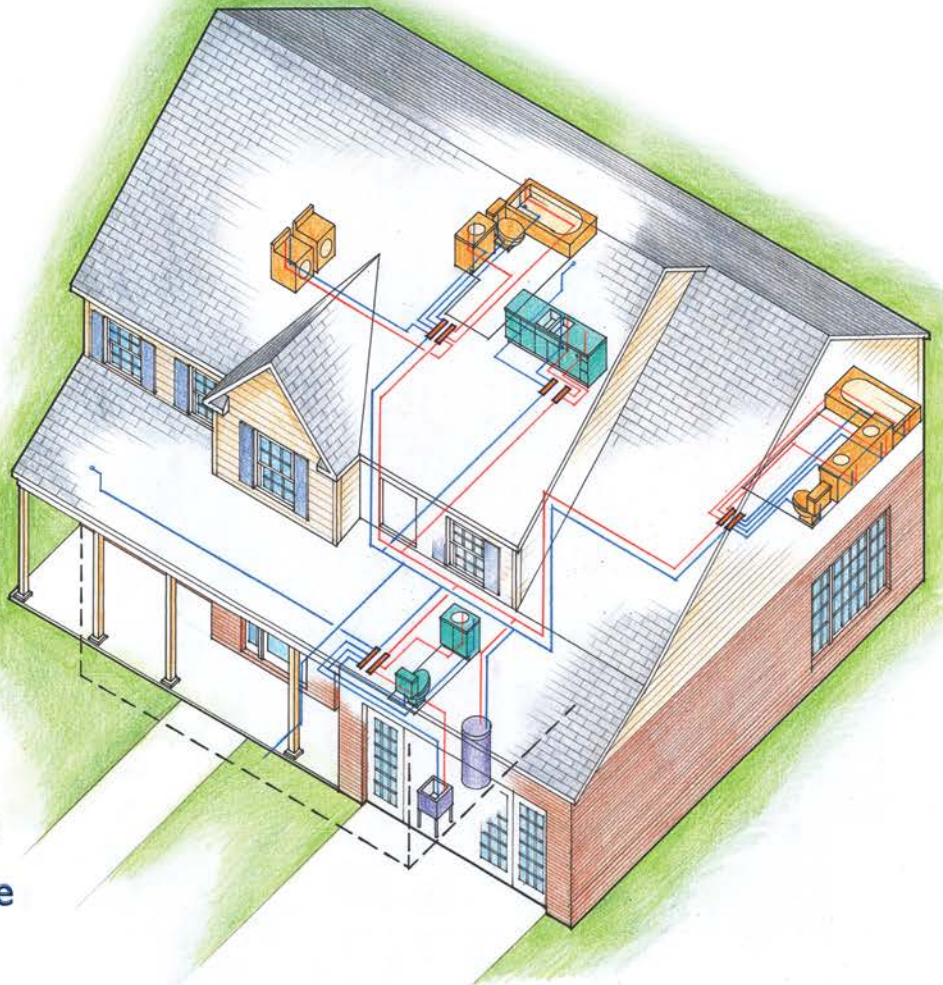


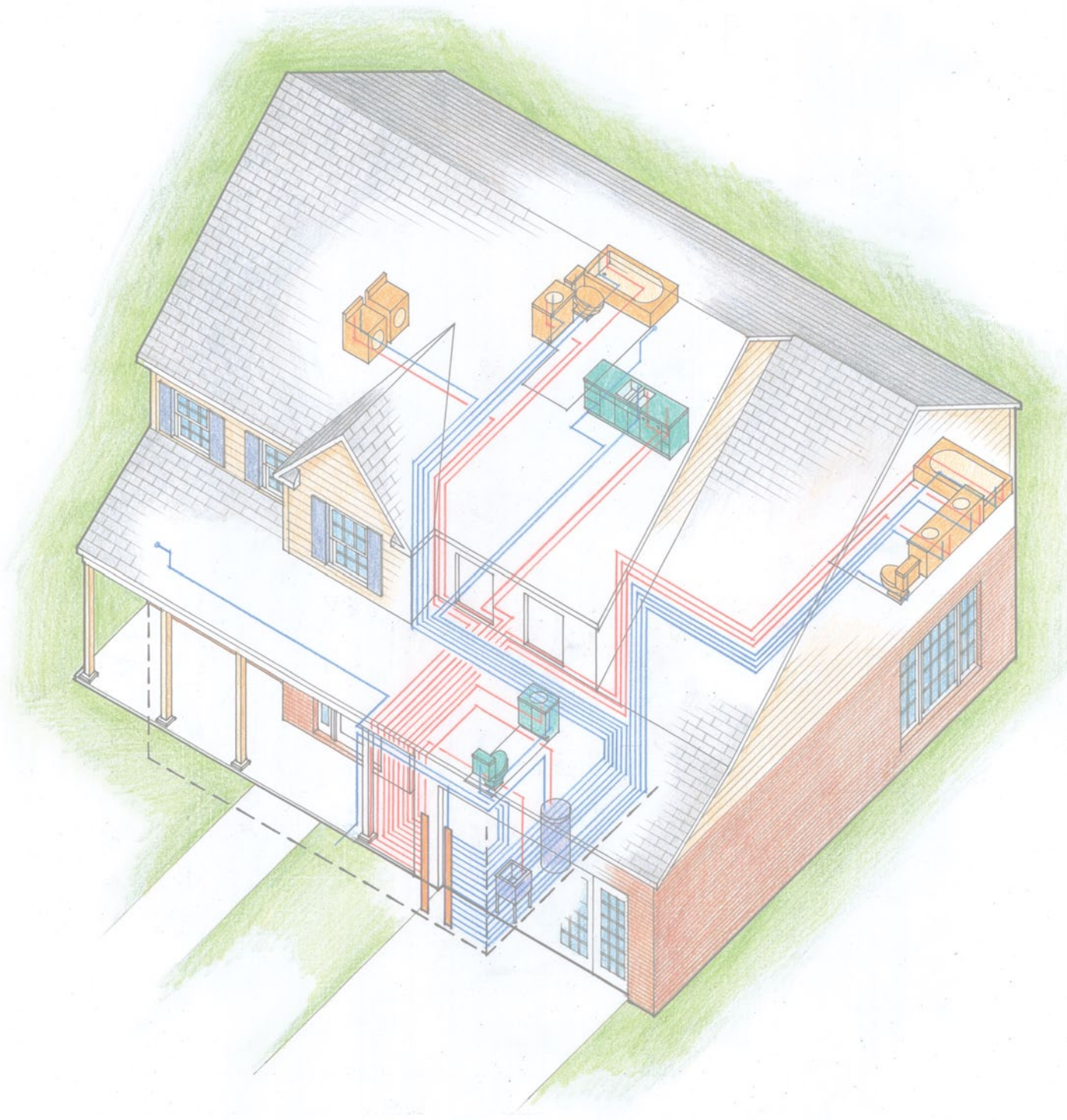
# DESIGN GUIDE

## Residential PEX Water Supply Plumbing Systems

Second Edition

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





# DESIGN GUIDE

## Residential PEX Water Supply Plumbing Systems

Second Edition

Prepared for



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## For Further Information:

Please consult the following websites for the latest version of this publication. Print on demand version available through ICC ES only.

