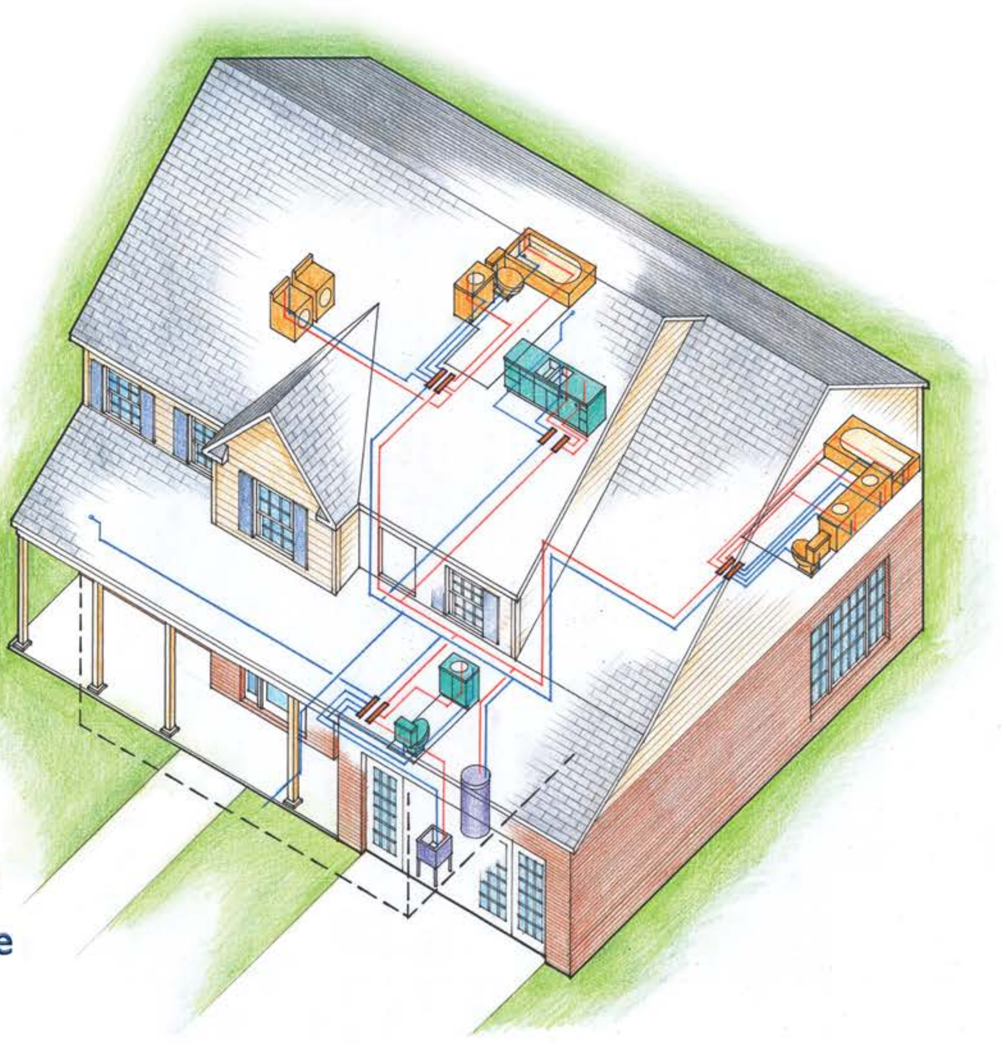
DESIGN GUIDE

Residential PEX Water Supply Plumbing Systems

Second Edition

Applications
Advantages
Material Properties
Joining Methods
Code Acceptance
System Design
Installation
and more



