Inside / Indoor Piping Materials for Ground Source Geothermal Systems

A presentation by The Plastics Pipe Institute

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The Plastics Pipe Institute

PPI Represents the Plastic Pipe Industry

- PPI was formed in 1950 to research and develop test methods for plastic pressure pipes
- Today: Non-profit trade association serving North America, based in Irving, TX

PPI Mission: To advance the acceptance and use of plastic pipe systems through research, education, technical expertise, and advocacy

Members: Over 170 member firms involved with the plastic pipe industry

PPI Website: www.plasticpipe.org

The Plastics Pipe Institute

PPI Building & Construction Division (BCD)

- BCD is focused on plastic pressure pipe and tubing systems used within buildings and on building premises for applications such as plumbing, water service, fire protection, hydronic heating & cooling, snow & ice melting, district energy heating & cooling, and ground source geothermal piping systems.

BCD Materials: CPVC, HDPE (Geothermal), PEX, PE-RT, PEX-AL-PEX, and PP (PP-R & PP-RCT)

BCD homepage: https://plasticpipe.org/BuildingConstruction

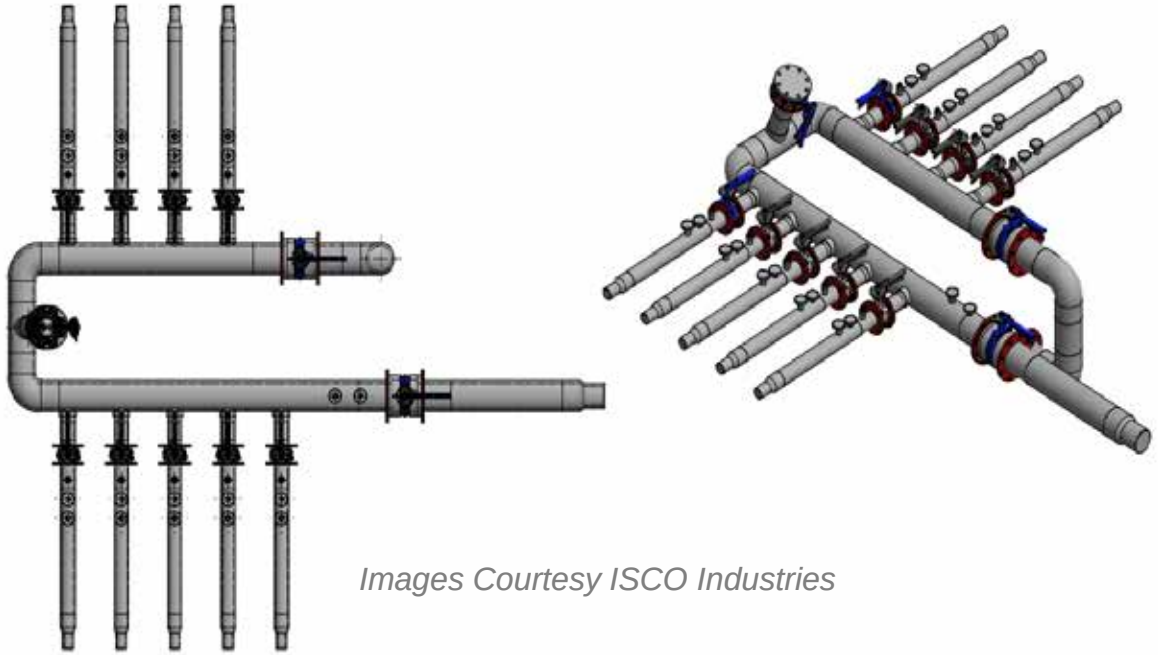
Inside / Indoor Piping Materials for Geothermal Systems

- **The “Ground Loop Pipe” is the heat exchanger with the Earth**
- **Inside or “indoor” piping** refers to headers or manifolds inside vaults or buildings, the piping connecting ground loops to heat pumps, and the piping used to distribute hydronic energy throughout a building