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# INSTALLATION

## Cross-Linked Polyethylene (PEX) Hot- and Cold-Water Distribution Systems and Service Lines

Portions of this chapter have been extracted from the Plastic Pipe and Fittings Association (PPFA) document entitled “Cross-Linked Polyethylene (PEX) Hot- and Cold-Water Distribution Systems,” released in 2012, and are included with permission from the PPFA. It is provided as a general reference to supply basic information regarding the installation process for PEX piping in residential water service applications. It should not be used in place of the applicable manufacturers’ instructions for the installation of any particular system. Local codes may vary, and must be consulted before beginning any piping installation.

### Important Notice

The information in this manual was gathered from publicly available sources, including reports of tests conducted by various independent entities under the test conditions specified in the standards listed. The contents of this manual are informational only and are not intended as an endorsement or warranty with respect to any product or system. The Plastic Pipe and Fittings Association (PPFA) and its members have no responsibility for the design, administration, results, or evaluation of any test. PPFA and its members make no warranties, express or implied, as to: the fitness of any product or system for any particular purpose; the suitability of any product or system for any specific application; or the performance of any product or system in actual construction.



Products or systems used or installed must meet all applicable plumbing or building code provisions as well as the manufacturer's installation or application instructions. Local code authorities and the product or system manufacturer should be consulted with respect to unresolved questions or uncertainties. In the event there is any conflict or inconsistency between the content of this manual and the applicable building or plumbing codes and the manufacturer's installation or application instructions, the codes and the instructions shall be followed.

### Revision Policy

The PPFA Polyolefin Pipe Product Line Committee is responsible for proposing revisions of the manual. All suggestions and recommendations for revisions shall be addressed to the Committee, which shall respond to them as promptly as reasonably possible. The Committee shall review the manual in its entirety at least once every three (3) years.

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## Manual Content & Use

This manual contains information on the installation of Cross-linked Polyethylene (PEX) tubing for hot- and cold-water distribution systems in residential and light commercial installations using tubing up to 2 inch diameter.

Information in this manual shall not be separated as it is often interrelated.

Consult local codes for additional installation requirements.

For additional information contact:

Local officials having jurisdiction (for codes)

Manufacturer (for specific product information)

PPFA (for general installation instructions)

Plastics Pipe Institute (PPI)

## Other Uses of Cross-Linked Polyethylene (PEX) Tubing

- Residential and commercial potable cold- and hot-water distribution systems
- Residential fire protection systems
- Hydronic radiant heating and cooling, using warm or chilled fluids
- Outdoor snow and ice melting
- Outdoor turf conditioning
- Ice surface piping
- Hot-water distribution piping
- Hot-water baseboard piping
- Warm- and hot-water radiator connection piping
- Potable water service pipes
- Geothermal ground loop heat exchangers
- Chilled water piping
- Specialized industrial and mining applications

PEX is typically *not* used for refrigerant line piping or medical gas applications.

PEX is a unique material that provides many opportunities for new applications. Please discuss your application with any PEX manufacturer to determine if PEX is the material of choice for the application.

Consult tubing manufacturer for details.

## Tubing Identification

Check the PEX tubing for the proper ASTM identification marking.

Use	ASTM Standard	Canadian Standard
-----	---------------	-------------------

Hot/Cold Water	F876 or F876 / F877 and Standard for Fittings	CSA B137.5
----------------	---	------------

Check for potable water listing (NSF International [NSF-pw], or other recognized listing agency).

### Marking

### Typical Example

Tube size	$\frac{3}{4}$ " CTS (0.875 O.D.)	
ASTM Standard	ASTM F876 or F876/F877	
Standard dimension ratio	SDR 9	
Pressure rating	160 psi @ 73.4°F, 100 psi @ 180°F	
*Marks of listing agencies	NSF-pw	NSF International
	CSA	CSA Group
	UPC	IAPMO R&T
	UL	Underwriters Laboratories
	ICC – ES PMG	ICC Evaluation Services
	or others	

*\*Note: Manufacturers may choose the agency (or agencies) with which they list. All of the examples shown are not required on an individual product.*

List of fittings standards with which tubing is compatible	Examples (ASTM F1807, F1960, F2080 or others)
Manufacturer name or trademark	Depends upon manufacturer
Production code	Depends upon manufacturer
Material Designation Code	Depends on product use See “designation code” section

## Fitting Identification

All fittings shall be marked with manufacturer's name or trademark or other identification mark, plus the ASTM standard specification with which the fitting complies.

## Applicable Standards

- ASTM F876 – Standard Specification for Cross-linked Polyethylene (PEX) Tubing
- ASTM F877 – Standard Specification for Cross-linked Polyethylene (PEX) Plastic Hot and Cold Water Distribution Systems
- ASTM F1807 – Standard Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR 9 Cross-linked Polyethylene (PEX) Tubing and SDR 9 Polyethylene of Raised Temperature (PE-RT) Tubing
- ASTM F1960 – Standard Specification for Cold Expansion Fittings with PEX Reinforcing Rings for use with Cross-linked Polyethylene (PEX) Tubing
- ASTM F2159 – Standard Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR 9 Polyethylene of Raised Temperature (PE-RT) Tubing
- ASTM F2080 – Standard Specification for Cold-Expansion Fittings With Metal Compression-Sleeves for Cross-Linked Polyethylene (PEX) Pipe
- ASTM F2098 – Standard Specification for Stainless Steel Clamps for Securing SDR9 Cross-linked polyethylene (PEX) Tubing to Metal Insert Insert and Plastic Insert Fittings
- CSA B137.5 – Cross-linked Polyethylene (PEX) Tubing Systems for Pressure Applications
- ANSI/AWWA C904-06 – AWWA Standard for Cross-Linked Polyethylene (PEX) Pressure Pipes 1/2 inch (12 mm) through 3 inch (76 mm) for Water Service
- NSF/ANSI 61 – Drinking Water System Components – Health Effects
- NSF/ANSI 14 – Plastic Piping System Components and Related Materials

## Limitations on PEX Use

Do not use in applications where the temperature of the water could exceed 180°F at 100 psi unless specifically approved in the code, e.g., water heater relief line. See manufacturer's recommendations for higher operating temperatures at lower pressures.

**Do not use in any application where tubing will be exposed to direct sunlight.**

Do not allow tubing to come in extended contact with any of at least the commonly encountered construction materials listed below: (This list is not all-inclusive.)

- Pipe thread sealing compounds
- Fire wall penetration sealing compounds. *Exception: water soluble, gypsum-based caulking or other sealants approved by the PEX tube manufacturer*

- Petroleum-based materials or sealants such as:
  - Kerosene, Benzene, Gasoline, Solvents, Fuel Oils, Cutting Oils, Asphaltic Paint, and Asphaltic Road Materials, Acetone, Toluene, and/or Xylene

Consult your tubing manufacturer if you have questions about these or any other materials not listed.

Do not place any PEX tubing in heavily contaminated soils or other heavily contaminated environments.

Do not use tubing with gouges, cuts, cracks, abrasions, evidence of chemical attack, or other defects, or tubing that has been crushed or kinked.

Do not use PEX in swimming pool piping systems.

