reaches the ice blockage. This is usually performed at moderately warm water temperatures. The maximum water temperature allowed for thawing is 180°F.

After thawing, PEX tubing can immediately be put back into service, unless there are signs of damage.

Follow the manufacturer's published guidelines and recommendations.

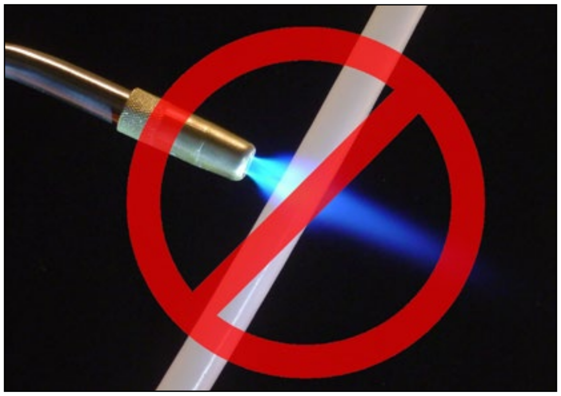


Figure 9.56 Inappropriate Use of Flame on PEX Tubing

NOTICE: Do not use an open flame, excessive heat, or an electric resistance pipe thawing device (e.g., HotShot™) to thaw frozen plastic pipe, as this could damage the tubing and result in property damage and loss of water pressure (see **Figure 9.56**).

Disinfection of Potable Water Systems

New or repaired potable water systems shall be disinfected prior to use where required by the Authority Having Jurisdiction. The method to be followed shall be that prescribed by the local code or Health Authority. See **Chapter 3 *Material Properties*** section on "Resistance to Disinfectants" for more information.

One resource for disinfections procedures is the "AWWA Technical Report Disinfecting Building Potable Water Plumbing in New or Repaired Systems," first published in November 2024. Excerpt: "The purpose of this technical report is to recommend procedures for the process of preparing and disinfecting new and repaired building potable water systems. Guidance provided in this technical report was developed for implementation in buildings constructed with a reasonable standard of clean and sanitary practices to keep water piping, components, and equipment clean during construction or repair."

Pressure Testing and Inspection of the Completed System

Pressure testing of a completed piping system is typically required by local code regulations and the tubing manufacturer to ensure pressure-tightness. When performing hydrostatic testing (i.e., testing with water pressure), test the system with potable water only to prevent contamination. Do not allow water in the system to freeze.

Test pressure shall be at least equal to the expected working pressure of the plumbing system, but not less than 50 psi (345 kPa) and not greater than 160 psi at 73°F (1,103 kPa at 23 °C), or as recommended by the tubing manufacturer.

If it is difficult to test using pressurized water because of freezing conditions, insufficient water supply, or insufficient water pressure, pressure testing using compressed air or inert gas (e.g., helium, nitrogen) is a recommended solution, when approved by the PEX system manufacturer and local codes. While some types of plastic pipe and fitting materials are not suitable and not permitted to be tested with compressed air or gas, PEX tubing is not subject to brittle failure.

For systems that incorporate plastic fittings, valves, or manifolds, air testing shall be in accordance with each component manufacturer's instructions. If the manufacturer of any pressurized component does not recommend air pressure testing at the required pressure, then that component must be isolated or removed from the system prior to an air pressure test.

WARNING: Compressed air or inert gas used for pressure testing has high potential (stored) energy. Any uncontrolled release of that energy can present serious safety hazards.

ASTM F2786 *Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Gaseous Testing Media Under Pressure (Pneumatic Leak Testing*) provides several recommendations for safely testing polyethylene pipes in a wide variety of sizes and situations. See **PPI Recommendation F *Testing PEX and PE-RT Tubing Systems with Compressed Air or Gas*** for more details.

Friction Losses

For friction loss through PEX tubing, please use the **PPI Plastic Pipe Design Calculator** at www.plasticpipecalculator.com.

For friction loss through PEX fittings, please contact the PEX system manufacturer.

Water Service Lines / Building Supply Lines

10

A water service line delivers potable water from the water main, typically a community water system (CWS) or public water supply (PWS), to the property line and into a building. Some codes define the portion of this pipe within the property as the building supply line.

Crosslinked polyethylene (PEX) tubing is an ideal piping material for buried water service lines and building supply lines in practically all applications because it is a strong, tough, reliable material with exceptional resistance to chlorine and chloramines. It is both sustainable, with lower costs to the environment for production and usage, and resilient, thanks to excellent resistance to corrosion, water disinfectants, seismic events, and other types of external damage.

PEX tubing has been used successfully for water service line and building supply line applications in North America for over 25 years, providing safe delivery of potable water and protecting the health of building occupants in both new construction and rehabilitation work, such as lead service line (LSL) replacements.

Background on PEX Tubing for Water Service Line

Crosslinked polyethylene is a high-temperature, flexible pressure piping system with exceptional resistance to slow crack growth (SCG), pressure cycling, seismic movements, and potable water disinfectants like chlorine and chloramines. In North America, PEX tubing systems are used for water service lines, building supply lines, hot- and cold-water distribution, residential fire protection, hydronic distribution, radiant heating and cooling, outdoor snow and ice melting, district energy piping, geothermal ground heat exchangers, and other demanding applications.

Most of the properties and characteristics of PEX tubing and joining systems are thoroughly described **Chapter 2 *Advantages***, **Chapter 3 *Material Properties***, and **Chapter 5 *Joining Methods***, so this chapter will focus on the use of PEX tubing for water service line and building supply line applications.

Advantages of PEX Water Service Line Tubing

There are numerous advantages of PEX water service line tubing as compared with alternative materials such as Type K soft copper tubing.

Corrosion Resistance

Unlike buried metal pipes, plastic water service and building supply lines are non-metallic and will not corrode either due to aggressive soil or water. PEX water service tubing will not suffer mineral build-up, scaling or internal deposits, nor will it contribute dissolved metals into drinking water.

Water Velocity

The maximum recommended flow velocity through PEX water service tubing is 10 feet per second (3.0 m/s) for cold water up to 80°F (26.5°C). For required velocities beyond 10 fps, contact the tubing manufacturer.

Light Weight and Longer Coils

PEX tubing weighs five to six times less than Type K copper per equivalent length. The lighter weight can reduce shipping costs and allow the product to be handled more easily on jobsites, with the potential to improve worker safety (see **Figure 10.1**).

The lighter weight also allows PEX tubing to be handled in longer coil lengths (e.g., 300 ft/91 m) than copper, reducing the need for couplings in certain installations (see **Figure 10.2**).

Continuous Footage Markings

PEX tubing is marked at least every five feet showing the footage mark, and this can reduce waste by identifying coil lengths, potentially reducing installation time and scrap by allowing installers to easily select the right coil for each installation. See **Figure 10.3** for an example of a footage marking.

Figure 10.1 Worker Carrying PEX Tubing

Figure 10.2 PEX Tubing in Long Coil

Figure 10.3 Footage Marking on PEX

Low Thermal Conductivity

As an advanced polymer material, PEX tubing has a significantly lower thermal conductivity than metallic water service line. As reported in **PPI TR-48 *R-Value and Thermal Conductivity of PEX and PE-RT***, the PEX k-value = 2.86 (BTU·in)/(ft^2·hr·°F) or 0.41 W/(m·°K), while the copper k-value = 196 (BTU·in)/(ft^2·hr·°F) or 28 W/(m·°K). This data indicates that copper is 68 times more conductive than PEX, transferring heat through the tubing wall more rapidly.

The benefit of this property is that PEX tubing can resist heat transfer and can delay the freezing of water within tubing, providing reliable delivery of water even in extremely cold weather (see **Table 10.1**).