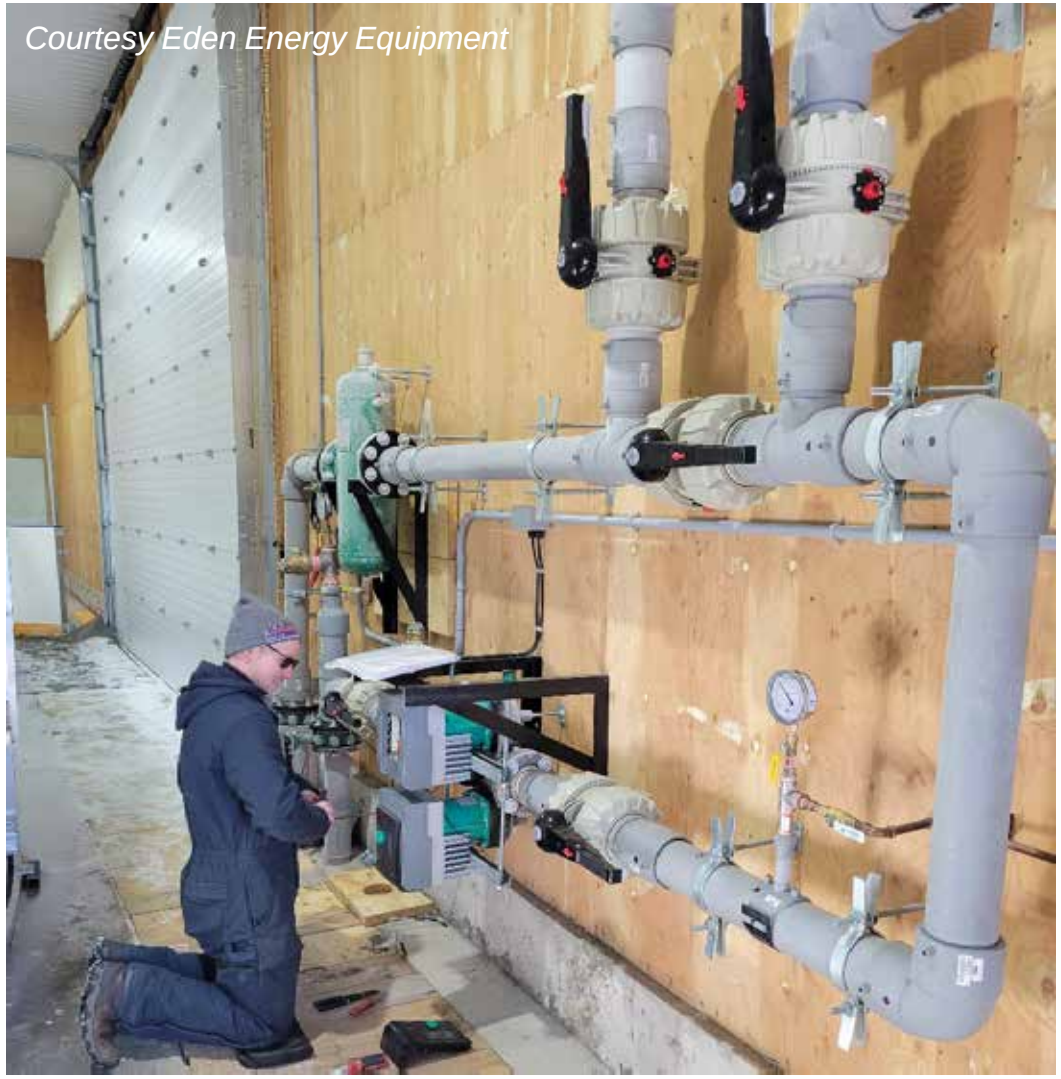
Image Courtesy Eden Energy Equipment

Inside / Indoor Piping Materials for Geothermal Systems

Examples of Inside or Indoor piping



Images Courtesy ISCO Industries



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Inside / Indoor Piping Materials for Geothermal Systems

Presentation Outline: This presentation will address

1. Industry standard and code requirements for inside / indoor piping materials

2. Recommended types of piping materials for inside / indoor piping in geothermal systems

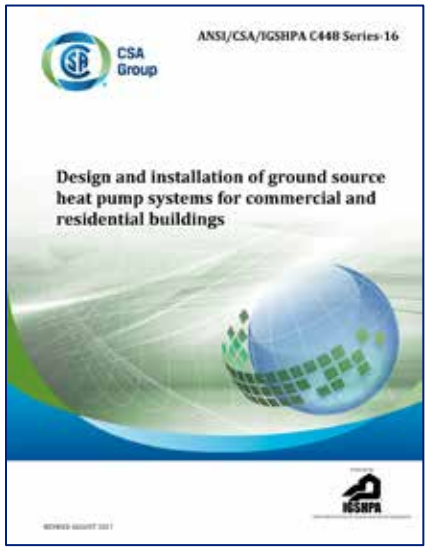
3. PPI resources for sizing and designing inside / indoor piping

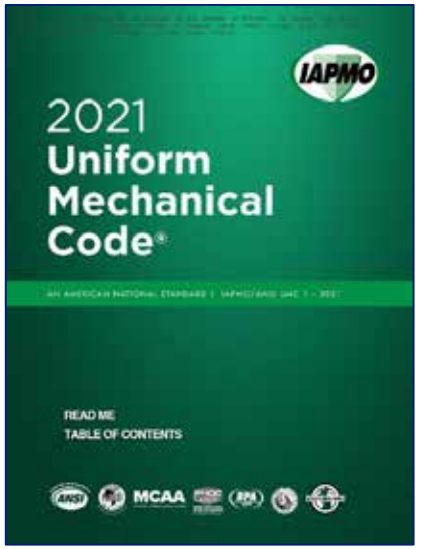
Courtesy Eden Energy Equipment

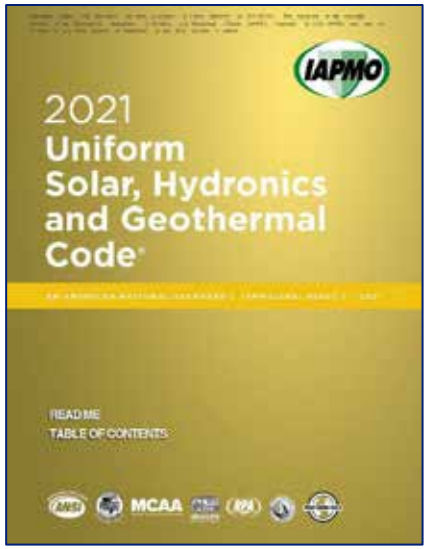
1. Geothermal Code Requirements for Inside/Indoor Piping

Review the following Model Codes:

- ANSI/CSA/IGSHPA C448-2016
- 2021 ICC International Mechanical Code (IMC)
- 2021 IAPMO Uniform Mechanical Code (UMC)
- 2021 IAPMO Uniform Solar, Hydronics and Geothermal Code (USHGC)







Geothermal Code Requirements for Inside/Indoor Piping

ANSI/CSA/IGSHPA C448.0 General Requirements

Building loop (or indoor piping) — piping that connects the heat pump equipment in the building to the ground heat exchanger after the transition between the ground heat exchanger piping or ground heat exchanger manifold inside the building.

Geothermal Code Requirements for Inside/Indoor Piping

ANSI/CSA/IGSHPA C448.0 General Requirements

5.5 Indoor piping, fittings, and accessories

5.5.1 General

5.5.1.1

Piping, fittings, and pipe accessories connected to a ground source heat pump system shall be appropriate for the intended use and shall be installed in accordance with the relevant safety and fire specifications and with good industry practice.

5.5.1.2

Piping, fittings, pipe accessories, and all components that come into contact with the system heat transfer fluid shall be compatible with that fluid.

5.5.1.3

Plastic-to-metal connections shall be intended for the systems covered in this Standard.

Geothermal Code Requirements for Inside/Indoor Piping

ANSI/CSA/IGSHPA C448.1 Commercial and institutional buildings

8.1.2 Interior piping systems design elements

The design and selection of the interior piping distribution system should consider

a) operating temperature;
b) operating pressure;
c) pipe expansion and contraction;
d) hanger requirements;
e) water chemistry; and
f) workforce capability of installation personnel.

Geothermal Code Requirements for Inside/Indoor Piping

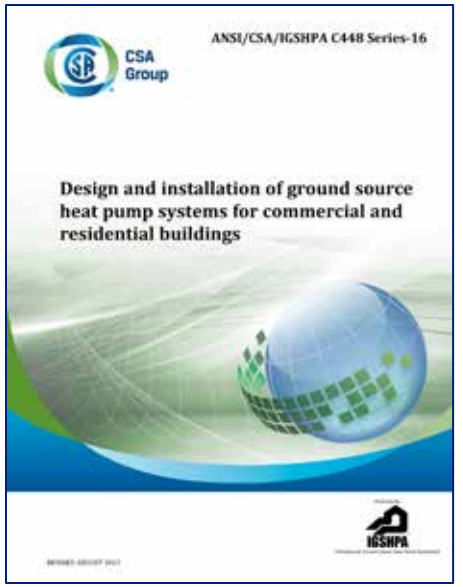
ANSI/CSA/IGSHPA C448.1 Commercial and institutional buildings

8.1.3 Interior piping material

8.1.3.1 Material recommendations

Interior piping systems shall be comprised of

a) polyethylene (PE) or crosslinked polyethylene (PEX) material (see Clause 8.1.3.2);
b) steel piping systems (schedule 10 and 40) (see Clause 8.1.3.3);
c) copper piping systems (copper Type K and L) (see Clause 8.1.3.4);
d) fibreglass reinforced polypropylene pipe (PP-RCT) (see Clause 8.1.3.5); or
e) PVC piping material (special cases) (see Clause 8.1.3.6).