Copper or brass fittings, when used in a PEX piping system, have the same limitations as copper or brass fittings used in plumbing or heating systems.

Store fittings in containers that are free of oil, grease, lubricants, solder flux, or other chemicals and away from corrosive atmospheres (Example: Ammonia).

### Designation Codes of ASTM F876

The tubing material designation code shall consist of the abbreviation for the type of plastic (PEX) followed by four Arabic digits that describe short-term properties in accordance with applicable ASTM standards.

The first digit is for chlorine resistance tested in accordance with Test Method F2023.

A digit “0” indicates that the PEX tubing either has not been tested for chlorine resistance or that the PEX tubing does not meet the minimum requirement for chlorine resistance.

A digit “1” indicates the PEX tubing has been tested and meets the F 876 requirement for minimum chlorine resistance at the end use condition of 25% at 140°F (60°C) and at 75% at 73°F (23°C). A digit “2” is reserved for future application.

A digit “3” indicates that the PEX tubing has been tested and meets the F 876 requirement for minimum chlorine resistance at end use condition of 50% at 140°F and 50% at 73°F.

A digit “4” is reserved for future application.

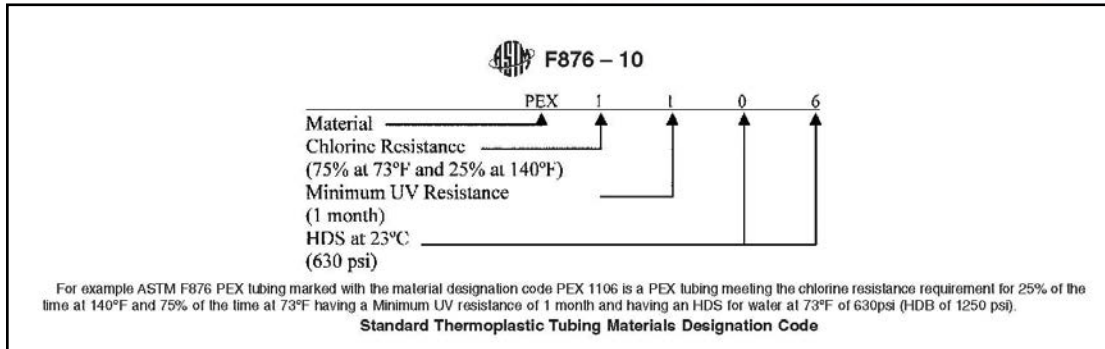
A digit “5” indicates that the PEX tubing has been tested and meets the requirement for minimum chlorine resistance at end use conditions of 100% of the time at 140°F.

The second digit is for demonstrated UV resistance of PEX material when tested in accordance with Test Method F2657. A digit “0” indicates that the PEX tubing either has not been tested for UV resistance or that the PEX tubing does not meet the minimum requirement for UV resistance. A digit “1” indicates that the PEX tubing has been tested and meets the requirements for 1 months exposure rating. A digit “2” indicates that the PEX tubing has been tested and meets the requirements for 3 months exposure rating. A digit “3” indicates that the PEX tubing has been tested and meets the requirements for 6 months exposure rating.

The last two digits are the hydrostatic design stress for water at 73°F (23°C) in units of 100 psi with any decimal figures dropped.



Where the hydrostatic design stress code contains less than two figures, a zero is used for the third digit.

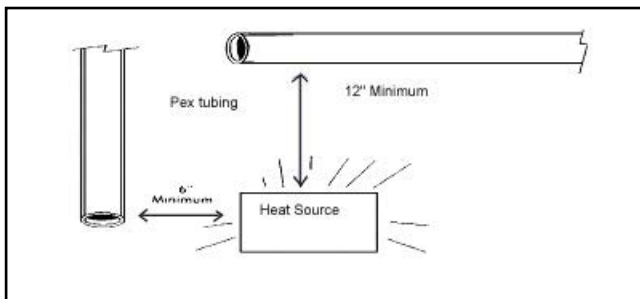


## TUBING INSTALLATION PRACTICES

### General Installation

Review all limitations on the use of cross-linked polyethylene tubing, and the fitting system you have selected to use.

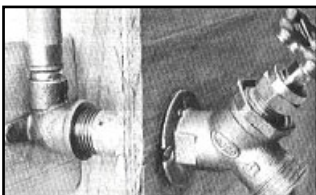
Keep tubing a minimum of 12 inches vertically or 6 inches horizontally from sources of high heat, such as recessed light fixtures, flue gas vents, or heating appliances.



Do not install PEX tubing downstream of any point-of-use water heater or immersed coil heater in a boiler where the output temperature can exceed 180°F or closer than 6 inches upstream. Contact manufacturer for recommended metallic transition fittings.

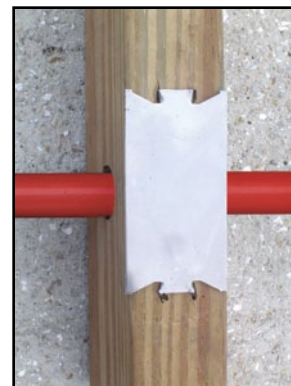
PEX tubing may be connected directly to residential electric water heaters, if the local

code and manufacturer’s instructions allow. When connecting PEX tube to gas water heaters, the tube must be kept at least 6 inches away from the exhaust vent of the heater. Flexible metal water heater connectors may be needed in some instances.



Hose bibbs shall not be supported by PEX tubing. Hose bibbs shall be anchored to prevent strain on PEX tubing.

Use only continuous length tubing (no fittings) when installing PEX under or within a slab. Protect PEX tubing with nonmetallic sleeves where it penetrates a slab or foundation. (Examples: PVC bend guides, PE sleeving). Protect tubing from nail damage where appropriate.



Nail plate

## Bending the Tubing

Tubing Size (in. nominal)	Minimum Bending Radius (in.) CTS
3/8	4
1/2	5
3/4	7
1	9

The following recommended minimum bending radius values are based on 8xOD and should be considered a guideline, consult the manufacturer for product specific recommendations.

Using bend supports often allow for tighter bend radius.

*NOTE: If using tubing in coils, and bending the tubing against the coil direction, the minimum bending radius is 3 times the radius given above (e.g., 3/8" tubing = 3 x 4 = 12").*

## Handling and Storing Tubing and Fittings



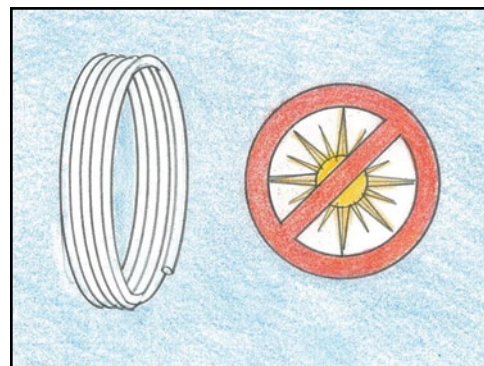
Do not drag the tubing over rough terrain, rocks, or any surface that can cut, puncture, or damage the tubing wall.



Do not crush or kink the tubing.



Inspect all tubing and fittings before and after installation. Cut out and replace all damaged sections or fittings.



Tubing shall be stored in a way to protect the system from mechanical damage (slitting, puncturing, etc.). Tubing and fittings shall be stored undercover for cleanliness and to avoid exposure to sunlight. Consult manufacturer for recommended limits for outside storage.