PPFA Plastic Pipe and Fittings Association

ICC ES PMG

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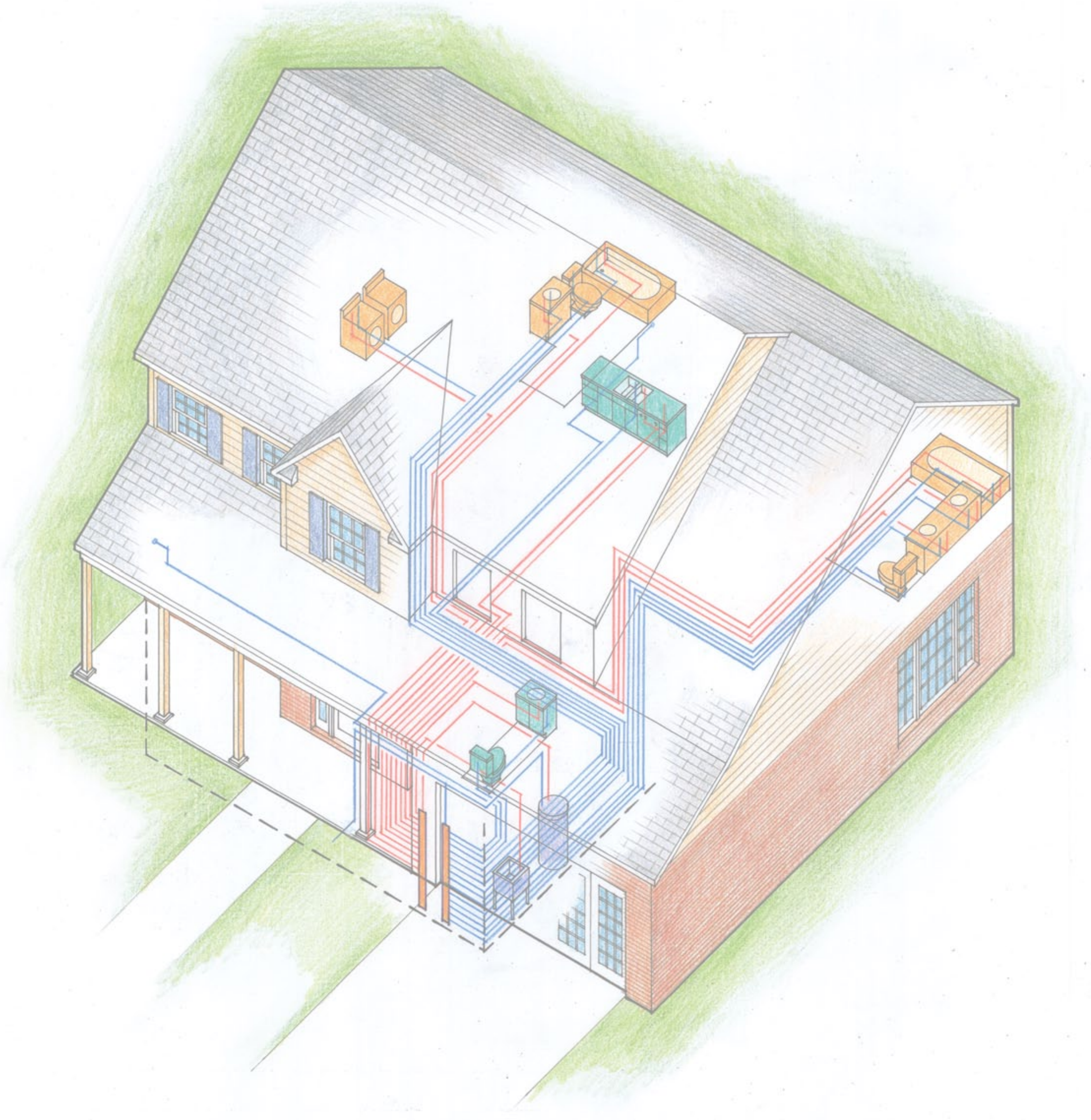

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Residential PEX Water Supply Plumbing Systems

Second Edition

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3 MATERIAL PROPERTIES

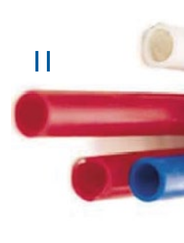
PEX is a material made up of molecules of high-density polyethylene (HDPE) that are permanently linked to each other by a process called crosslinking. Crosslinking makes PEX a "semi-thermoset" polymer, which gives it long-term stability.

Polyethylene can be crosslinked using several technologies. All methods induce links between the single strands of PE to form a dense network through radical reactions. The number of links between the strands 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. This is sometimes referred to as the PEX-a Process.
>
> **Silane –** This method involves grafting a reactive silane molecule to the backbone of the polyethylene. This is sometimes referred to as the PEX-b Process.
>
> **Electron beam –** This method involves subjecting a dose of high-energy electrons to the PE. This is sometimes referred to as the PEX-c Process.