Geothermal Code Requirements for Inside/Indoor Piping

ANSI/CSA/IGSHPA C448.1 Commercial and institutional buildings

8.1.3.6 PVC piping material (special cases)

The following shall apply for PVC piping material (special cases):

a) PVC piping has been used for water distribution in these kinds of systems in the past. Care shall be taken during the installation of PVC systems due to the thermal expansion of the pipe.

b) The minimum pressure rating of the piping distribution shall be 100 psi.

c) Piping system joints should be made with glued socket fittings. The manufacturer's recommendation shall be followed for the installation of such systems.

d) There is potential pipe degradation due to the refrigerant oil interaction with the pipe polymers. This interaction shall be verified before using PVC piping systems. A watertight seal shall be provided at any point where piping or tubing passes through an outside wall or floor below ground level, and shall not interfere with the integrity of the piping over time.

Geothermal Code Requirements for Inside/Indoor Piping

2021 ICC International Mechanical Code (IMC)

TABLE 1210.4
GROUND-SOURCE LOOP PIPE

MATERIAL	STANDARD (see Chapter 15)
Chlorinated polyvinyl chloride (CPVC)	ASTM D2846; ASTM F441; ASTM F442
Cross-linked polyethylene (PEX)	ASTM F876; CSA B137.5; CSA C448; NSF 358-3
Polyethylene/aluminum/polyethylene (PE-AL-PE) pressure pipe	ASTM F1282; CSA B137.9
High-density polyethylene (HDPE)	ASTM D2737; ASTM D3035; ASTM F714; AWWA C901; CSA B137.1; CSA C448; NSF 358-1
Polypropylene (PP-R)	ASTM F2389; CSA B137.11; NSF 358-2
Polyvinyl chloride (PVC)	ASTM D1785; ASTM D2241
Raised temperature polyethylene (PE-RT)	ASTM F2623; ASTM F2769; CSA B137.18; CSA C448; NSF 358-4

- Table 1210.4 provides the list of approved **Ground-Source Loop Pipe** materials
- The IMC does not mention “inside” or “indoor” piping

Geothermal Code Requirements for Inside/Indoor Piping

2021 ICC International Mechanical Code (IMC)

- Table 1202.4 provides the list of approved **Hydronic Pipe** materials

TABLE 1202.4
HYDRONIC PIPE

MATERIAL	STANDARD (see Chapter 15)
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D1527; ASTM F2806
Chlorinated polyvinyl chloride (CPVC) plastic pipe	ASTM D2846; ASTM F441; ASTM F442
Chlorinated polyvinyl chloride/aluminum/chlorinated polyvinyl chloride (CPVC/AL/CPVC)	ASTM F2855
Copper or copper-alloy pipe	ASTM B42; ASTM B43; ASTM B302
Copper or copper-alloy tube (Type K, L or M)	ASTM B75; ASTM B88; ASTM B135; ASTM B251
Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX) pressure pipe	ASTM F1281; CSA CAN/CSA-B-137.10
Cross-linked polyethylene (PEX) tubing	ASTM F876; ASTM F3253; CSA B137.5
Ductile iron pipe	AWWA C115/A21.15; AWWA C151/A21.51
Lead pipe	FS WW-P-325B
Polyethylene/aluminum/polyethylene (PE-AL-PE) pressure pipe	ASTM F1282; CSA B137.9
Polypropylene (PP) plastic pipe	ASTM F2389
Polyvinyl chloride (PVC) plastic pipe	ASTM D1785; ASTM D2241
Raised temperature polyethylene (PE-RT)	ASTM F2623; ASTM F2769; CSA B137.18
Steel pipe	ASTM A53; ASTM A106
Steel tubing	ASTM A254

Geothermal Code Requirements for Inside/Indoor Piping

2021 IAPMO Uniform Mechanical Code (UMC)

- Appendix F covers Geothermal Energy Systems
- Table F 104.2 provides the list of approved **Plastic Ground Source Loop Piping**
- The UMC refers to Ch. 12 for **Indoor Piping** (see next slide)

TABLE F 104.2
PLASTIC GROUND SOURCE LOOP PIPING

MATERIAL	STANDARD
Cross-linked polyethylene (PEX)	ASTM F876, CSA B137.5, CSA C448, NSF 358-3
High Density Polyethylene (HDPE)	ASTM D2737, ASTM D3035, ASTM F714, AWWA C901, CSA B137.1, CSA C448, NSF 358-1
Polypropylene (PP)	ASTM F2389, CSA B137.11, NSF 358-2
Polyethylene Raised Temperature (PE-RT)	ASTM F2623, ASTM F2769, CSA B137.18, CSA C448, NSF 358-4

F 104.5 Indoor Piping. Indoor piping, fittings, and accessories that are part of the groundwater system shall be in accordance with Chapter 12. Such materials shall be rated for the operating temperature and pressures of the system and shall be compatible with the type of transfer medium.