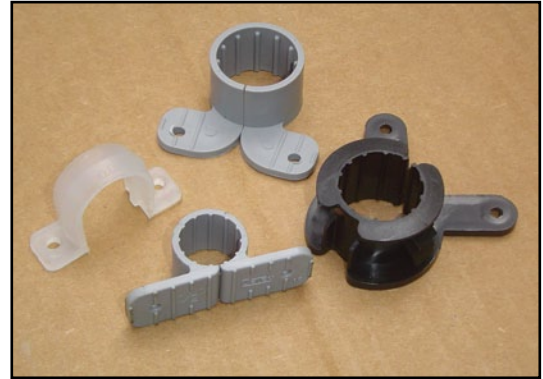
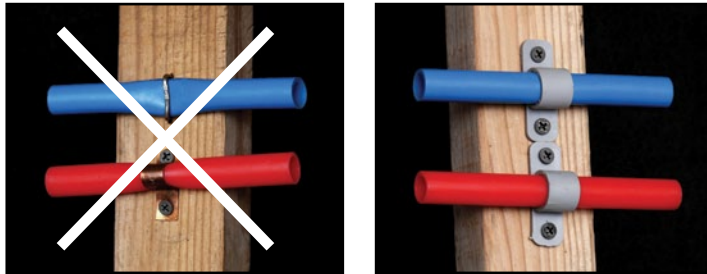
## TUBING SUPPORTS

### Selection and Inspection

Plastic hangers and straps are recommended, but metal supports that are designed for use with plastic tubing can be used.

Do not use supports that pinch or cut the tubing. Support should allow free tubing movement.

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



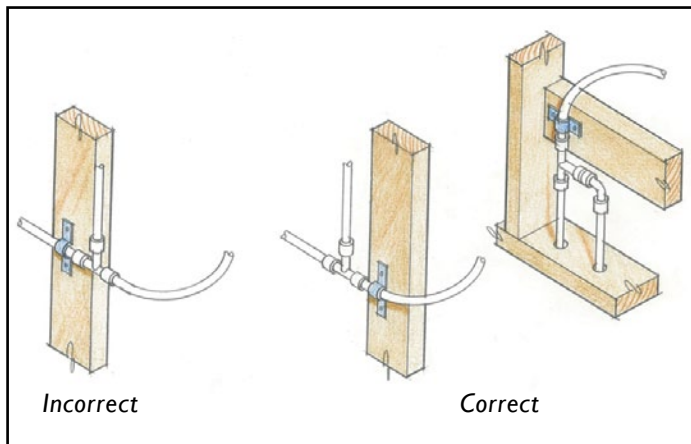
### Support Spacing and Location

#### Horizontal Tubing Support Spacing

Nominal Tubing Diameter (inch)	Spacing (inch)
3/8, 1/2, 3/4, 1	32
1-1/4, 1-1/2, 2	48

*Note: Some codes allow only up to 32”, check with your local AHJ before installing.*

Vertical tubing shall be supported at every floor (8-feet to 10-feet height) and at the mid-floor guide between floors.

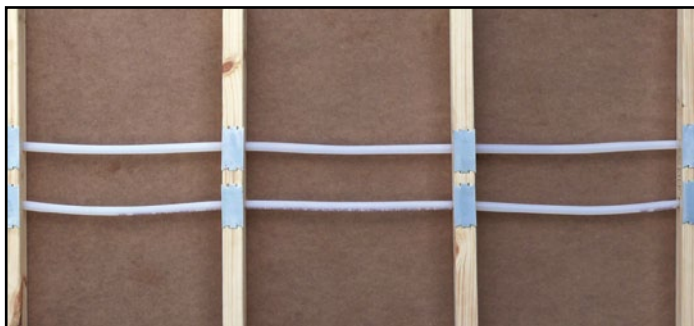


When penetrating metal studs, utilize a properly-designed bushing or sleeving material on all penetrations to protect tubing.

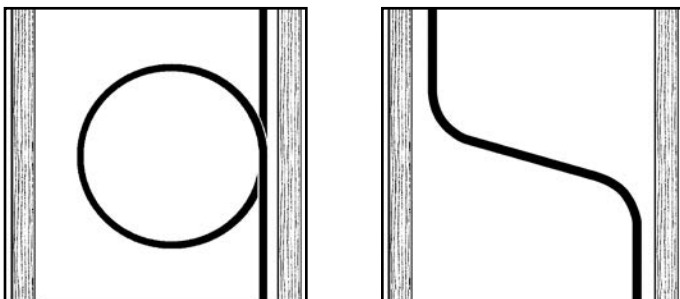
Tubing and fittings shall be installed without placing stress on the connection. Stress on connections frequently occurs when tubing is not properly strapped at changes of directions. See illustrations for proper methods.

### Expansion/Contraction of Tubing

Do not pull tubing tight during installation. This can cause excessive tensile forces on fittings and connections when tubing cools and contracts. Allow 1/8-inch slack per foot of installed tubing. Expansion can usually be accommodated by the tubing's flexibility for sizes up to and including 1 inch. Expansion loops or offsets may be used if needed depending on installation and sizes used



*Allow 1/8-inch slack per foot of installed tubing.*



*Expansion loops (left) and offsets (right) also provide means to accommodate tubing expansion and contraction.*

### Hydraulic Shock (Pressure Surge)

The following table provides the maximum pressure that will occur from rapid closure of a valve in the various tubing systems at a given velocity. The faster the velocity, the greater the potential hydraulic shock (pressure surge).

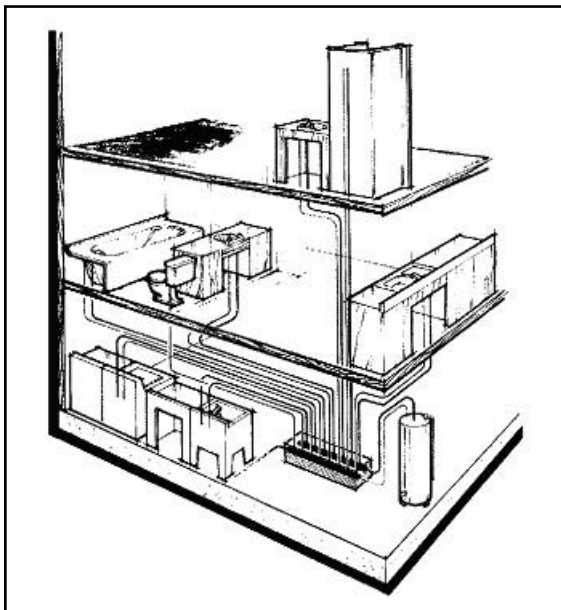
Excessive hydraulic shock (pressure surge) may result in audible water hammer with metallic piping systems, though this is highly unlikely with PEX tubing due to the flexibility of the tubing itself.

The table shows the additional hydraulic shock (pressure surge) that can occur in various types of pipes at the water velocities shown when a fast-acting valve closes. Hydraulic shock pressure is in addition to the system static pressure (measured on site). To determine the instantaneous total system pressure that occurs, add the hydraulic shock pressure to the static pressure.