Table 10.1 Thermal Conductivity of PEX and Copper Tubing

Material	Thermal Conductivity	
	BTU-in/(ft^2-hr-°F)	W/(m-°K)
PEX	2.86	0.41
Copper	196	28

Freeze-Break Resistance

PEX tubing is less susceptible to the effects of cold temperatures, retaining its flexibility even below freezing (i.e., does not become brittle). If water-filled PEX tubing freezes, the elasticity of the material typically allows it to expand without cracking or splitting, and then it will return to its original size upon thawing. This applies when PEX tubing has room to expand evenly along its length, as is typical when installed in the ground. However, since the insulating properties (i.e., lower thermal conductivity) of PEX tubing slows heat transfer through the tubing wall, there is less chance of water freezing within PEX tubing in cold environments.

See **PPI TR-52 *Resistance of PEX Pipe and Tubing to Breakage When Frozen (Freeze-break Resistance)*** and consult with tubing manufacturer for more information.

PEX Water Service Line Requirements

According to plumbing codes, the requirements for PEX tubing to be used as a water service line or building supply line are the same as for indoor potable water applications. For example, PEX tubing and fittings intended for potable (drinking) water shall meet the requirements of **NSF/ANSI/CAN 61 *Drinking Water System Components - Health Effects***, **NSF/ANSI/CAN 372 *Drinking Water System Components, Lead Content***, and **ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*** or **CSA B137.5 *Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications***.

For water service line applications outside of the property line and the jurisdiction of the plumbing code, **AWWA C904 *Crosslinked Polyethylene (PEX) Pressure Tube, 1/2 Inch Through 3 Inch for Water Service***, is the ANSI-approved standard for PEX tubing intended to deliver potable water into homes and buildings and is the standard typically required by water utilities for this application. AWWA C904 was first published in 2006 and contains requirements including dimensions, degree of crosslinking, quick burst pressures, design factor, long-term hydrostatic strength (LTHS), pressure ratings, chlorine resistance, UV resistance, excessive pressure-temperature capability, hot-bend and cold-bend tests, marking requirements, quality control, and more.

Some important examples of the requirements of AWWA C904 are listed below. AWWA C904 also contains information regarding the proper installation of underground PEX potable water service lines that is appropriate for these installations.

Long-Term Hydrostatic Strength

AWWA C904 requires PEX tubing to demonstrate long-term hydrostatic strength resulting in a pressure rating for PEX tubing of 160 psig at 73°F (1103 kPa at 23°C). This is also known as the *Pressure Class* or *Pressure Rating*.

Chlorine Resistance

PEX water service tubing is highly resistant to elevated levels of free chlorine, up to 4.0 ppm, and is also highly resistant to elevated levels of chloramines. AWWA C904 requires that all PEX tubing must have a minimum extrapolated lifetime of 50 years when tested in accordance with **ASTM Test Method F2023 *Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water*** based on class 1 conditions of 25% of the time hot at 140°F and 75% of the time at 73°F operating at 80 psig (e.g., intermittent hot water, ≤ 6 hours/day). This is a very conservative approach for water service line applications, which typically operate at an annual average water temperature of 73°F (23°C) or less.

At the typical water service line end-use operating condition of 160 psig at 73°F (1103 kPa at 23°C), the extrapolated time-to-failure for PEX tubing meeting the requirements of AWWA C904 is in excess of 100 years, with regards to resistance to chlorine.

PPI Statement A *Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants on Crosslinked Polyethylene (PEX) Pipe and Tubing used in Treated Potable Water* reports on laboratory testing that was performed to evaluate the resistance of PEX tubing to water containing chloramines. According to PPI Statement A, "Based on these results, it is the position of PPI 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."

For information on the use of chlorine dioxide (ClO_2) and PEX tubing, please see **PPI TN-67 *Chlorine Dioxide and Plastic Hot- And Cold- Water Plumbing Distribution Pipes***.

Ultraviolet (UV) Resistance

AWWA C904 requires that all PEX tubing must have a minimum ultraviolet (UV) resistance performance categorized by a digit '3' in the material designation code for PEX tubing, which is based on a minimum of 6 months of UV resistance when tested in accordance with **ASTM Test Method F2657 *Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing***, which uses natural outdoor exposure for the tubing at exposure levels based on worst-case North American location near Phoenix, AZ, and evaluated in accordance with ASTM F876.

PEX Material Designation Code

The performance requirements of AWWA C904 are comprehensive and robust. Based on the above-listed chlorine and UV resistance requirements, the minimum Material Designation

Code for PEX tubing according to AWWA C904 is "**PEX 1306**" (see **Figure 10.4**). PEX Material Designation Codes such as "PEX 3306" or "PEX 5306" exceed the minimum requirements and, therefore, also comply.

See **Chapter 3 *Material Properties*** for details about the four-digit PEX Material Designation Code.

Figure 10.4 PEX Markings

Joining PEX Water Service Line

There are several types of joining techniques and fittings approved for use with PEX water service tubing. The primary type of fitting or valve is a compression-joint fitting produced according to AWWA C800, typically produced of lead-free brass. These are the same valves and fittings designed for use with Type K copper tubing and high-density polyethylene (HDPE) water service tubing (see **Figure 10.5**).

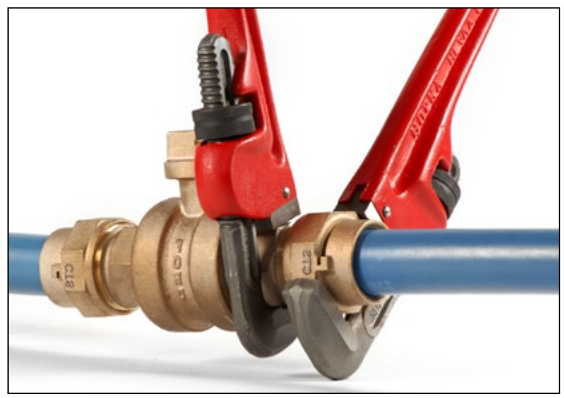


Figure 10.5 AWWA C800 Compression Joint Valve

Stainless steel or plastic insert stiffeners are required when using these fittings with HDPE or PEX to ensure long-term security of the connection (see **Figures 10.6** and **10.7**). These inserts are very thin and have a negligible effect on pressure loss.

Figure 10.6 Stainless Steel Insert Stiffener

Figure 10.7 PEX with Stainless Steel Insert Stiffener

In addition, several types of metal and polymer fittings which are designed specifically for PEX tubing may be approved for water service and building supply line applications. This includes fittings produced to nationally-accredited standards such as ASTM F1807, F1960, F2080, F2159, F3347, and F3348 as well as ASSE 1061 for push-fit fittings (see **Figure 10.8**). See ***Chapter 5 Joining Methods*** for details about each of these fitting options.

As stated in AWWA C904, "Each such fitting should be qualified before use by investigation and by tests when necessary to determine that the fitting is suitable and safe for the intended service." This includes specific approvals from fitting manufacturers for buried water service and building supply line applications.

Figure 10.8 Collection of Various PEX Fitting Systems

PEX Water Service Line Installation

PEX water service line installs much the same as HDPE and copper tubing. For reliable installations, follow the installation requirements listed below as well as the requirements in AWWA C904 and those of the tubing manufacturer.

Handling on the Jobsite

The following handling procedures are recommended:

- Store tubing to protect against damage from crushing, excessive heat, harmful chemicals, or overexposure to sunlight
- Prevent cuts, scratches, nicks, and gouges in the tubing
- Do not drag tubing over rough ground or pull through bored holes containing sharp-edged material, to prevent abrasion
- Unroll and uncoil tubing carefully to avoid kinking

Bending and Flexibility

The minimum bending radius for PEX water service line is **8 times** the Outside Diameter of the tube. See **Table 10.2** and **Figure 10.9** for details about the bending radius for each diameter.

Bending the tubing too tightly may cause kinking, which could damage the tubing and/or restrict the flow of water. See **Figure 10.10** for an example of installing PEX tubing as a lead service line replacement while following the minimum bending radius.