PEX pipe produced by any of the three methods must meet the same qualification requirements as specified in the PEX standards. The letter designations are not related to any type of rating system.

Although the three methods of crosslinking produce slightly different pipe characteristics, all three are commonly used to manufacture approved PEX products. As required in any manufacturing process, procedures for each technology must be established and followed with good quality control checks in place to produce quality products.



For instance, ASTM Standard Specification F876 states, "This specification covers crosslinked polyethylene (PEX) tubing that is outside diameter controlled, made in standard thermoplastic tubing dimension ratios, and pressure rated for water at three temperatures. This specification covers one PEX tubing material in one standard dimension ratio and having pressure ratings for water of three temperatures. The pressure ratings decrease as the temperature is increased. PEX tubing shall be made from polyethylene compounds which have been crosslinked by peroxides, Azo compounds, or silane compounds in extrusion, or by electron beam after extrusion, or by other means such that the tubing meets the performance requirements. The following tests shall be performed: dimensions and tolerances; density; sustained pressure test; burst pressure; environmental stress cracking test; degree of crosslinking; stabilizer functionality; and oxidative stability in potable chlorinated water applications."

Temperature and Pressure Capabilities

PEX piping meets all requirements for temperature and pressure capabilities in residential applications. Consensus standards published by ASTM International and Canadian Standards Association specify temperature and pressure capabilities of PEX systems, and components used in residential applications bear the appropriate test marking.

A pressure rating is the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur. *Temperature/pressure ratings for plastic pipes are based on an extrapolated time-to-failure prediction as defined in ASTM Test Method D2837.* Pressure ratings for PEX pipes are derived from the recommended hydrostatic design basis (HDB) and hydrostatic design stress (HDS) values as issued by PPI. These recommended grades are listed in PPI Technical Report TR-4.

One example of these test requirements is the Hydrostatic Sustained Pressure Strength test: These laboratory tests are performed at several temperatures and are used to demonstrate the pressure ratings which will be marked on PEX pipes. These pressure ratings for water temperatures are 160 psig at 73.4°F and 100 psig at 180°F. Some PEX pipes are also pressure-rated for 80 psig at 200°F.

Another example of these test requirements is the excessive temperature and pressure test: In the event of a water heating system malfunction, PEX systems are designed to accommodate short-term conditions of 48 hours at 210°F and 150 psi until repairs can be made to the water heating system. The most commonly used Temperature & Pressure relief valves (T&P) activates (opens) at either of these temperature or pressure conditions. All PEX systems have been tested to withstand T&P activation for 30 days to ensure that safety requirements are met. As such, PEX systems DO NOT require the use of a special T&P valve.

Corrosion Resistance

PEX pipe will not pit or stress corrode. Corrosion, as an electrolytic process, requires the presence of electrically conductive materials – primarily lead, iron, steel and copper. PEX is a dielectric material, a non-conductor, and does not corrode like metal pipes. Independent testing of PEX pipe and fittings using aggressive potable water conditions demonstrated that neither the pipes nor the fittings suffered from pitting or corrosion. This testing utilized potable water with corrosive pH levels between 6.5 and 6.7, much lower and more aggressive than levels found in common water systems.

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

A related aspect of corrosion in pipes is concerned with flow erosion. Flow erosion tests of PEX fittings were conducted by the PPI, and there was no weight loss. See *Erosion Study on Brass Insert Fittings Used in PEX Piping Systems, PPI-TN-26* for discussion and results.

Erosion

PEX pipe has a smooth interior surface and can withstand high velocities. Under the test conditions reported in *PPI TN-26 Erosion Study on Brass Insert Fittings Used in PEX Piping Systems,* no detectable erosion of the pipe surface occurred at water velocities in excess of 12 ft/sec. Design velocities are generally restricted by factors other than the PEX pipe (i.e. valves, fittings).

Tuberculation

The potential for tuberculation of PEX pipe is minimal. Tuberculation 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 pipe has a smooth interior surface, which provides minimal opportunity for the precipitation of minerals such as calcium carbonate.