Hydraulic Shock (psi at 73 F)				
Velocity (fps)	4	6	8	10
PEX	58	87	116	145
Copper	200	300	400	505
Galvanized Steel	240	360	475	595

For normal plumbing installations, water hammer arrestors are not necessary with a PEX tubing system.

In predominantly metal piping systems in which PEX is used, it may be necessary to install water hammer arrestors.



*This drawing represents a typical manifold system*

### Parallel Water Distribution Manifold Plumbing (Parallel) Systems

Each faucet or water outlet is fed by its own dedicated line from the manifold. Manifolds for hot water should be installed near the water heater to minimize hot water delivery time. Manifolds shall be installed at least 36 inches away vertically, or 18 inches away horizontally from the water heater. A manifold for cold water only may be installed near the water supply.

The following information applies to a PEX tubing plumbing manifold system in addition to the general limitations and installation information on PEX tubing and fittings in this manual.

- Manifolds can be installed in a horizontal or vertical position.
- In larger installations, with multiple water heaters, use a manifold at each water heater for the fixtures served by the water heater.

- Tubing shall 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.
- Shut-off valves may be placed at the manifold or at the fixture. Check with your local inspector for the local requirements.
- Tubing shall not be pulled tight. Leave slack to allow for expansion and contraction.
- 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.
- 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.
- Manifolds shall be accessible and protected from freezing and exposure to sunlight.
- Hot-water and cold-water manifolds shall be sized in accordance with the following table:

Nominal Size Internal Diameter (in.)	Maximum Demand (gpm)	
	Velocity of 4 fps	Velocity of 8 fps
3/8	1.2	2.5
1/2	2	5
3/4	6	11
1	10	20
1-1/4	15	31
1-1/2	22	44
2	26	52

- 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.

- Individual distribution lines supplied from a manifold and installed as part of a parallel water distribution system shall be sized in accordance with the following table:

Minimum Sizes of Fixture Water Supply Lines in Manifold Systems	
Fixture	Minimum Pipe Size (in.)
Bathtubs and Whirlpool Tubs	1/2
Tub and Shower	1/2
Shower only (Single Head)	3/8
Bathroom Lavatory	3/8
Water Closet, Residential	3/8
Water Closet, Commercial	1/2
Kitchen Sink	3/8
Laundry Washing Machine	3/8
Utility Sink	3/8
Bar Sink	3/8
Urinal, Flush Tank	3/8
Urinal, Flush Valve	1/2

## Retro-Fit Installations

PEX tubing is ideal for retro-fit applications. The flexibility of the product and continuous lengths allow for easier installation in existing walls and structures than traditional rigid piping systems. Several varieties of fitting adapters are available for simple transition between piping systems, such as solder, threaded, and polybutylene adapters. Also, PEX tubing is available in coils and straight lengths which are often used for easier installation in existing walls. Consult the manufacturer for available product offerings. The use of PEX in retro-fit applications should follow the same installation guidelines described in this manual as new construction regarding the use and design of the PEX system.

## Thawing PEX Tubing Systems

PEX tubing systems should not be intentionally subjected to freezing.

Do not use open torch or excessive heat to thaw PEX tubing. Tubing failure or damage can result. Use a hot air gun or a blow dryer.

Heat (DO NOT USE A TORCH) must be applied directly to the frozen tubing section. Temperature on tubing shall not exceed 180°F.



Several suitable methods exist to thaw PEX tubing. They include:

- A commercial system that pumps heated water through the tube to the ice blockage, and returns the cooled water for reheating
- Wet hot towels
- Hot water
- Hand-held hair dryer
- Low-wattage electrical heating tape

### Pressure Testing and Inspection of the Completed System

Test system with water.

Test pressure shall be at least equal to the expected working pressure (main pressure), but not less than 40 psi and not greater than 200- psi at 73°F.

Compressed air or any other compressed gases should not be used for pressure testing plastic plumbing systems.

#### EXCEPTIONS:

For plastic piping systems specifically designed for use with compressed air or gasses;

- Manufacturers' instructions must be strictly followed for installation, visual inspection, testing and use of the systems, and
- Compressed air or other gas testing is not prohibited by the authority having jurisdiction (AHJ).

When compressed air or other gas pressure testing is specifically authorized by the applicable written instructions of the manufacturers of all plastic pipe and plastic pipe fittings products installed at the time the system is being tested and compressed air or other gas testing is not prohibited by the authority having jurisdiction (AHJ).

The manufacturer should be contacted if there is any doubt as to how a specific system should be tested.

Do not allow water in system to freeze.

### Disinfection of Potable Water Systems

If disinfection of the system is required by code, and the conditions are not specified, the following procedures can be used.

<b>Chlorine Concentration</b>	<b>Disinfection Period</b>	<b>Authority</b>
50 to 100 ppm	3 hours	AWWA*
50 ppm	6 hours	ICC**

\* *American Water Works Association*

\*\* *International Code Council*



Select one the recommended test procedures.

Pre-mix the solution before injection into the system.

Thoroughly flush all lines of the system at the end of the disinfection period.

**Failure to do so may damage the plumbing system.**

## Buried PEX Water Service Lines

### Material

Plumbing codes approves the use of ASTM F876 and CSA B137.5 tubing within the jurisdiction of the code, generally meaning within the property line. PEX intended for use for municipal service lines (outside the property line) should be manufactured according to ANSI/AWWA C904. This standard describes cross-linked polyethylene (PEX) pressure pipe for water service.

### Fittings

Consult PEX manufacturer for proper fittings for water service application.

Compression joint fittings or valves in accordance with AWWA C800 are compatible with PEX tubing. As with CTS polyethylene pipe, insert stiffeners are required.

### Trench Preparation

Trench bottom shall be solid with no hollows, lumps, rocks, or other materials that could damage the tubing.

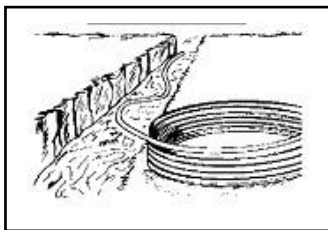
### Laying the Tubing

Tubing should be laid with sufficient slack (snaking) to accommodate any contraction due to cooling prior to backfilling. Tubing will expand or contract approximately 1.00 inch in length for each 10°F change in tubing temperature for each 100 feet of tubing.

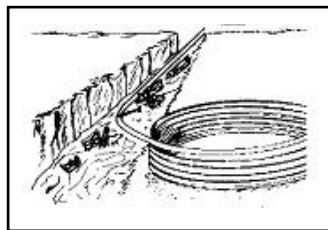
Minimum bending radius requirements for PEX tubing shall be followed. See “Bending the Tubing” Table.

Inspect tubing for damage. Remove and replace damaged sections.

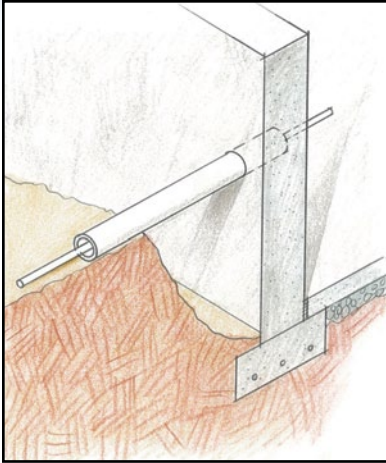
In poor soil conditions, such as mud, rock, black gumbo, or clay, it is necessary to excavate deeper and use good clean fill or granular fill to smooth the trench bottom.