Table 10.2 Minimum Bending Radius for PEX Water Service Tubing

Tube Size (nominal)	Tube OD (actual) in.	8X Minimum Bend Radius in.
3/4	0.875	7.0
1	1.125	9.0
1 1/4	1.375	11.0
1 1/2	1.625	13.0
2	2.125	17.0
3	3.125	25.0

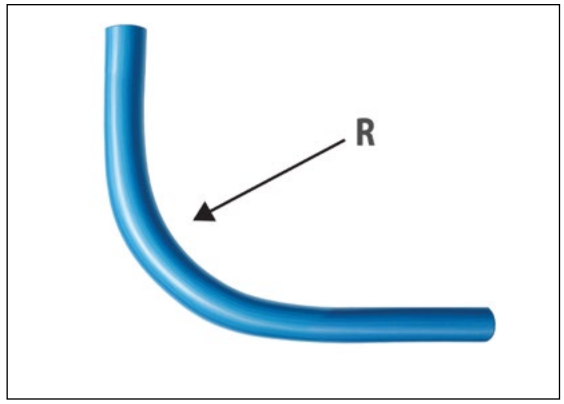


Figure 10.9 Bending Radius for PEX


Figure 10.10 Installing PEX Tubing as an LSL Replacement

Bend Supports

Bend supports or bend guides may be used to replace most elbow fittings for 90-degree changes in direction when using PEX as water service line tubing (see **Figure 10.11**).

Bends in PEX tubing are not permitted closer than 10 pipe diameters from any fitting or valve connection.

For example, with NTS 1 PEX tubing with an outside diameter (OD) of 1.125 in., the minimum length between the bend and fitting is 10 x 1.125 in. = 11.25 in. (28.57 cm).


Figure 10.11 Bend Support on PEX Tubing

Connections

There are several important steps to follow when connecting PEX water service line to valves or fittings.

Figure 10.12 Cutting PEX Tubing

- It is critical to use a proper tubing cutter, because PEX tubing must be cut squarely and cleanly before any connection (see **Figure 10.12**)
- When compression joint fittings are used, be sure to install an insert stiffener (see **Figure 10.7**)
- Insert tubing into fitting or valve ends, then tighten the fitting nuts per instructions
- For other PEX fittings, follow AWWA C904 and the manufacturer's instructions for assembly

Figure 10.13 PEX Tubing Installed with 10- to 20-Degree Gooseneck

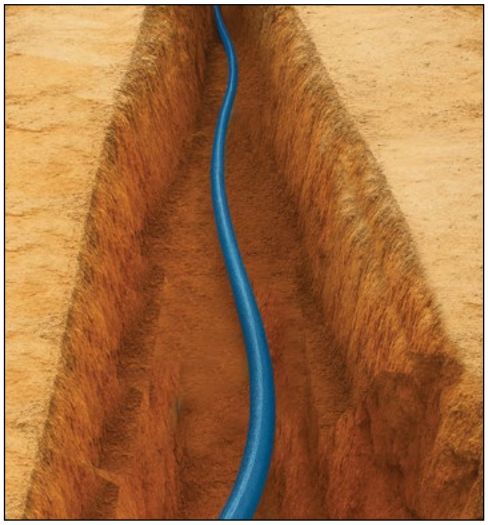


Figure 10.14 PEX Tubing in Trench with Slight Curve

Gooseneck

PEX water service tubing should leave the water main at a 10- to 20-degree angle above the horizontal to prevent stress on the connection. It is not required to use the 45-degree gooseneck common with copper service line (see **Figure 10.13**).

Thermal Expansion

The longitudinal (i.e., linear) expansion rate of PEX tubing is 1.1 inch per 10°F per 100 ft. length.

For example, if a 60 ft. (18.3 m) PEX service line is installed at an ambient air temperature of 90°F (32°C), and then the service water temperature is 60°F (16°C), this will be a 30°F (16.6°C) temperature reduction that will result in a tubing length reduction of 1.1 x 3 [30°F/10°F] x 0.6 [60 ft/100 ft] = 2 in. (50.8 mm).

It is recommended that installers allow a slight curve while laying PEX tubing in a trench to accommodate for changes in length when put into service (see **Figure 10.14**).

Horizontal Directional Drilling (HDD)

Horizontal Directional Drilling (HDD) uses trenchless techniques to drill a bore path through the ground which can be guided around obstacles or under streams, for example. The HDD process begins with boring a small, horizontal hole (pilot hole) under the crossing obstacle (e.g., a driveway) with a continuous string of steel drill rod. When the bore head and rod emerge on the opposite side of the crossing, a special cutter, called a back reamer, is attached and pulled back through the pilot hole. The reamer bores out the pilot hole so that the pipe can be pulled through. The pipe is usually pulled through from the side of the crossing opposite the drill rig.

PEX water service line is approved for installation using established HDD techniques. Care should be taken to prevent significant external damage to PEX tubing when installed using HDD methods, such as gouging by sharp rocks. See **Chapter 12 *Horizontal Directional Drilling (HDD)*** of the Plastics Pipe Institute's ***Handbook of Polyethylene Pipe*** for more information on this installation procedure.

Pressure Testing

AWWA C904 requires that "test pressure shall be at least equal to the expected working pressure (main pressure), but not less than 40 psi and not greater than 1.25 times working pressure at 73°F (23°C) for a minimum duration of 15 minutes and maximum of 2 hours."

Do not allow the water in system to freeze during testing. Suitable precautions should be taken to eliminate hazards to personnel in the proximity of lines being tested in the event of tubing system rupture.

Backfill and Embedment of PEX Tubing According to AWWA C904

AWWA C904 provides guidance with regards to backfill and embedment of PEX water service tubing.

- To prevent freezing water, water service tubing should be installed below the frost line
- PEX tubing should be installed in trench bottoms that provide continuous support and are free from rocks, stones, and debris, as per **ASTM D2774 *Standard Practice for Underground Installation of Thermoplastic Pressure Piping*** (see **Figure 10.15**)
- The initial backfill, from 3 in. (76 mm) below the pipeline to 4 in. to 6 in. (10 cm to 15 cm) above the tubing, should be sand or other materials, as allowed in ASTM D2774 or as approved by the tubing manufacturer
- If the installation will be subject to surface traffic, a minimum cover of 24 in. (61 cm) should be provided and trench backfill in the tubing zone should be compacted to at least 90% of the laboratory maximum density of the backfill soil

Figure 10.15 PEX Water Service Tubing in Trench

Permeation through Buried Pipes

Certain organic (e.g., hydrocarbon) compounds such as fuels, solvents, or other possible contaminants may permeate through plastic pipes, potentially contaminating the drinking water and damaging the pipe's integrity. This issue affects all types of buried pipes, including iron, copper, PVC, HDPE, or PEX.

Metal pipes use gaskets made of elastomeric materials, which may be susceptible to permeation by light hydrocarbons with smaller molecular sizes. Therefore, piping engineers must take special care when installing potable water lines through contaminated soil, regardless of the type of pipe material. If contamination is suspected, a chemical analysis of the soil or groundwater must be performed to determine the contaminant and its compatibility with PEX tubing.

The plastic piping industry provides the following techniques for dealing with suspected contamination of soil or groundwater:

- Surround the pipe with good clean soil of Class I or Class II material to allow the suspected contaminants to dissipate into the envelope of the surrounding soil; U.S. EPA guidelines prohibit the reuse of excavated hydrocarbon contaminated soil in the envelope of bedding or backfill material, or
- Sleeve the tubing in suspected areas, or
- Reroute the tubing around the contaminated area.

Locating Buried PEX Water Service Tubing

Available methods for locating buried PEX pipes include metallic detection tape, copper tracing wire, or electronic locating beacons, as required by the local codes or the project owner. Tracer wire may be secured to PEX tubing with nylon ties. Do not use adhesive tape to attach a tracer wire to the tubing.