APPENDIX F
GEOTHERMAL ENERGY SYSTEMS

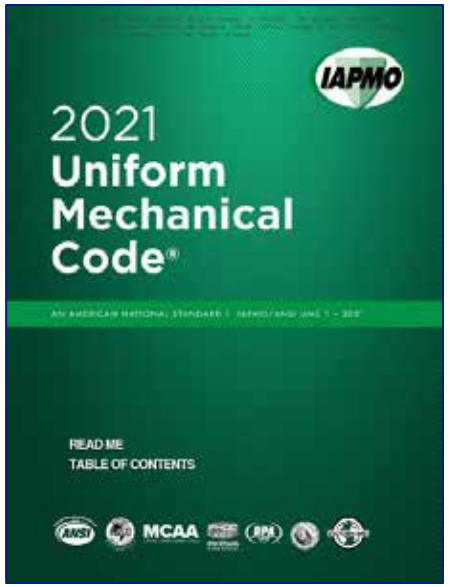
Geothermal Code Requirements for Inside/Indoor Piping

2021 IAPMO Uniform Mechanical Code (UMC)

- Chapter 12 Table 1210.1 provides the list of approved **Materials for Hydronic System Piping, Tubing and Fittings**

TABLE 1210.1
MATERIALS FOR HYDRONIC SYSTEM PIPING, TUBING, AND FITTINGS

MATERIAL	STANDARDS	
	PIPING/TUBING	FITTINGS
Copper/Copper Alloy	ASTM B42, ASTM B43, ASTM B75, ASTM B88, ASTM B135, ASTM B251[3], ASTM B302, ASTM B447	ASME B16.15, ASME B16.18, ASME B16.22, ASME B16.23, ASME B16.24, ASME B16.26, ASME B16.29, ASME B16.51, ASSE 1061, IAPMO PS 117
Ductile Iron	AWWA C115/A21.15, AWWA C151/A21.51	AWWA C110/A21.10[3], AWWA C153/A21.53
Steel	ASTM A53, ASTM A106, ASTM A254	ASME B16.5, ASME B16.9, ASME B16.11, ASTM A420
Stainless Steel	ASTM A269, ASTM A312, ASTM A554, ASTM A778	ASTM F1476, ASTM F1548, ASTM F3226, IAPMO PS 117
Gray Iron	—	ASTM A126
Malleable Iron	—	ASME B16.3
Chlorinated Polyvinyl Chloride (CPVC)	ASTM D2846, ASTM F441, ASTM F442, CSA B137.6	ASSE 1061, ASTM D2846, ASTM F437, ASTM F438, ASTM F439, ASTM F1970, CSA B137.6
Polyethylene (PE)	ASTM D1693, ASTM D2513, ASTM D2683, ASTM D2737, ASTM D3035, ASTM D3350, ASTM F714, AWWA C901, CSA B137.1, NSF 358-1	ASTM D2609, ASTM D2683, ASTM D3261, ASTM F1055, CSA B137.1, NSF 358-1
Cross-Linked Polyethylene (PEX)	ASTM F876, ASTM F3253, CSA B137.5, NSF 358-3	ASSE 1061, ASTM F877, ASTM F1055, ASTM F1807, ASTM F1960, ASTM F2080, ASTM F2098, ASTM F2159, ASTM F2735, ASTM F3253, CSA B137.5, NSF 358-3
Polypropylene (PP)	ASTM F2389, CSA B137.11, NSF 358-2	ASTM F2389, CSA B137.11, NSF 358-2
Polyvinyl Chloride (PVC)	ASTM D1785, ASTM D2241, CSA B137.3	ASTM D2464, ASTM D2466, ASTM D2467, ASTM F1970, CSA B137.2, CSA B137.3
Raised Temperature Polyethylene (PE-RT)	ASTM F2623, ASTM F2769, CSA B137.18	ASSE 1061, ASTM F1807, ASTM F2159, ASTM F2735, ASTM F2769, ASTM D3261, ASTM F1055, CSA B137.18
Cross-Linked Polyethylene/ Aluminum/Cross-Linked Polyethylene (PEX-AL-PEX)	ASTM F1281, CSA B137.10	ASTM F1281, ASTM F1974, ASTM F2434, CSA B137.10
Polyethylene/Aluminum/Polyethylene (PE-AL-PE)	ASTM F1282, CSA B137.9	ASTM F1282, ASTM F1974, CSA B137.9
Chlorinated Polyvinyl Chloride/Aluminum/ Chlorinated Polyvinyl Chloride	ASTM F2855	ASTM D2846



Geothermal Code Requirements for Inside/Indoor Piping

2021 IAPMO Uniform Solar, Hydronics and Geothermal Code (USHGC)

- Chapter 7 covers Geothermal Energy Systems
- Table 703.2 provides the list of approved **Plastic Ground Source Loop Piping**
- Section 703.5 refers to Ch. 4 for **Indoor Piping** (see next slide)

TABLE 703.2
PLASTIC GROUND SOURCE LOOP PIPING

MATERIAL	STANDARDS
Cross-Linked Polyethylene (PEX)	ASTM F876, ASTM F3253, CSA B137.5, CSA/IGSHPA C448, NSF 358-3
High Density Polyethylene (HDPE)	ASTM D2737, ASTM D3035, ASTM F714, AWWA C901, CSA B137.1, CSA/IGSHPA C448, NSF 358-1
Polypropylene (PP)	ASTM F2389, CSA B137.11, NSF 358-2
Polyethylene Raised Temperature (PE-RT)	ASTM F2623, ASTM F2769, CSA B137.18, CSA/IGSHPA C448, NSF 358-4

703.5 Indoor Piping. Indoor piping, fittings, and accessories that are part of the groundwater system shall be in accordance with Chapter 4. Such materials shall be rated for the operating temperature and pressures of the system and shall be compatible with the type of transfer medium.


CHAPTER 7
GEOTHERMAL ENERGY SYSTEMS

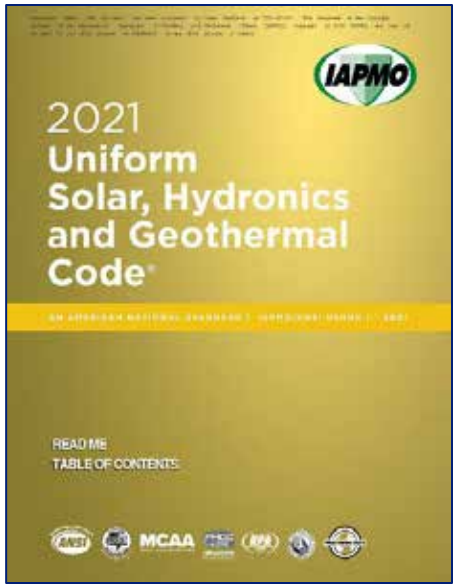
Geothermal Code Requirements for Inside/Indoor Piping

2021 IAPMO Uniform Solar, Hydronics and Geothermal Code (USHGC)

- Chapter 4 Table 409.1 provides the list of approved **Materials for Hydronic System Piping, Tubing and Fittings**