Correct



Incorrect



### Penetrating Foundation or Basement Walls

When PEX is run 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. The purpose of this protective sleeve is to prevent 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 to prevent leakage into the building.

*Note: Petroleum-based caulks or sealants should not come in direct contact with PEX.*

### Slab-on-Grade Installation

#### Laying and Supporting Tubing under Slab

Only continuously-run lengths of tubing without fittings shall be used when installing PEX under a slab. All connections shall be outside or above the slab. Tubing shall be completely buried by a suitable, easily compacted, backfill material such as sand or pea gravel. PEX tubing should be installed under the rebar, re-mesh, or tensioning cables in the slab. PEX tubing shall be covered or fastened to prevent the tubing from floating or being pulled up to the slab surface.

PEX tubing does not have to be sleeved its entire length where it lies beneath a slab. PEX tubing shall be protected with a non-metallic sleeve where it comes through the slab. Because PEX is flexible, it may need support to keep it from falling back onto the slab once it exits the slab. To prevent this, PEX can be carefully tied to re-bar, wood stakes or rigid drain pipe for support. This will serve to protect the PEX tubing as the slab is poured, leveled and smoothed and from subsequent framing and construction work.

If termiticides or pesticides are applied to the soil all ends of the tubing should be closed or capped to prevent entry 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 may be exposed to UV light for unspecified periods of time after the slab is poured and before the structure is framed and enclosed. To prevent damage from UV exposure, PEX tubing and fittings that are exposed above the slab shall be wrapped with an opaque covering such as black polyethylene bags or sheeting immediately after the pouring of the slab. This covering should extend down to the surface of the slab to protect all of the tube above the slab from excessive UV exposure. For specific limitations on UV exposure, consult the PEX tube manufacturer.

## Backfilling

Do not use clay, silt, or rocky backfill. Remove the construction materials, trash, or foreign objects from trench prior to backfilling.

The tubing and fittings should be surrounded with good clean fill, or sand, or river run gravel of 1/2-inch maximum particle size.

Compact the initial backfill around the tubing to provide adequate tubing support and prevent settlement. It is particularly important to adequately compact the soil around the tap connection.

It is recommended that the tubing be pressurized with water prior to backfilling to reveal any damage.

## Technical Data

### Tubing Dimensions and Weights

PEX Pipe Dimensions					
Nominal Diameter	OD	Wall	ID	Weight	Volume <sup>3</sup>
	inches <sup>1</sup>	inches <sup>2</sup>	inches	lb/ft	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
<sup>1</sup> Average OD from ASTM F 876 <sup>2</sup> Average wall thickness from ASTM F 876 <sup>3</sup> Typical pipe volumes in US gallons, not imperial					

Tubing water flow rate, velocity, and frictional losses are given in the following tables. Long-radius tubing bends have the same head loss as straight tubing.

### Flow Rate and Velocity

Flow Velocity								
Flow Rate	Flow Velocity ft/sec							
GPM	3/8"	1/2"	5/8"	3/4"	1"	1 1/4"	1 1/2"	2"
0.5	1.67	0.91	0.62	0.45	0.27	0.18	0.13	0.08
0.75	2.50	1.36	0.93	0.68	0.41	0.28	0.20	0.12
1.0	3.33	1.81	1.24	0.91	0.55	0.37	0.26	0.15
1.5	5.00	2.72	1.86	1.36	0.82	0.55	0.40	0.23
2.0	6.67	3.62	2.48	1.81	1.10	0.74	0.53	0.31
2.5	8.34	4.53	3.10	2.27	1.37	0.92	0.66	0.38
3.0	10.00	5.43	3.72	2.72	1.65	1.10	0.79	0.46
3.5	11.67	6.34	4.34	3.18	1.92	1.29	0.92	0.54
4.0		7.24	4.96	3.63	2.20	1.47	1.06	0.62
4.5		8.15	5.58	4.08	2.47	1.65	1.19	0.69
5.0		9.05	6.20	4.54	2.75	1.84	1.32	0.77
6.0		10.86	7.44	5.44	3.30	2.21	1.58	0.92
7.0			8.68	6.35	3.85	2.57	1.85	1.08
8.0			9.92	7.26	4.40	2.94	2.11	1.23
9.0			11.16	8.17	4.95	3.31	2.38	1.39
10.0				9.07	5.50	3.68	2.64	1.54
11.0				9.98	6.05	4.04	2.90	1.69
12.0				10.89	6.60	4.41	3.17	1.85
13.0				11.79	7.15	4.78	3.43	2.00
14.0					7.70	5.15	3.70	2.16
15.0					8.25	5.52	3.96	2.31
16.0					8.80	5.88	4.22	2.46
17.0					9.35	6.25	4.49	2.62
18.0					9.90	6.62	4.75	2.77
19.0					10.45	6.99	5.02	2.92
20.0					11.00	7.35	5.28	3.08
25.0						9.19	6.60	3.85
30.0						11.03	7.92	4.62

Flow Velocity <i>(continued)</i>								
Flow Rate	Flow Velocity ft/sec							
GPM	3/8"	1/2"	5/8"	3/4"	1"	1 1/4"	1 1/2"	2"
35.0							9.24	5.39
40.0							10.65	6.16
45.0							11.88	6.93
50.0								7.70
55.0								8.47
60.0								9.24
65.0								10.01
70.0								10.78
75.0								11.55

## Friction Losses

Type of Fitting	Equivalent Length of Tubing (ft.)			
	3/8" Size	1/2" Size	3/4" Size	1" Size
Coupling	2.9	2.0	0.6	1.3
Elbow 90°	9.2	9.4	9.4	10.0
Tee-branch	9.4	10.4	8.9	11.0
Tee-run	2.9	2.4	1.9	2.3

Friction losses stated are representative only, consult manufacturer for specific fitting friction losses of the connection system being used.

**Pressure Loss and Flow Rate**

Pressure Loss								
60°F (16°C) Water								
Flow Rate	Pressure Loss psi/100 ft of Pipe							
GPM	3/8"	1/2"	5/8"	3/4"	1"	1 1/4"	1 1/2"	2"
0.5	1.95	0.44	0.18	0.08	0.02	0.01	0.00	0.00
0.75	4.14	0.94	0.37	0.17	0.05	0.02	0.01	0.00
1.0	7.05	1.59	0.63	0.30	0.09	0.03	0.01	0.00
1.5	14.93	3.38	1.35	0.63	0.19	0.07	0.03	0.01
2.0	25.44	5.76	2.29	1.07	0.32	0.12	0.05	0.01
2.5	38.45	8.70	3.46	1.62	0.48	0.18	0.08	0.02
3.0	53.90	12.20	4.86	2.27	0.67	0.25	0.11	0.03
3.5	71.70	16.23	6.46	3.02	0.89	0.34	0.15	0.04
4.0		20.78	8.27	3.87	1.14	0.43	0.19	0.05
4.5		25.85	10.29	4.81	1.42	0.53	0.24	0.06
5.0		31.41	12.51	5.85	1.73	0.65	0.29	0.08
6.0		44.03	17.53	8.20	2.42	0.91	0.41	0.11
7.0			23.32	10.91	3.22	1.21	0.54	0.15
8.0			29.86	13.97	4.13	1.55	0.69	0.19
9.0			37.14	17.38	5.14	1.93	0.86	0.23
10.0				21.12	6.24	2.35	1.05	0.28
11.0				25.20	7.45	2.80	1.25	0.34
12.0				29.60	8.75	3.29	1.47	0.40
13.0				34.33	10.15	3.81	1.70	0.46
14.0					11.64	4.38	1.95	0.53
15.0					13.23	4.97	2.22	0.60
16.0					14.91	5.60	2.50	0.67
17.0					16.68	6.27	2.80	0.75
18.0					18.54	6.97	3.11	0.84
19.0					20.49	7.70	3.44	0.93
20.0					22.54	8.47	3.78	1.02
25.0						12.81	5.72	1.54