Lower Thermal Conductivity/Lower Specific Heat

PEX pipe reduces heat loss through the pipe wall, compared to metal pipes. This means that condensation is less likely to form on PEX pipes in humid environments, and less heat is lost to the environment in hot-water applications.

PEX tubing has a lower range of thermal conductivity, typically 60-70 times lower in comparison with metal plumbing pipes. According to a recent PPI Technical Report, the normalized thermal conductivity for PEX is 2.86 $(BTU \cdot in)/(ft^2 \cdot hr \cdot {}^\circ F)$. Since the wall thickness of PEX is less than 1" and varies by its nominal size (SDR-9), the following table shows the R-value by nominal diameter:

Tubing size	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
R-value	.0277	.0383	.0494	.0604	.0715	.0932

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

Flexibility

The flexible nature 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 pipe by hand; snap-on bend supports to hold the pipe in this position are sometimes used in place of elbows. There is a predetermined minimum bend radius of a 90-degree change of direction without installing a fitting (reference manufacturer's installation instructions). Minimizing joints and connections can result in quicker installations, less potential for leaks at fittings, and less resistance by reducing pressure loss through fittings.

Noise and Water Hammer 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 also with the mass of water that is flowing. When the flow of water is suddenly stopped, such as when a 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 ability of a plumbing pipe to dissipate energy due to surge 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 pipe is 180 times more rigid than PEX pipe.

The surge pressure that causes water hammer can produce instantaneous pressures of 300 to 400 psig, which can, over time, cause damage to rigid pipes, fittings, fixtures, and hot water tanks.

Ultimately, this means that with rigid piping systems, pressure surges can produce noticeable banging sounds as energy is dissipated, 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.

Testing was conducted at the Home Innovation Labs to measure actual pressure surges generated in piping systems of copper and PEX plumbing pipes in response to a quick-acting valve. Details of this study are found in Chapter 8.

In summary, the flexibility of PEX pipe allows the pipe itself to absorb energy from pressure surges and eliminate or reduce the occurrence of water hammer.

Resistance to Freeze Damage

PEX pipes are less susceptible to the effects of cold temperatures retaining their flexibility even below freezing. This flexibility means that if water-filled PEX piping freezes, the elasticity of the material allows it to expand without cracking or splitting, and then to return to its original size upon thawing. This applies when PEX pipes have room to expand evenly along their length, as is typical when installed within walls or ceilings. Water-filled PEX pipes, allowed to freeze inside a slab or highly compacted soil, may not be able to expand evenly and may suffer damage.

PEX Material Designation Code

As listed on page 12, ASTM F876 includes tests for many types of performance. Specifically, F876 has categories for PEX pipe performance in three key areas: chlorine resistance, UV resistance and hydrostatic design strength (HDS). Performance categories are defined in the "Material Designation Code," which is required to be on the printline of PEX pipes. For detailed information about the PEX Material Designation Code see Chapter 9.

Resistance to Chlorine and Chloramines

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. 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 the water distribution system.

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

All PEX pipe must be tested and certified by qualified third-party certification agencies to meet the requirements of ASTM F876, including chlorine resistance. The test conditions of ASTM F2023 require that the test fluid has a minimum oxidative reduction potential (ORP) of 825 mV. To produce test fluid with this high 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 domestic hot water temperature of 140°F and a pressure of 80 psi. Continuous recirculation, timed recirculation and traditional domestic conditions are evaluated by ASTM F2023. The minimum requirement applies to traditional domestic applications, while the other performance categories are also used in certain situations.

ASTM F876 has four categories representing various levels of chlorine resistance ranging from untested to 100% hot water recirculation, as listed in the Material Designation Code. See Chapter 9 for explanations of Material Designation Codes.

PEX piping systems use fittings that also must comply with ASTM standards, and are made from brass, copper, or high temperature engineered polymers that are also chlorine-resistant.

Regarding resistance to chloramines, a research project coordinated by the PPI[6], examined the relative oxidative aggressiveness of the common potable water disinfectants free chlorine and chloramines on crosslinked polyethylene (PEX) pipes. According to the study, "Based on these results, it is the position of PPI BCD that chloramines are less aggressive than free chlorine to PEX pipes. Testing of oxidative resistance using free chlorine, in accordance with ASTM F2023, will provide a conservative estimate of the time-to-failure for PEX pipes when used with the disinfectant chloramines."