TABLE 409.1
MATERIALS FOR HYDRONIC AND SOLAR THERMAL SYSTEM, PIPING, TUBING, AND FITTINGS

MATERIAL	STANDARDS	
	PIPING/TUBING	FITTINGS
Copper/Copper Alloy	ASTM B42, ASTM B43, ASTM B75, ASTM B88, ASTM B135, ASTM B251*, ASTM B302, ASTM B447	ASME B16.15, ASME B16.18, ASME B16.22, ASME B16.23, ASME B16.24, ASME B16.26, ASME B16.29, ASME B16.51, ASSE 1061, ASTM F3226, IAPMO PS 117
Steel	ASTM A53, ASTM A106, ASTMA254	ASME B16.5, ASME B16.9, ASME B16.11, ASTM A420, ASTM F3226, IAPMO PS 117
Gray Iron	—	ASTM A126
Malleable Iron	—	ASME B16.3
Chlorinated Polyvinyl Chloride (CPVC)	ASTM D2846, ASTM F441, ASTM F442, CSA B137.6	ASSE 1061, ASTM D2846, ASTM F437, ASTM F438, ASTM F439, ASTM F1970, CSA B137.6
Polyethylene (PE)	ASTM D1693, ASTM D2513, ASTM D2683, ASTM D2737, ASTM D3035, ASTM D3350, ASTM F714, ASTM F2165, AWWA C901, CSA B137.1, NSF 358-1	ASTM D2609, ASTM D2683, ASTM D3261, ASTM F1055, ASTM F2165, CSA B137.1, NSF 358-1
Cross-Linked Polyethylene (PEX)	ASTM F876, ASTM F2165, ASTM F3253, CSA B137.5, NSF 358-3	ASSE 1061, ASTM F877, ASTM F1055, ASTM F1807, ASTM F1960, ASTM F2080, ASTM F2098, ASTM F2159, ASTM F2165, ASTM F2735, ASTM F3253, ASTM F3347, ASTM F3348, CSA B137.5, NSF 358-3
Polypropylene (PP)	ASTM F2165, ASTM F2389, CSA B137.11, NSF 358-2	ASTM F2165, ASTM F2389, CSA B137.11, NSF 358-2
Polyvinyl Chloride (PVC)	ASTM D1785, ASTM D2241, CSA B137.3	ASTM D2464, ASTM D2466, ASTM D2467, ASTM F1970, CSA B137.2, CSA B137.3
Raised Temperature Polyethylene (PE-RT)	ASTM F2165, ASTM F2623, ASTM F2769, CSA B137.18	ASSE 1061, ASTM D3261, ASTM F1055, ASTM F1807, ASTM F2159, ASTM F2165, ASTM F2735, ASTM F2769, CSA B137.18
Cross-Linked Polyethylene/Aluminum/ Cross-Linked Polyethylene (PEX-AL-PEX)	ASTM F1281, ASTM F2165, CSA B137.10	ASTM F1281, ASTM F1974, ASTM F2165, ASTM F2434, CSA B137.10
Polyethylene/Aluminum/Polyethylene (PE-AL-PE)	ASTM F1282, ASTM F2165, CSA B137.9	ASTM F1282, ASTM F1974, ASTM F2165, CSA B137.9
Stainless Steel	ASTM A269, ASTM A312, ASTM A554, ASTM A778	ASTM F1476, ASTM F1548, ASTM F3226, IAPMO PS 117
Chlorinated Polyvinyl Chloride/Aluminum/ Chlorinated Polyvinyl Chloride (CPVC/AL/CPVC)	ASTM F2855	ASTM D2846



Geothermal Code Requirements for Inside/Indoor Piping

Flame and Smoke Ratings: UMC

- The 2021 UMC requires that if piping is to be installed within a return air plenum that requires "non-combustible materials" then the piping must demonstrate a flame spread rating ≤ 25 and a smoke spread rating ≤ 50 when tested according to **ASTM E84** or **UL 723**

- These values are generated using the so-called "Steiner Tunnel" test

- Codes are subject to change, so check with local codes for specific requirements!

Image of Steiner Tunnel at UL LLC

Geothermal Code Requirements for Inside/Indoor Piping

Flame and Smoke Ratings: IMC

- The 2021 IMC requires testing according **ASTM E84** or **UL 723** or **UL 2846**

- IMC Section 602.2.1.7 allows that plastic water distribution piping and tubing listed and labeled in accordance with **UL 2846** as having a peak optical density not greater than 0.50, an average optical density not greater than 0.15, and a flame spread distance not greater than 5 feet (1524 mm) and installed in accordance with its listing may be used

- Codes are subject to change, so check with local codes for specific requirements!

- In **Canada**, flame and smoke spread testing is in accordance with **CAN/ULC S102.2**

Geothermal Code Requirements for Inside/Indoor Piping

Flame and Smoke Ratings: Testing

- Many plastic pipes are somewhat combustible, so flame and smoke certifications may be achieved with the use of pipe insulation (which is also required for thermal reasons)

- Each pipe manufacturer must carry their **own certifications** which describe how the products were tested and how they may be installed

Example list (partial) of ASTM E84 certifications on Uponor PEX materials

The following list of insulation types (at minimum thickness of ½") are approved for use with UPONOR's AquaPEX™, hePEX™, helioPEX™ X2 products when installed with UPONOR fittings and valves meter of 3 ½ inches. The insulations noted must be Listed to ASTM C547 by an approved.

Insulation	Flame Spread Rating (according to ASTM E84)	Smoke Developed Rating (according to ASTM E84)
Mason Alley-K	< 25	< 50
Armaflex Composite		
Johns Manville Micro-Lok		
Johns Manville Micro-Lok HP		

Geothermal Code Requirements for Inside/Indoor Piping

Flame and Smoke Ratings: Testing

- Many plastic pipes are somewhat combustible, so flame and smoke certifications may be achieved with the use of pipe insulation (which is also required for thermal reasons)

- Each pipe manufacturer must carry their **own certifications** which describe how the products were tested and how they may be installed

Example list (partial) of ASTM E84 certifications on Uponor PEX materials

The following outlines the performance of UPONOR PEX pipe determined in accordance with the noted standards.