Pressure Loss <i>(continued)</i>								
60°F (16°C) Water								
Flow Rate	Pressure Loss psi/100 ft of Pipe							
GPM	3/8"	1/2"	5/8"	3/4"	1"	1 1/4"	1 1/2"	2"
30.0						17.95	8.01	2.16
35.0							10.66	2.87
40.0							13.65	3.68
45.0							13.98	4.57
50.0								4.56
55.0								6.63
60.0								7.79
65.0								9.04
70.0								10.37
75.0								11.78

Shown is pressure loss in units of psi per 100 feet of pipe.

### Connection (Transition) to Other Piping Materials

Solder copper transition fittings onto the copper pipe and allow cooling before connecting to PEX tubing. High heat (greater than 180°F) may damage the PEX tubing.

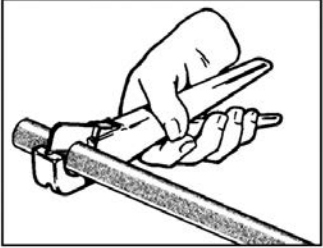
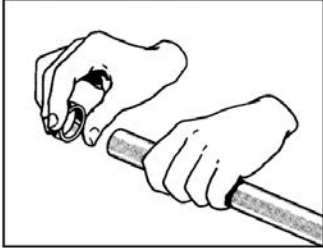
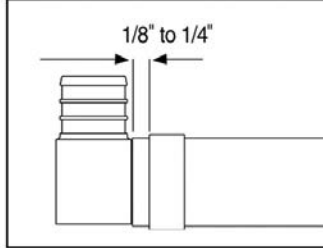
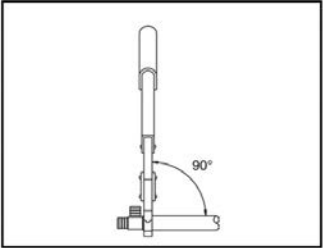
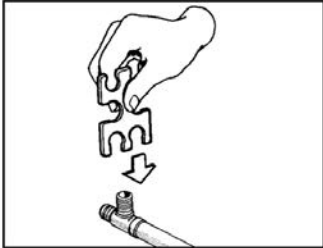
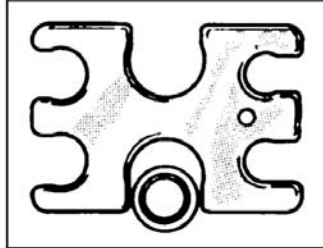
Do not use plastic male pipe threads or non-gasketed plastic female pipe threads when making a connection to metal pipe threads. Use only manufacturer's recommended transition fittings.

When making connections to CPVC pipe or fittings, use only approved transition fittings.

## Joining Procedures Utilizing Metallic or Polymer Insert Fittings

### Insert Fitting with a Black Copper Crimp Ring (ASTM F1807 or ASTM F2159)

#### Making a PEX Crimp Connection

		
<p>1. Square off tubing to proper length. Uneven, jagged or irregular cuts will produce unsatisfactory connections.</p>	<p>2. Slide the correct size crimp ring over end of the tubing.</p>	<p>3. Insert the fitting into the pipe to the shoulder or tube stop. Position the ring 1/8" to 1/4" from the end of the tubing.</p>
		
<p>4. Center the crimping tool jaws exactly over the ring. Keep the tool at 90° and close the handles completely. DO NOT CRIMP TWICE.</p>	<p>5. When checking crimps with a GO/NO GO gauge, push the gauge STRAIGHT DOWN over the crimped ring. NEVER slide the gauge in from the side. Do not attempt to gauge the crimp at the jaw overlap area. The overlap area is indicated by a slight removal of the blackening treatment.</p>	<p>6. A crimp connection is considered good if the GO gauge fits the ring and the NO GO does not. A crimp connection is considered bad if the GO gauge does not fit the ring or the NO GO gauge does fit. Bad crimps must be cut out of the tubing and replaced.</p>

#### Making a Connection

#### Incorrect Connections

The consequence of not following correct procedures is a potential for leaks.

- Ring crimped over end of tube  
Result: Doesn't cover enough ribs and/or tool could crush or crack fitting
- Tool not at 90 degrees to tube when crimped  
Result: Insufficient rib coverage; tubing dented



- Ring not completely covered by crimp tool  
Result: Ring distortion, non-uniform crimp
- Tubing not cut squarely  
Result: Insufficient rib coverage
- Ring too far from pipe end  
Result: Insufficient rib coverage

## Tools and Rings

Use tools recommended by fitting and tubing manufacturers.

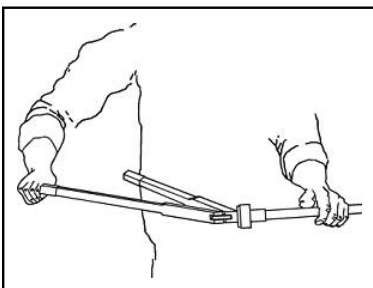
All tools must make a full-circle crimp.

Check tool adjustment at least daily and readjust as necessary.

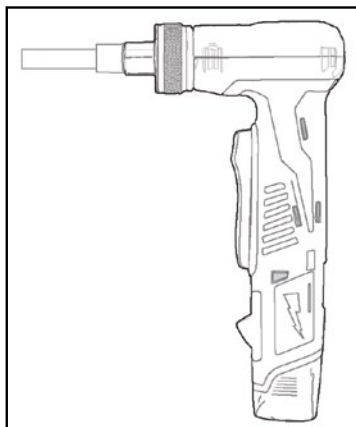
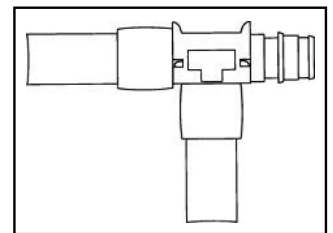
Use only black-colored crimp rings designed for this PEX system.