Thawing Frozen PEX

In the unlikely event of a freeze, several suitable methods exist to thaw frozen water inside PEX tubing:

- Use a commercial hot-water injection system that pumps heated water through the tubing to the ice blockage and returns the cooled water for reheating
- Expose the buried tubing and apply wet hot towels to frozen area
- Expose the buried tubing and apply hot water to frozen area
- Expose the buried tubing and use a hand-held hair dryer or electric heat gun
- Expose the buried tubing and apply low-wattage electrical heating tape

In all cases, do not apply open flame directly to PEX tubing, as this could cause permanent damage.

APPENDIX A
Performance Test Setup and Data

Diagrams of Piping Layouts for Different Test Runs

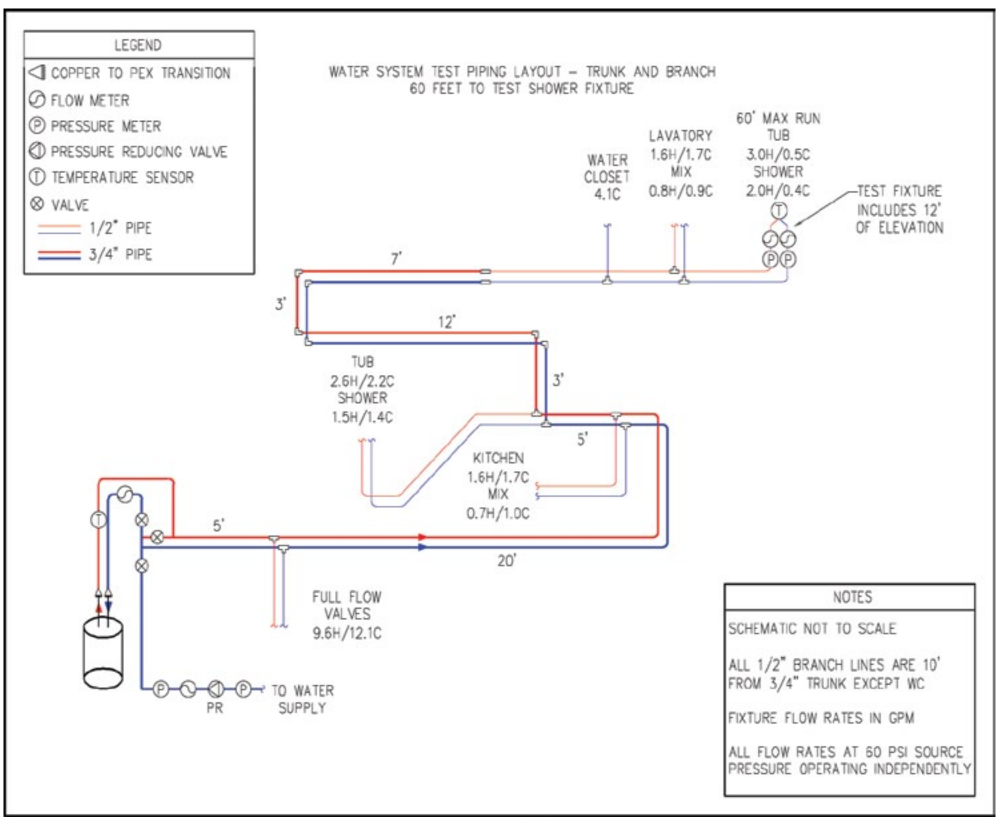


Figure A.1 Water System Test Piping Layout – Trunk and Branch, 60' to TF

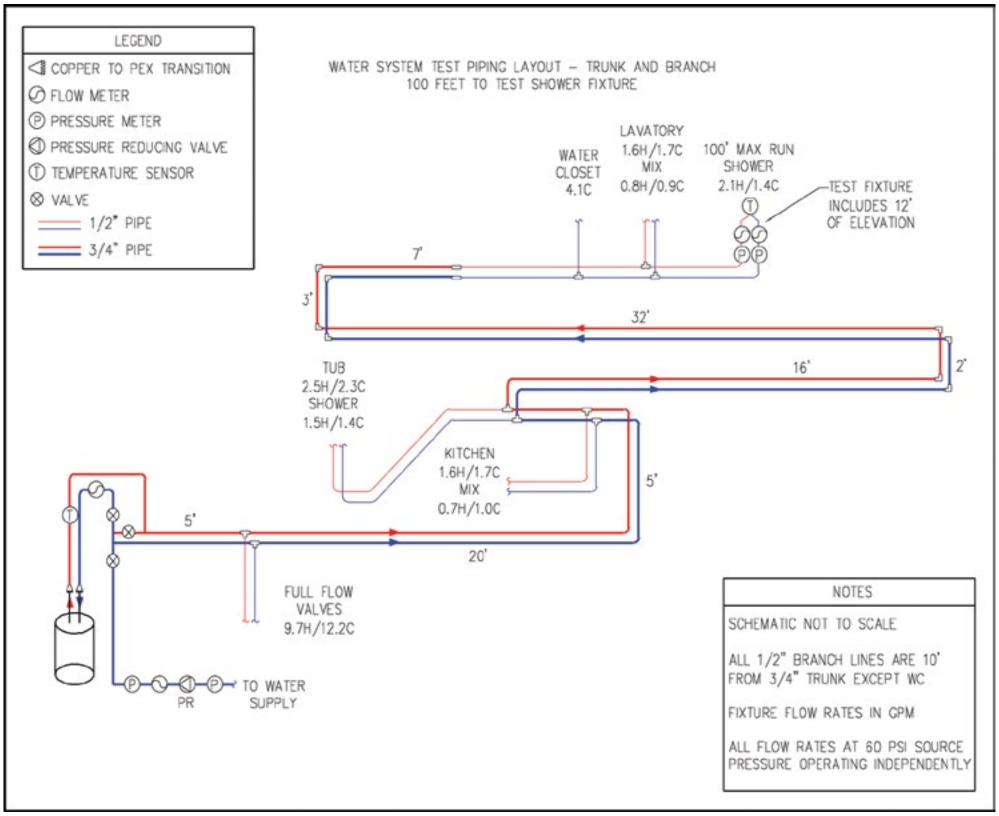


Figure A.2 Water System Test Piping Layout – Trunk and Branch, 100' to TF

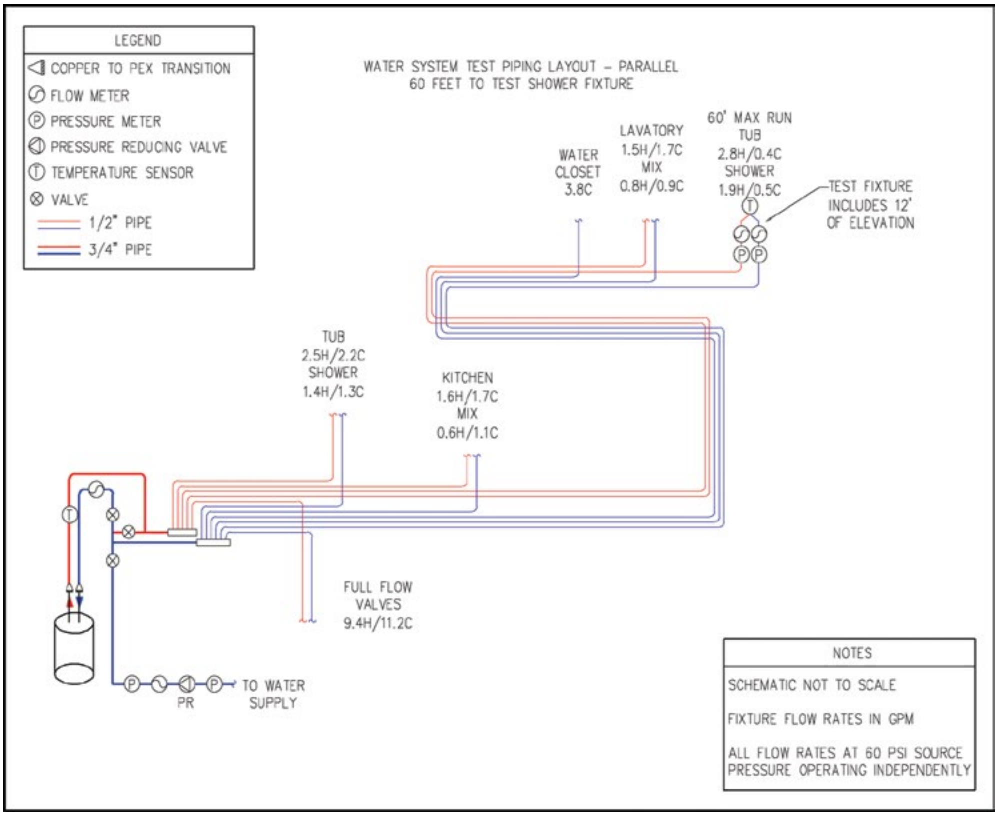


Figure A.3 Water System Test Piping Layout – Parallel, 60' to TF

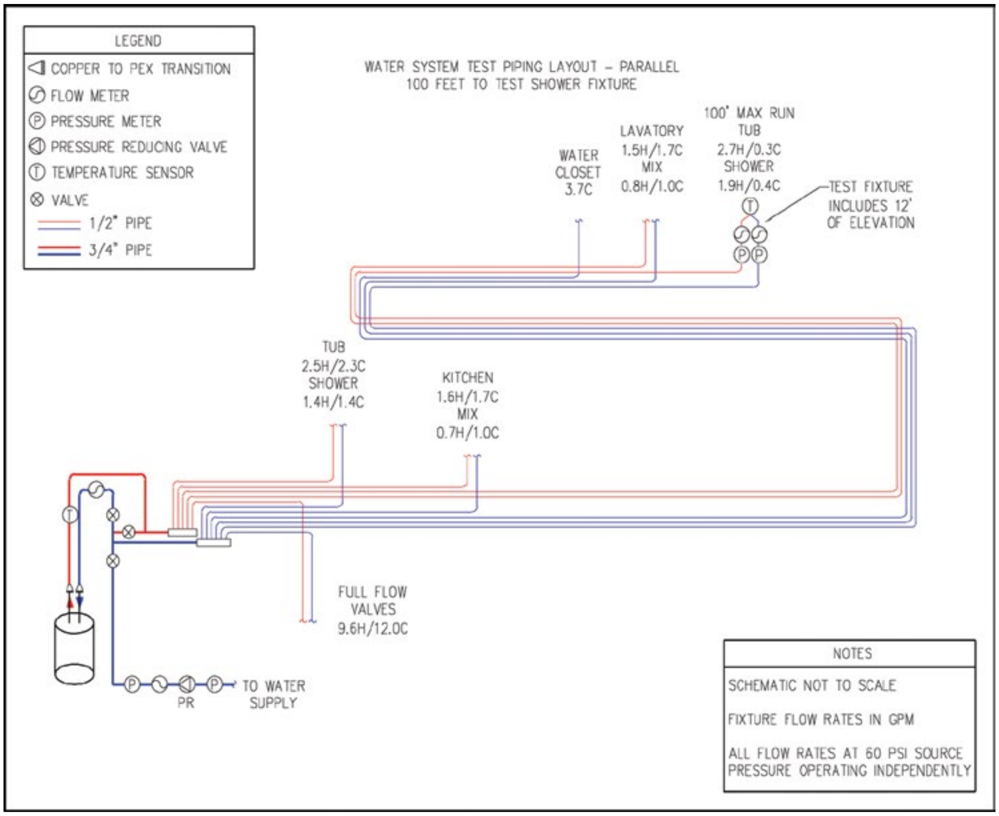


Figure A.4 Water System Test Piping Layout – Parallel, 100' to TF

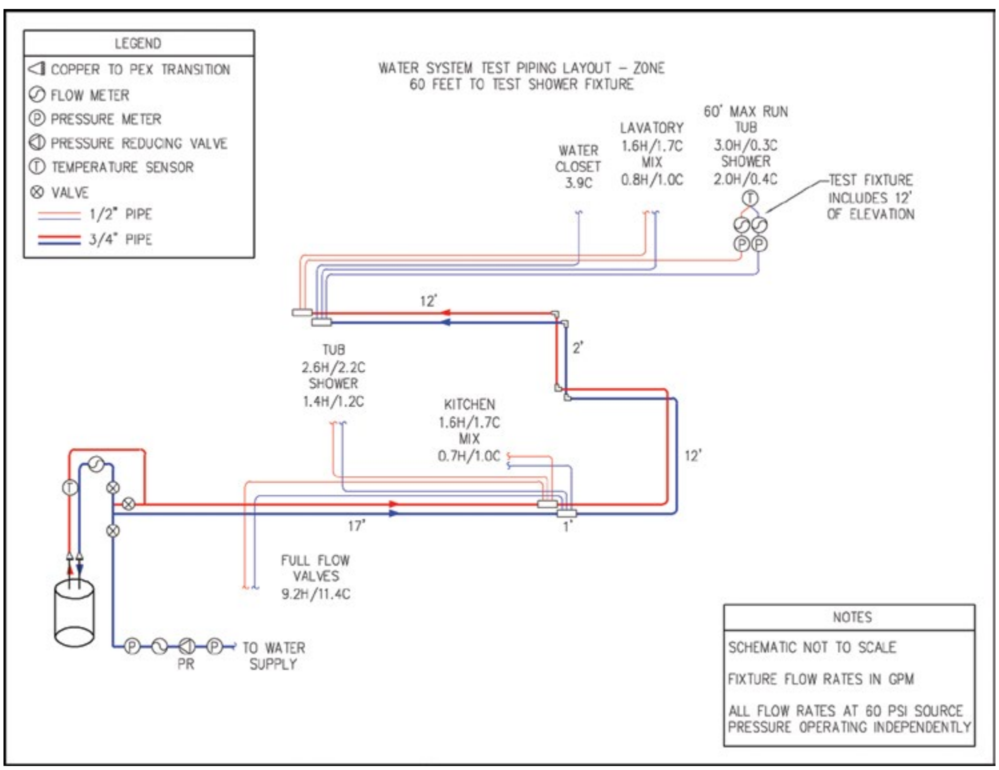


Figure A.5 Water System Test Piping Layout – Zone, 60' to TF

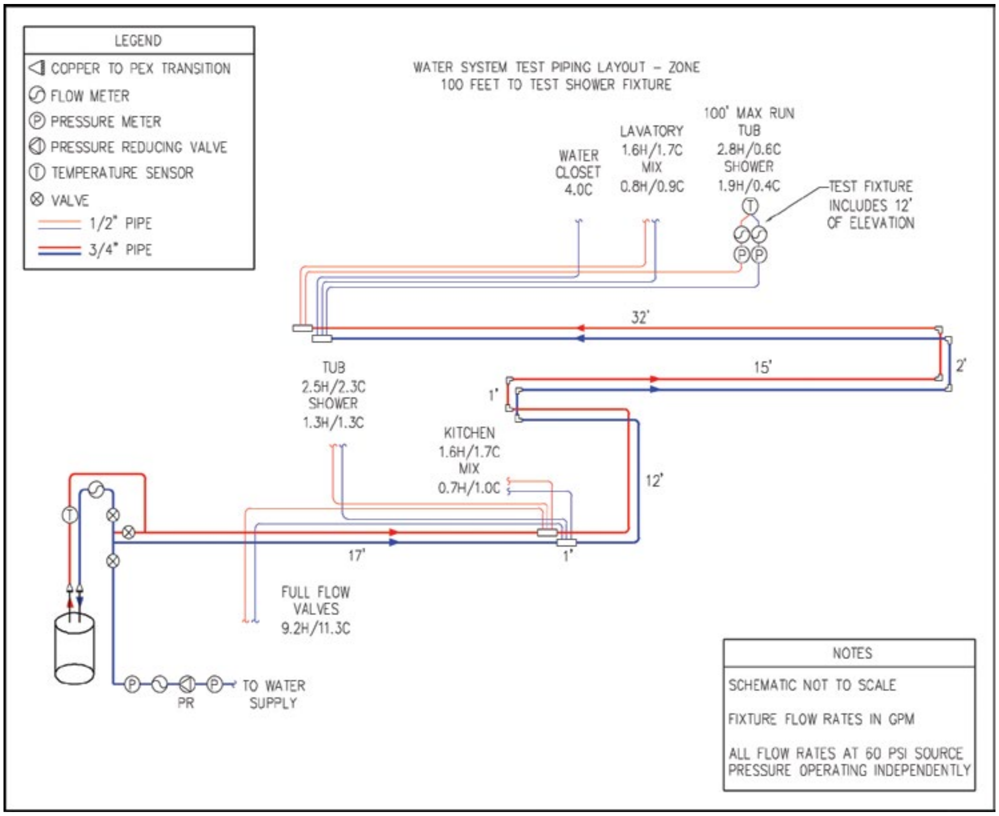


Figure A.6 Water System Test Piping Layout – Zone, 100' to TF

Table A.1 Simultaneous Flow Performance Data – 100′ Maximum Length, 60 psi Source Pressure

Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	GPM	GPM	GPM	psi	GPM	psi	GPM	psi
Trunk and Branch 100′ 60 psi Static	0.0	0.0	0.0	60.0	0.0	54.3	0.0	55.4
TF	2.5	0.5	2.1	60.0	2.2	50.0	0.3	55.2
TF+Lav	4.3	1.8	2.5	60.0	2.2	49.1	0.3	53.5
TF+WC	6.8	4.6	2.2	60.0	2.2	50.1	0.2	46.5
TF+Kit	4.3	1.5	2.8	60.0	2.2	49.2	0.3	54.9
TF+Sh2	5.2	1.6	3.6	60.0	2.1	47.9	0.3	54.8
TF+Sh2+Kit	6.9	2.7	4.2	60.0	2.1	47.4	0.3	54.5
TF+Sh2+Kit+Lav	8.6	4.2	4.4	60.0	2.1	47.1	0.3	52.1
TF+Sh2+Kit+Lav+WC	12.5	7.2	5.3	60.0	2.1	44.4	0.2	44.5
Zone 100′ 60 psi Static	0.0	0.0	0.0	60.0	0.0	54.2	0.0	55.2
TF	2.5	0.5	2.1	60.0	2.2	49.7	0.3	54.9
TF+Lav	4.13	1.7	2.6	60.0	2.2	49.0	0.3	54.1
TF+WC	6.8	4.7	2.1	60.0	2.2	50.1	0.2	49.6
TF+Kit	4.3	1.6	2.7	60.0	2.2	49.1	0.3	54.8
TF+Sh2	5.2	1.7	3.5	60.0	2.2	48.4	0.3	54.7
TF+Sh2+Kit	6.9	2.8	4.0	60.0	2.1	47.9	0.3	54.3
TF+Sh2+Kit+Lav	8.6	4.2	4.4	60.0	2.1	47.2	0.3	53.1
TF+Sh2+Kit+Lav+WC	12.5	7.4	5.1	60.0	2.1	46.3	0.2	47.8
Parallel 100′ 60 psi Static	0.0	0.0	0.0	60.0	0.0	54.1	0.0	55.1
TF	2.5	0.5	2.1	60.0	2.1	46.4	0.3	54.8
TF+Lav	4.3	1.5	2.8	60.0	2.1	46.3	0.3	54.7
TF+WC	6.8	4.6	2.1	60.0	2.1	47.1	0.3	54.6
TF+Kit	4.3	1.4	2.9	60.0	2.1	46.2	0.3	54.7
TF+Sh2	5.2	1.7	3.5	60.0	2.1	45.7	0.3	54.7
TF+Sh2+Kit	6.9	2.7	4.1	60.0	2.1	45.3	0.3	54.6
TF+Sh2+Kit+Lav	8.6	3.9	4.7	60.0	2.1	45.0	0.3	54.4
TF+Sh2+Kit+Lav+WC	12.5	7.7	4.8	60.0	2.1	45.6	0.3	53.9

TF = Test Shower Fixture, 15′ elevation; **Lav** = Lavatory, both valves open, 15′ elevation;
WC = Water Closet, tank type, 15′ elevation; **Kit** = Kitchen, mid-position, 4′ elevation;