ASTM E84 – Surface Burning Characteristics

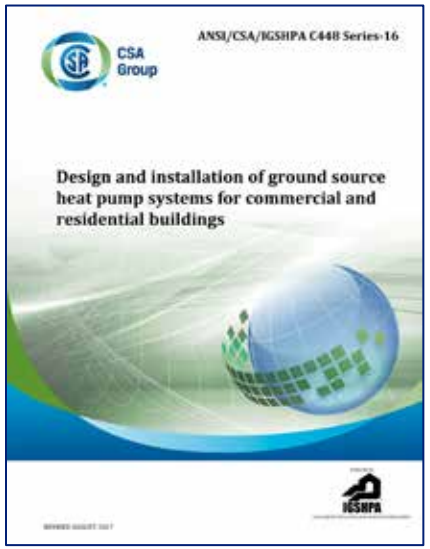
Limitations	Flame Spread Index	Smoke Developed Index
3 ½-inch maximum nominal diameter tubing; supported continuously with 23 gauge UPONOR PEX-a Pipe supports, with exposed area of UPONOR pipe between PEX-a-Pipe supports is encased with approved pipe insulations. Piping is to be clamped with standard support clamps following UPONOR installation instructions.	< 25	< 50

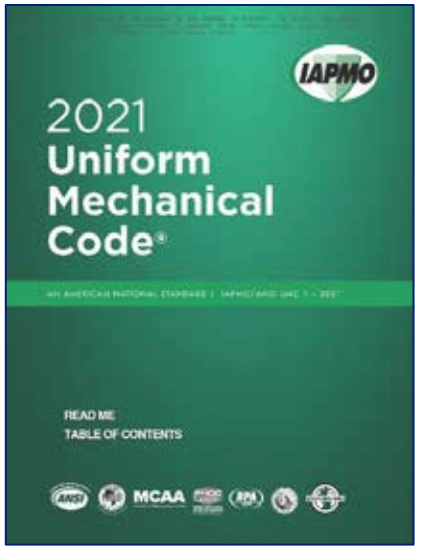
Note1: Different sizes and different colors corresponding to AquaPEX™, hePEX™, helioPEX™ X2 are dependent on manufacturer's availability.

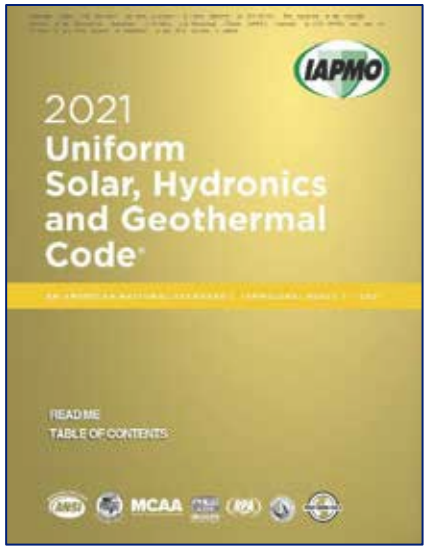
Geothermal Code Requirements for Inside/Indoor Piping

Summary:

- ANSI/CSA/IGSHPA C448 is being updated – changes have yet to be approved
- The 2024 ICC International Mechanical Code (IMC) will no longer allow Lead pipes
- The 2024 IAPMO Uniform Mechanical Code (UMC) will have Geothermal Energy Systems as Ch. 17
- The 2024 IAPMO Uniform Solar, Hydronics and Geothermal Code (USHGC) will have numerous revisions







2. Recommended Piping Materials for Inside/Indoor Piping

The piping materials recommended for inside/indoor piping are:

- **Cu** *copper*
- **Steel** *schedule 10 or schedule 40*
- **CPVC** *chlorinated polyvinyl chloride*
- **HDPE** *high density polyethylene*
- **PEX** *crosslinked polyethylene*
- **PE-RT** *polyethylene of raised temperature resistance*
- **PP-R, PP-RCT** *polypropylene*

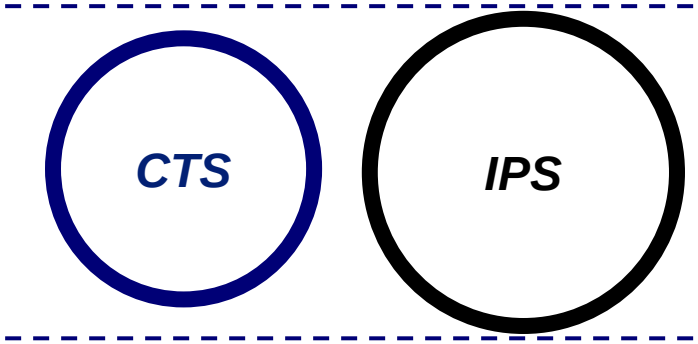
This presentation will focus on the five approved plastic pipe materials

Recommended Piping Materials for Inside Piping

“Tubing vs. Pipe”

- “**Tubing**” means the actual Outside Diameter is 1/8 inch larger than the nominal size
- “**Pipe**” means the actual Outside Diameter matches that of iron/steel pipe of the same nominal size, or products where the actual OD matches the nominal size (e.g., DN 63 pipe = 63 mm OD)
- Tubing uses nominal sizes such as ‘**NTS 3/4**’; also known as **Copper Tube Size** (CTS)
- Pipe uses nominal sizes such as ‘**NPS 3/4**’; also known as **Iron Pipe Size** (IPS)

- **IPS** pipes are typically larger than **CTS** pipes
- Example: 1 inch CTS Tubing OD = 1.125” (28.6 mm)
  1 inch IPS Pipe OD = 1.315” (33.4 mm) **15% larger**



Recommended Piping Materials for Inside Piping

Example of **SDR 64** vent pipe vs. **SDR 11** pressure pipe

Dimension Ratios

- Most* plastic pipe and tubing follows a ***Standard Dimension Ratio*** *(SDR)*
- SDR Definition: *the ratio of outside diameter to wall thickness, calculated by dividing the average outside diameter of the tubing by the minimum wall thickness*
- Bigger SDR number = thinner wall and lower pressure rating

Exception: Pipes that follow **Schedule 40/80 dimension schemes do not use SDRs*

- For the same **SDR**, each diameter of the pipe type (e.g., ¾, 1, 2) has the same pressure capability & rating
- SDR is also known as “wall type”
- Examples:
  - **PEX tubing** is **SDR 9** (wall thickness is 1/9 of the OD)
  - **HDPE pipe** may be **SDR 9, SDR 11, SDR 13.5**, **SDR 17**, etc.
  - E.g., For SDR 11 pipe, wall thickness is 1/11 of the OD = 9% of the OD

Recommended Piping Materials for Inside/Indoor Piping

1. CPVC: What is CPVC?

- CPVC is polyvinyl chloride (PVC) that has been chlorinated via a *free radical chlorination reaction*
- CPVC material is produced by adding a chlorine molecule (C) to PVC
- Chlorine added to PVC gives CPVC higher temperature performance and improved fire and corrosion resistance
- CPVC pressure pipe is a **distinct material from PVC pressure pipe**, with additional capabilities
- Recognized in all model codes for inside/indoor piping