## Joining Procedures Utilizing ASTM F1960 Fittings and PEX Rings

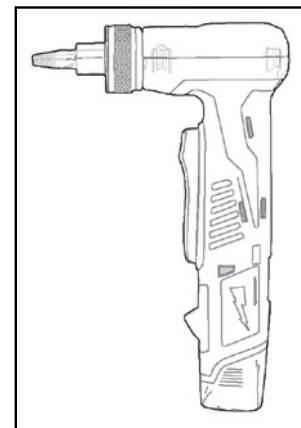
1. Cut the PEX tubing perpendicular to the length of the tubing using a cutter designed for plastic tubing. Remove all excess material or burrs that might affect the fitting connection.
2. Slide the PEX Ring over the end of the tubing.
3. The PEX Ring should extend over the end of the tubing no more than 1/16 inch. The end of the tubing and inside of the PEX Ring must be dry and free of grease or oil to prevent the PEX Ring from sliding out of place during expansion.



4. When using the hand expander tool, place the free handle of the tool against your hip, or place one hand on each handle when necessary. Fully separate the tool handles and insert the expander head into the end of the tubing until it stops. Be sure you have the correct size expander head on the tool. Full expansion is necessary to make a proper connection. Bring the handles together to expand. Separate the handles, remove the head from the tubing and rotate it 1/8 turn. Slide the tool head into the tubing in the newly rotated position and expand again.



**IMPORTANT:** Rotation of the expander head in either direction after every expansion is necessary to provide smooth and even expansion of the tubing. If you fail to reposition the head after each expansion, the segments of the tool head may cause deep grooves in the tubing, which could result in potential leak paths.

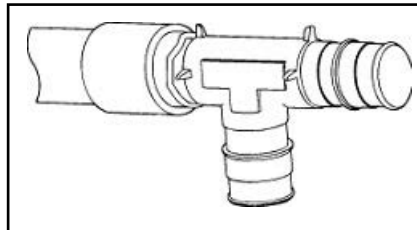


When using the battery expander tool, slide the expander head into the tubing until it stops. Full expansions are necessary to make a proper connection. Press the trigger to expand. The head for pipe sizes up to 1-1/2" will auto-rotate. For 2" pipe refer to the hand expander instructions.

5. Repeat the expansion process until the tubing and ring are snug against the shoulder on the expander head.
6. Immediately remove the tool and slide the tubing over the fitting until the tubing reaches the stop on the fitting. As you slide the tubing over the fitting, you should feel some resistance. If the tubing reaches the shoulder of the fitting without any resistance, the tubing may be over-expanded and may require additional time to fully shrink over the fitting. To ensure a proper connection, the PEX Ring must be seated up against the shoulder of the PEX fitting.
7. At minimum, ASTM F1960 connections must be pressure tested to the system's working pressure. PEX tubing and fittings are safe for air and hydrostatic testing. Refer to your local code for additional requirements.

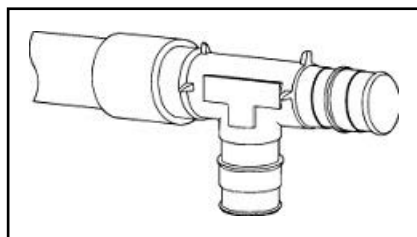
### ASTM F1960 Connections, Helpful Hints

- Holding the tubing in the expanded position increases the time it takes for the tubing to shrink around the fitting.
- The tubing should hold the fitting firmly after just a few seconds. If the fitting appears loose for more than a few seconds, the tubing has been over-expanded.
- If there is more than 1/16 inch between the PEX Ring and the fitting, square cut the tubing 2 inches away from the fitting and make another connection using a new PEX Ring.



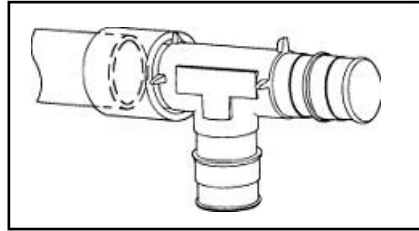
*Incorrect*

- Ring does not meet the pipe stops on the fitting. Tubing and rings should both meet the pipe stops on the fitting.



*Incorrect*

- Tubing does not meet the pipe stops on the fitting. Tubing and rings should both meet the pipe stops on the fitting.

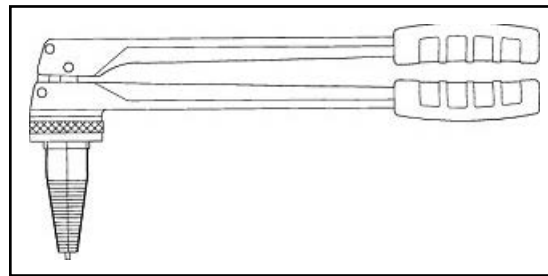
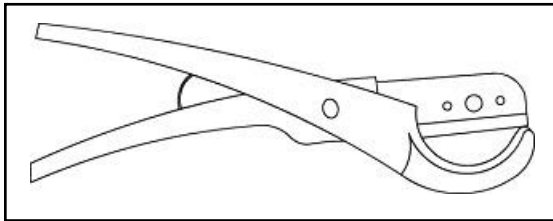


*Incorrect*

- Tubing and ring do not meet the pipe stops on the fitting. Tubing and rings should both meet the pipe stops on the fitting. Tubing is not cut square.

## Tools

There are a variety of PEX expander tools that are designed for ease of use when making reliable, permanent connections.



## Joining Procedures Utilizing ASTM F2080 Fittings and Compression Sleeves

### Summary

Fittings shall be joined to PEX pipe by first expanding the end of the pipe with the expander tool, inserting the cold-expansion fitting into expanded pipe, then pulling the compression-sleeve over the PEX pipe and the fitting, compressing the pipe between the compression sleeve and the fitting.

### Procedure

1. Slide the compression sleeve onto the pipe so that the inside-beveled end is facing toward the end of the pipe. Slide the compression-sleeve far enough down the pipe so that it will not prevent expansion of the pipe.
2. Insert the head of the expander tool into the pipe. The expander tool segments shall be centered inside the pipe.

3. Fully expand the pipe, holding it open for approximately 3 seconds, and remove the tool. Rotate the pipe approximately 30°, insert the expander-tool into the pipe and repeat the expansion process. This ensures that the pipe is round inside.
4. The cold-expansion fitting should be inserted within 30 seconds of the expansion; otherwise the pipe will shrink back to its original size and become too small for fitting insertion. The fitting is properly inserted when the PEX pipe is pushed up against the last rib of the cold-expansion fitting. If full insertion is not possible, remove the cold-expansion fitting immediately and expand the pipe again for 3 seconds.
5. When the expansion is complete, and the cold-expansion fitting is inserted properly into the PEX pipe, the metal compression sleeve shall be pulled over the fitting with the compression tool (this may be the same tool as the expander tool or a separate tool).
6. Use the compression tool to pull the compression sleeve over the cold-expansion fitting and the PEX pipe end until the sleeve touches the collar of the fitting or until the tool stops.
7. The maximum allowable gap between the edge of the compression sleeve and the collar of the cold-expansion fitting shall be 0.040 inch. If this gap is too large, then repeat the compression step and/or adjust the tool.

### Other Fitting Systems

Some PPFA Members have proprietary fitting systems for which ASTM standards have not been written. These systems are typically listed as meeting the performance requirements of ASTM F877 for PEX systems but their fitting dimensions and materials have not been specified in a standard. These fittings are typically available only through a single manufacturer and the components of the system do not interchange with similar looking parts from a different manufacturer. When using these systems, users are cautioned to be sure they do not mix components from different manufacturers even if they look the same.



# 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