Sh2 = 2nd Shower, full open valve, 6′ elevation

Table A.2 Simultaneous Flow Performance Data – 100′ Maximum Length, 80 psi Source Pressure

Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	GPM	GPM	GPM	psi	GPM	psi	GPM	psi
Trunk and Branch 100′ 80 psi Static	0.0	0.0	0.0	80.0	0.0	74.5	0.0	75.4
TF	2.9	0.4	2.5	80.0	2.6	68.7	0.3	75.1
TF+Lav	5.0	2.0	3.0	80.0	2.6	67.9	0.3	73.0
TF+WC	7.8	5.5	2.3	80.0	2.6	69.4	0.3	62.4
TF+Kit	5.0	1.7	3.3	80.0	2.6	68.5	0.3	75.0
TF+Sh2	6.0	1.8	4.1	80.0	2.6	67.9	0.3	74.8
TF+Sh2+Kit	7.9	2.9	5.0	80.0	2.5	66.3	0.3	74.3
TF+Sh2+Kit+Lav	9.9	4.8	5.2	80.0	2.5	65.2	0.3	71.3
TF+Sh2+Kit+Lav+WC	14.4	8.3	6.1	80.0	2.4	61.6	0.3	60.9
Zone 100′ 80 psi Static	0.0	0.0	0.0	80.0	0.0	74.6	0.0	75.4
TF	2.9	0.5	2.4	80.0	2.6	68.7	0.3	75.1
TF+Lav	5.0	1.9	3.1	80.0	2.5	67.3	0.3	74.0
TF+WC	7.8	5.5	2.3	80.0	2.6	68.9	0.3	67.6
TF+Kit	5.0	1.7	3.2	80.0	2.6	68.2	0.3	74.8
TF+Sh2	6.0	1.8	4.1	80.0	2.5	67.2	0.3	74.8
TF+Sh2+Kit	7.9	34.1	4.8	80.0	2.5	65.9	0.3	74.5
TF+Sh2+Kit+Lav	9.9	4.8	5.1	80.0	2.5	65.0	0.3	72.7
TF+Sh2+Kit+Lav+WC	14.4	8.6	5.8	80.0	2.5	63.0	0.3	65.0
Parallel 100′ 80 psi Static	0.0	0.0	0.0	80.0	0.0	74.5	0.0	75.3
TF	2.9	0.4	2.5	80.0	2.5	63.6	0.3	75.0
TF+Lav	5.0	1.7	3.3	80.0	2.5	63.3	0.3	74.8
TF+WC	7.8	5.3	2.6	80.0	2.5	64.4	0.3	74.6
TF+Kit	5.0	1.7	3.3	80.0	2.5	63.4	0.3	74.8
TF+Sh2	6.0	1.7	4.2	80.0	2.5	62.6	0.3	74.8
TF+Sh2+Kit	7.9	3.0	4.9	80.0	2.4	62.0	0.3	74.7
TF+Sh2+Kit+Lav	9.9	4.5	5.4	80.0	2.4	61.5	0.3	74.5
TF+Sh2+Kit+Lav+WC	14.4	8.9	5.5	80.0	2.4	62.0	0.3	73.8