Recommended Piping Materials for Inside/Indoor Piping

CPVC: Chlorinated Polyvinyl Chloride

- A high-temperature pressure piping system; rated for operation **up to 200°F (93°C)**
- Introduced for potable plumbing in 1959 (60+ years ago) followed by other uses
- Used for hot- and cold-water distribution, hydronic heating & cooling, industrial and process piping applications
- Provided in straight pipes lengths in both CTS sizes and IPS sizes
- Produced according to ASTM D2846, F441, F442 and/or CSA B137.6

Common types: CPVC 4120-05, CPVC 4120-06 (material designation codes)

Courtesy Lubrizol (x2)

Recommended Piping Materials for Inside/Indoor Piping

CPVC Configurations

- CPVC is provided in straight lengths
- Copper Tube Size (CTS) diameters ½ to 2 in SDR 11 wall type
- Iron Pipe Size (IPS) diameters ½ to 24 in Schedule 40/80 and several SDRs
- Fittings are molded in both CTS and IPS sizes

Recommended Piping Materials for Inside/Indoor Piping

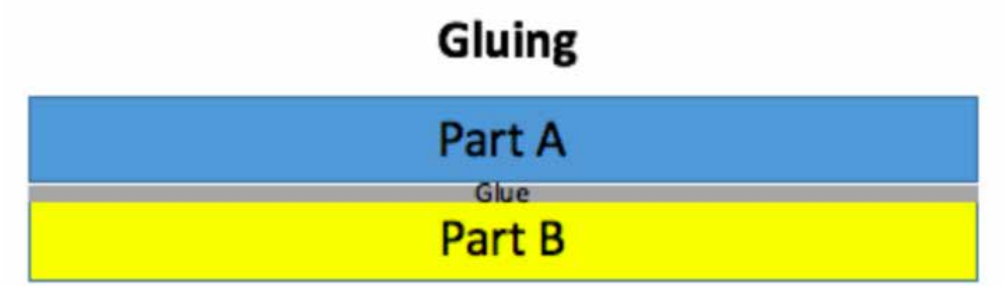
CPVC Joining

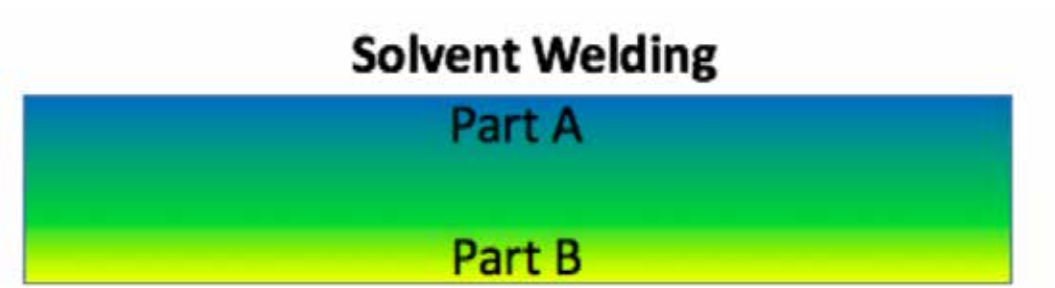
- CPVC pipe & fittings are joined via:
  - Solvent Cement
  - Push-fit Fittings
  - Grooved mechanical fittings
  - Flanged connections

Solvent Cement is <u>Not Glue</u>

- **Glues** work by providing a sticky layer between two components to create a bond

- **Solvent welding** requires the two components to come into contact as the solvent cements allow the parts to molecularly bond with each other (i.e., welding)





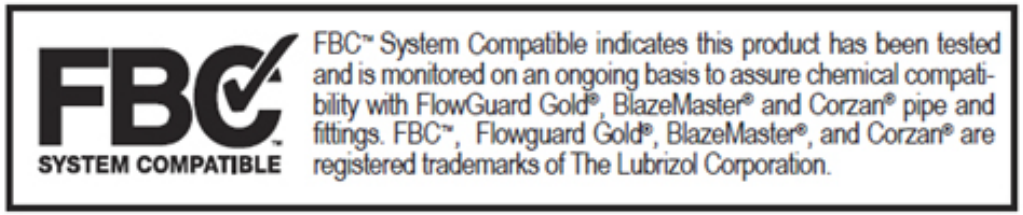
Recommended Piping Materials for Inside/Indoor Piping

CPVC Chemical Compatibility

- CPVC materials have certain incompatibilities with some construction materials
- Each CPVC manufacturer should test for and publish chemical compatibility

Example:

- The **FBC™ System Compatible Program** is a resource made available to manufacturers of ancillary products intended to be used with CPVC to help determine whether a product is chemically compatible with Lubrizol Advanced Materials' FlowGuard®, BlazeMaster®, Corzan®, and products made with TempRite Technology
- Visit *https://www.lubrizol.com/CPVC/FBC-System-Compatible-Program -*



Recommended Piping Materials for Inside/Indoor Piping

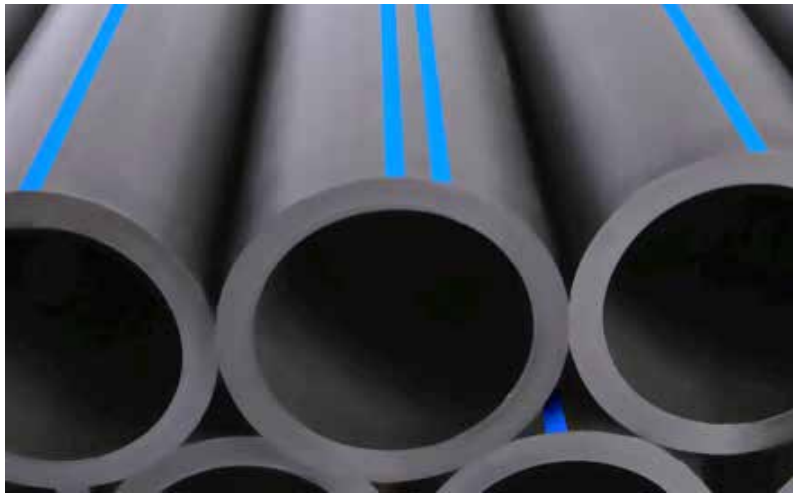
CPVC Summary

- Strong rigid piping material with high temperature capabilities (rated for **200°F**)
- Available in wide range of CTS and IPS diameters
- Available in various wall types and thicknesses (e.g., SDR 11, SDR 13.5, Schedule 40/80, etc.) depending on the required pressure rating
- Wide variety of fitting shapes and sizes available
- More economical than copper
- Several domestic sources

Recommended Piping Materials for Inside/Indoor Piping

2. HDPE: High Density Polyethylene

- High density polyethylene (HDPE) is the most common type of piping material used for ground heat exchangers, with decades of proven service for this application
- Strong and tough material, suitable for applications up to **140°F (60°C)**
  - Pressure ratings of pipes must be de-rated above **80°F (27°C)**
- High chemical resistance, corrosion resistant, economical
- Produced according to ASTM D2239, D3035, F714 and/or CSA B137.1
- Recognized in all model codes for inside/indoor piping



Common types:

- PE3608, PE4710 (thermoplastic material designation codes)

Recommended Piping Materials for Inside/Indoor Piping

What do the codes PE3408, PE3608, and PE4710 mean?