In summary, PEX pipe 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.

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

Ultraviolet (UV) Resistance

Like most plastics, the long-term performance of PEX will be affected by UV radiation from sunlight. Although most PEX pipes have some UV resistance, PEX pipes should not be stored outdoors where they are exposed to the sun. PEX pipes should not be installed outdoors, unless they are 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, cover the pipe with a UV-blocking sleeve or pipe insulation as approved by the pipe manufacturer.

Each PEX pipe manufacturer publishes a maximum recommended UV exposure time limit, based on the UV resistance of that pipe as determined in accordance with the stringent 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 North American location for UV energy. Exposed pipes are then re-tested for chlorine resistance in accordance with ASTM F2023 and must show no significant reduction in pipe lifetime.

ASTM F876 has four categories for UV resistance, representing various levels of UV resistance ranging from untested: to 6 months continuous exposure, as listed in the Material Designation Code. See Chapter 9 for explanations of Material Designation Codes. Do not allow PEX pipes to be over-exposed beyond these limits.

- "Ensure that accumulative exposure time to sunlight during storage and installation does not exceed the maximum recommended UV exposure limit as indicated by the manufacturer."

Caution

- Do not store PEX pipes outdoors.
- Keep PEX pipes in original packaging until time of installation.
- Ensure that exposure to sunlight during installation does not exceed the maximum recommended UV exposure time as recommended by the manufacturer.

Safe for Drinking Water

Since PEX piping is used to transport potable water, it must comply with federal regulations for public safety. PEX materials are inert (not chemically reactive) and cannot contaminate the potable water passing through them. The fittings are mechanical and do not require the use of solvents or chemicals that might leach into the water when the system is first used.

Testing and certification must comply with NSF/ANSI Standard 61: *Drinking Water System Components - Health Effects,* and NSF/ANSI Standard 14: *Plastic Pipe System Components and Related Materials.* The primary focus of Standard 61 is to establish minimum health effect requirements for chemical contaminants and impurities that are indirectly imparted into drinking water from products, components, and materials used in potable water systems.

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

PEX pipes do not contain lead[7], harmful volatile organic compounds (VOCs) or BPA (Bisphenol A).

[7] NSF/ANSI Standard 61 – Annex G is used to determine product compliance with the ≤0.25% percent maximum weighted average lead content requirement of certain state and federal regulations. PEX pipes must comply with Annex G to be lead-free.

GLOSSARY

ASTM: American Society for Testing and Materials

Corrosion: deterioration in metals caused by oxidation or chemical action

Crosslinked polyethylene: a polyethylene material which has undergone a change in molecular structure using a chemical or a physical process whereby the polymer chains are chemically linked. Crosslinking of polyethylene into PEX for pipes results in improved properties such as elevated temperature strength and performance, chemical resistance, and resistance to slow crack growth.

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 the PEX pipe to change direction or size, such as a tee, elbow, or coupling

Fixture: a device or appliance at the end of a water supply distribution pipe line. Example: lavatory, water closet, tub/shower, dishwasher

IAPMO: International Association of Plumbing and Mechanical Officials

ICC: International Code Council

IPC: International Plumbing Code

IRC: International Residential Code

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

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

NSPC: National Standard Plumbing Code

Outlet: see fixture

Parallel: a plumbing design that utilizes a central manifold and distribution piping 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

PPFA: Plastic Pipe and Fittings Association

PPI: Plastics Pipe Institute

Scaling: process of mineral buildup on the interior of a pipe

Test fixture: the tub-shower unit farthest from the water source that was instrumented to measure flow rate, flowing pressure, and mixed water temperature in the lab tests

Thermoplastic: having the property of becoming soft when heated and hard when cooled

Thermoset: having the property of becoming permanently hard and rigid when heated or cured

Trunk and branch: a plumbing design that has a large main line that feeds smaller pipes to each fixture

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

UPC: Uniform Plumbing Code

Wait time: the time it takes for hot water to be delivered to the Test Fixture; delivery time

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

Zone: a plumbing system that uses trunk lines from the water source to small manifolds at grouped fixtures, such as a bathroom; can be flow-through or closed end