TF = Test Shower Fixture, 15′ elevation; **Lav** = Lavatory, both valves open, 15′ elevation;
WC = Water Closet, tank type, 15′ elevation; **Kit** = Kitchen, mid-position, 4′ elevation;
Sh2 = 2nd Shower, full open valve, 6′ elevation

Table A.3 Simultaneous Flow Performance Data – 60' Maximum Length, 60 psi Source Pressure

Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	GPM	GPM	GPM	psi	GPM	psi	GPM	psi
Trunk and Branch 60' 60 psi Static	0.0	0.0	0.0	60.0	0.0	54.2	0.0	55.1
TF	2.5	0.5	2.1	60.0	2.2	50.8	0.3	54.9
TF+Lav	4.3	1.8	2.5	60.0	2.2	49.9	0.3	53.7
TF+WC	6.8	4.7	2.1	60.0	2.2	50.8	0.2	46.5
TF+Kit	4.3	1.4	3.0	60.0	2.2	49.9	0.3	48.6
TF+Sh2	5.2	1.6	3.5	60.0	2.2	48.7	0.3	54.7
TF+Sh2+Kit	6.9	2.7	4.2	60.0	2.1	48.0	0.3	54.5
TF+Sh2+Kit+Lav	8.6	4.2	4.4	60.0	2.1	47.7	0.3	52.4
TF+Sh2+Kit+Lav+WC	12.5	7.3	5.2	60.0	2.1	46.0	0.2	46.5
Zone 60' 60 psi Static	0.0	0.0	0.0	60.0	0.0	54.0	0.0	55.2
TF	2.5	0.5	2.0	60.0	2.2	50.6	0.3	55.0
TF+Lav	4.3	1.7	2.6	60.0	2.2	50.1	0.3	54.5
TF+WC	6.8	4.7	2.1	60.0	2.2	50.9	0.3	51.7
TF+Kit	4.3	1.7	2.7	60.0	2.2	50.2	0.3	54.8
TF+Sh2	5.2	1.6	3.6	60.0	2.2	49.2	0.3	54.7
TF+Sh2+Kit	6.9	2.7	4.2	60.0	2.2	48.5	0.3	54.4
TF+Sh2+Kit+Lav	8.6	4.1	4.5	60.0	2.1	48.0	0.3	53.5
TF+Sh2+Kit+Lav+WC	12.5	7.5	5.0	60.0	2.1	47.4	0.2	49.7
Parallel 60' 60 psi Static	0.0	0.0	0.0	60.0	0.0	27.6	0.0	28.5
TF	2.5	0.5	2.0	60.0	2.2	48.8	0.3	54.9
TF+Lav	4.3	1.5	2.8	60.0	2.2	48.6	0.3	54.8
TF+WC	6.8	4.8	2.0	60.0	2.2	49.3	0.3	54.6
TF+Kit	4.3	1.7	2.7	60.0	2.2	48.5	0.3	54.8
TF+Sh2	5.2	1.7	3.5	60.0	2.1	47.8	0.3	54.8
TF+Sh2+Kit	6.9	2.7	4.2	60.0	2.1	47.3	0.3	54.6
TF+Sh2+Kit+Lav	8.6	4.0	4.6	60.0	2.1	46.9	0.3	54.5
TF+Sh2+Kit+Lav+WC	12.5	7.8	4.6	60.0	2.1	47.5	0.3	54.0

TF = Test Shower Fixture, 15' elevation; **Lav** = Lavatory, both valves open, 15' elevation;
WC = Water Closet, tank type, 15' elevation; **Kit** = Kitchen, mid-position, 4' elevation;
Sh2 = 2nd Shower, full open valve, 6' elevation

Table A.4 Simultaneous Flow Performance Data – 60' Maximum Length, 80 psi Source Pressure

Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	GPM	GPM	GPM	psi	GPM	psi	GPM	psi
Trunk and Branch 60' 80 psi Static	0.0	0.0	0.0	80.0	0.0	74.6	0.0	75.4
TF	2.9	0.4	2.5	80.0	2.6	69.9	0.3	75.2
TF+Lav	5.0	2.0	3.0	80.0	2.6	68.9	0.3	73.8
TF+WC	7.8	5.5	2.3	80.0	2.6	70.2	0.3	66.4
TF+Kit	5.0	1.7	3.3	80.0	2.6	69.4	0.3	75.0
TF+Sh2	6.0	1.8	4.2	80.0	2.6	68.2	0.3	75.1
TF+Sh2+Kit	7.9	2.9	5.0	80.0	2.5	66.9	0.3	74.7
TF+Sh2+Kit+Lav	9.9	4.7	5.2	80.0	2.5	66.1	0.3	72.1
TF+Sh2+Kit+Lav+WC	14.4	8.4	6.0	80.0	2.5	63.4	0.3	63.6
Zone 60' 80 psi Static	0.0	0.0	0.0	80.0	0.0	74.5	0.0	75.3
TF	2.9	0.5	2.4	80.0	2.6	70.2	0.3	75.1
TF+Lav	5.0	1.8	3.1	80.0	2.6	69.0	0.3	74.4
TF+WC	7.8	5.6	2.2	80.0	2.6	70.2	0.3	69.9
TF+Kit	5.0	1.8	3.2	80.0	2.6	69.4	0.3	74.9
TF+Sh2	6.0	1.9	4.1	80.0	2.6	68.4	0.3	74.8
TF+Sh2+Kit	7.9	2.9	5.0	80.0	2.5	66.7	0.3	74.5
TF+Sh2+Kit+Lav	9.9	4.6	5.3	80.0	2.5	66.0	0.3	73.4
TF+Sh2+Kit+Lav+WC	14.4	8.7	5.7	80.0	2.5	64.5	0.3	67.7
Parallel 60' 80 psi Static	0.0	0.0	0.0	80.0	0.0	74.5	0.0	75.3
TF	2.9	0.5	2.4	80.0	2.5	66.9	0.3	75.1
TF+Lav	5.0	1.6	3.4	80.0	2.5	66.3	0.3	75.0
TF+WC	7.8	5.4	2.5	80.0	2.5	67.3	0.3	74.7
TF+Kit	5.0	1.6	3.4	80.0	2.5	66.4	0.3	74.9
TF+Sh2	6.0	1.8	4.2	80.0	2.5	65.8	0.3	75.0
TF+Sh2+Kit	7.9	2.9	5.0	80.0	2.5	64.8	0.3	74.8
TF+Sh2+Kit+Lav	9.9	4.5	5.5	80.0	2.5	63.8	0.3	74.6
TF+Sh2+Kit+Lav+WC	14.4	9.0	5.4	80.0	2.5	64.2	0.3	73.9

TF = Test Shower Fixture, 15' elevation; **Lav** = Lavatory, both valves open, 15' elevation;
WC = Water Closet, tank type, 15' elevation; **Kit** = Kitchen, mid-position, 4' elevation;
Sh2 = 2nd Shower, full open valve, 6' elevation

APPENDIX B
Other Applications

Radiant Heating and Cooling Systems

Hydronic radiant heating systems utilize flexible plastic tubing such as PEX embedded within floors, walls, or ceilings. Warm water is circulated through the tubing, which conducts heat to the panel, which then radiates heat to the space, warming the objects and people in the room, while also allowing warm air to gently rise from heated floors. The resulting comfort and efficiency are unmatched with other forms of heat delivery.

Figure B.1 Radiant Floor Heating Tubing in a Residential Application

Figure B.2 Radiant Floor Heating tubing in a Commercial Application

Warm fluid may be produced by a variety of heat sources such as high efficiency boilers, geoexchange ground source heat pumps, air-to-water heat pumps, electric boilers, biomass boilers, or thermal solar collection systems. Benefits of hydronic radiant heating include increased efficiency, more uniform heat distribution in the lower portion of rooms, quieter operation, better control of indoor relative humidity in wintertime, and easier zoning. Radiant heating systems are commonly found in many types of construction and many applications, from houses to schools to hotels.

Some radiant heating systems also operate as cooling systems, circulating chilled water through floors, walls, or ceilings to absorb thermal energy from people and spaces. Radiant cooling systems improve comfort and efficiency, as the reduced cooling load on the traditional air-based system can be significantly reduced, lowering air movement, noise, and fan loads.

The reduction in size of the air handling equipment is often enough to offset the cost of the heating/cooling pipes. Radiant cooling systems are typically employed in commercial spaces where the humidity can be controlled by computerized control systems to manage air dehumidification and prevent condensation on surfaces.

Figure B.3 Snow and Ice Melt Piping for a Ski Lodge

Snow and Ice Melting Systems

Hydronic snow and ice melting (SIM) systems utilize PEX tubing embedded in outdoor surfaces to augment the removal of snow and ice by circulating a heat transfer fluid, usually glycol and water, through the pipes. The durability and flexibility of PEX tubing allows these systems to provide years of reliable service, without worries about corrosion or failing electrical connections.

SIM systems are used in a wide variety of applications across North America, including sidewalks, steps, driveways, ramps, parking lots, loading docks, carwashes, roadways, bridges, and even helicopter landing pads. Systems are also used at hospitals, train stations, airports, hotels, and ski lodges. Most of these types of areas can be considered as high-traffic/high-hazard situations where 24/7 accessibility might be required, but many SIM systems are also found in private residences for driveways, walkways, and steps.

Figure B.4 Snow and Ice Melting in Operation at a Commercial Building

Benefits include safety, improved building access, no snow removal costs, elimination of sand and salt, reduced liability, and obvious convenience. Many SIM systems are less expensive to operate than traditional methods of snow removal, such as plowing.

Turf Conditioning

Figure B.5 Turf Conditioning in a Football Stadium

Turf conditioning or pitch heating systems utilize plastic tubing installed within the soil layer of natural turf at specific depths as determined by the turf experts in outdoor applications such as stadiums (e.g., football, baseball, soccer), golf courses, and other field surfaces. Warm fluid is circulated through the embedded tubing at a controlled temperature to gently warm the grass roots, providing optimal root zone temperature for continued growth, even in cold weather, and the potential to melt snow or ice.

Embedded soil temperature sensors guide control systems to modulate heat input as needed. Large surfaces are often split into multiple zones to respond to specific weather, wind, and sun exposures.

These systems can extend the growing season of natural grass surfaces for use in late autumn and winter, allowing the fields to recover faster after use. It has been reported that warm soil is softer than cold soil or artificial turf, and can even reduce player injuries. Turf conditioning systems may also melt snow, keeping playing surfaces accessible, visible, and safer.

In warmer climates, hydronic turf conditioning systems are also used with chilled water to absorb excessive solar thermal energy from outdoor grass surfaces to protect the grass from overheating. Chilled water can be produced from geothermal ground source heat pumps, cooling towers, chillers, or large bodies or water (e.g., a lake) when available.

Turf conditioning systems have been used for decades in European soccer fields and are widely used across North America in professional football, baseball, soccer facilities, and golf courses.

Geothermal Ground Source Heat Pump Systems

Figure B.6 Horizontal Geothermal Application

Geothermal ground source heat pump systems typically utilize buried pipes as the ground heat exchanger, transferring heat to and from the earth during cooling and heating operation, respectively. Ground source geothermal systems have the potential to reduce heating costs by 70% and cooling costs by 50%, or more, as compared to other sources of heating and cooling energy. PEX pipes are ideally suited for these applications, due to their flexibility, toughness and proven longevity. The flexibility of PEX assists installation in curved trenches; its high resistance to slow crack growth provides resistance to damage in both vertical and horizontal applications; its smooth interior permits excellent flow of heat transfer fluids; and its long-term history in pressurized applications ensures reliability, even when buried in the ground. PEX tubing conforming with ASTM F876 or CSA B137.5 is approved in model ground source geothermal codes such as CSA/ANSI/IGSHPA C448, the IAPMO Uniform Mechanical Code (UMC), the IAPMO Uniform Solar, Hydronic and Geothermal Code (USHGC), and the ICC International Mechanical Code (IMC). Please see **PPI TN-55 *Plastic Piping Materials for Ground Source Geothermal Heating and Cooling Applications*** for more information.

Figure B.7 Residential Fire Sprinkler with PEX Tubing

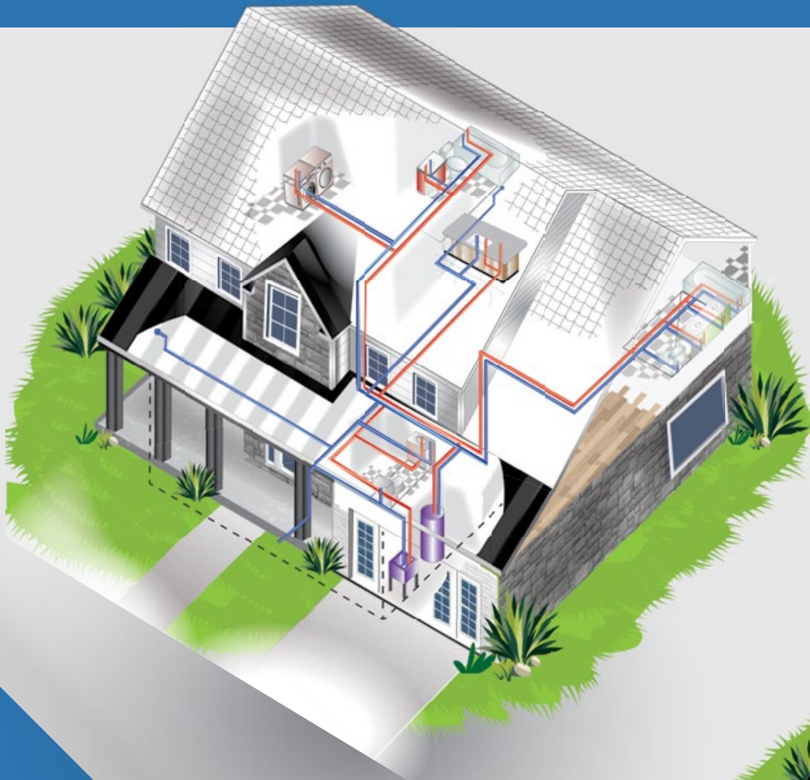
Fire Protection

PEX tubing and fitting systems which are listed to the appropriate UL standards can be used to supply water to fire suppression sprinklers for residential applications. While many sprinkler systems are largely independent from the water distribution system, for some building types they can be combined with a building's cold-water plumbing system in a multi-purpose system. This has the potential to reduce installation costs and the total amount of pipe and fittings installed. Sprinklers, PEX tubing, and fittings must comply with National Fire Protection Association (NFPA) requirements for residential fire sprinkler systems. Several PEX systems meet the requirements of NFPA 13D or IRC P2904 for residential applications. Local codes must be consulted when implementing any fire sprinkler system to ensure that PEX and/or combined systems are permitted for each building type.

Figure B.8 Purple PEX Tubing for Water Reuse

Water Reuse/Reclaim

Reclaim water systems reuse greywater, commonly defined as wastewater from bathtubs, shower drains, sinks, washing machines, and dishwashers. Greywater accounts for 60% of the outflow produced in homes. By designing plumbing systems to separate it from blackwater, greywater can be reused for irrigation, toilets, and exterior washing, resulting in water conservation. PEX tubing systems may be used for reclaimed water systems and may contain special color codes or marking on the products to indicate this application. Be sure to consult your local regulations and the PEX system manufacturer when selecting materials for reclaimed water systems.



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