- Thermoplastic pipe material designation codes (e.g., PE3608, PE4710) are defined in **ASTM F412**
- Specific properties make up the PE pipe Material Designation Code (defined in **ASTM D3350):**
  - First digit: “the cell classification number value for density”
  - Second digit: “the cell classification number value for slow crack growth resistance”
  - Third & Fourth digits: “the hydrostatic design stress when tested with water at 73°F, in units of 100 psi”

PE4710 vs. PE3408:

- Higher density/stiffness
- Much higher slow crack growth resistance
- Higher hydrostatic design stress (1,000 psi vs. 800 psi)
- Higher Design Factor (0.63 vs. 0.50)
- Higher pressure ratings

Recommended Piping Materials for Inside/Indoor Piping

HDPE Connections

- HDPE connections are typically via **heat fusion** (three types of fusion)
  1. Butt fusion (pipe-to-pipe or fitting-to-fitting) joints are produced according to **ASTM Standard D3261**
  2. Socket fusion (pipe-to-fitting) joints are produced according to **ASTM Standard D2683**
  3. Electrofusion (pipe-to-fitting) joints are produced according to **ASTM Standard F1055**
- Fusion joints shall be installed in accordance with **ASTM Standard Practice F2620**
- Electrofusion joints shall be installed in accordance with **ASTM Standard Practice F1290**

Butt fusion joint

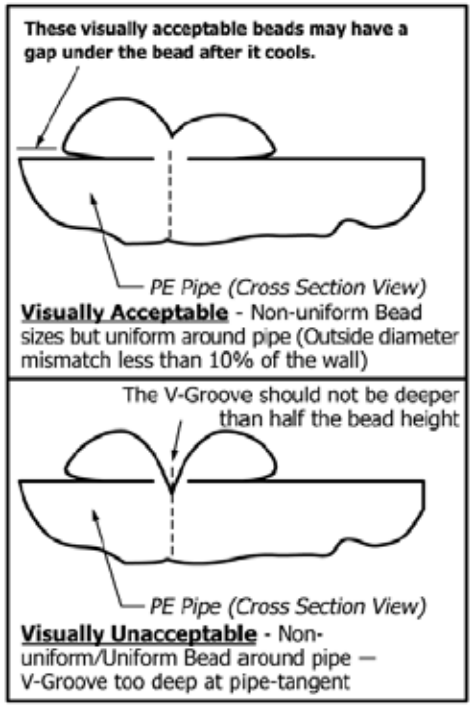
Electrofusion fitting

Socket fusion caps for testing

Recommended Piping Materials for Inside/Indoor Piping

HDPE Connections

- **ASTM F2620** ***Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings***
  is the industry's practice for heat fusion (based somewhat on **PPI TR-33**)
- First published in 2006, latest edition **2020**




Designation: F2620 – 20a[ε1]

Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings[1]

1. Scope*

1.1 This practice describes procedures for making joints with polyethylene (PE) pipe and fittings by means of heat fusion joining in, but not limited to, a field environment. Other suitable heat fusion joining procedures are available from various sources including pipe and fitting manufacturers. This practice does not purport to address all possible heat fusion joining procedures, or to preclude the use of qualified procedures developed by other parties that have been proved to produce reliable heat fusion joints.

1.2 The parameters and procedures are applicable only to joining polyethylene pipe and fittings of related polymer chemistry. They are intended for PE fuel gas pipe in accordance with Specification D2513 and PE potable water, sewer and industrial pipe manufactured in accordance with Specification F714, Specification D3035, and AWWA C901 and C906. Consult with the pipe manufacturers to make sure they approve this procedure for the pipe to be joined (see Appendix X1).

Note 1—The parameters and procedures shown for Section 8, Procedure 2—Butt Fusion, were developed and validated using testing documented in Plastic Pipe Institute (PPI) TR-33. The parameters and procedures shown in Section 9, Procedure 3— Saddle Fusion, were developed and validated using testing documented in PPI TR-41.

Note 2—Information about polyethylene pipe and fittings that have related polymer chemistry is presented in Plastics Pipe Institute (PPI) TR-33 and TR-41.

1.3 Parts that are within the dimensional tolerances given in present ASTM specifications are required to produce sound joints between polyethylene pipe and fittings when using the joining techniques described in this practice.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 The text of this practice references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the practice.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2513 Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

F714 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter

F1056 Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings

F3124 Practice for Data Recording the Procedure used to Produce Heat Butt Fusion Joints in Plastic Piping Systems or Fittings

F3183 Practice for Guided Side Bend Evaluation of Polyethylene Pipe Butt Fusion Joint

F3190 Practice for Heat Fusion Equipment (HFE) Operator Qualification on Polyethylene (PE) and Polyamide (PA) Pipe and Fittings

2.2 *PPI Documents:*

TR-33 Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene[3]

Recommended Piping Materials for Inside/Indoor Piping

HDPE Summary

- Tough, durable, flexible, strong material
- Proven over 40+ years in ground loop applications
- Wide range of diameters and wall types
- Many domestic sources
- Mechanical fittings (e.g., Victaulic) are options
- Available in various wall types and thicknesses (e.g., SDR 7.4, SDR 9, SDR 11, SDR 13.5, etc.), depending on the required pressure rating
- Material has its temperature limitations
- Heat fusion requires training, equipment, and attention to detail

Recommended Piping Materials for Inside/Indoor Piping

3. PEX: Crosslinked (X) Polyethylene

- Crosslinked polyethylene (PEX) is modified HDPE with enhanced capabilities for temperature
- PEX is a high-temperature, flexible pressure pipe, 50 years of global usage in pressure applications
- Crosslinking creates a three-dimensional matrix of connected molecules
- Approved for geo ground loops in North America since **2008**
- Produced according to ASTM F876 and/or CSA B137.5
- Recognized in all model codes for inside/indoor piping

- PEX is widely used for plumbing, water service, fire protection, hydronic heating and cooling, snow and ice melting, and ground source geothermal piping systems

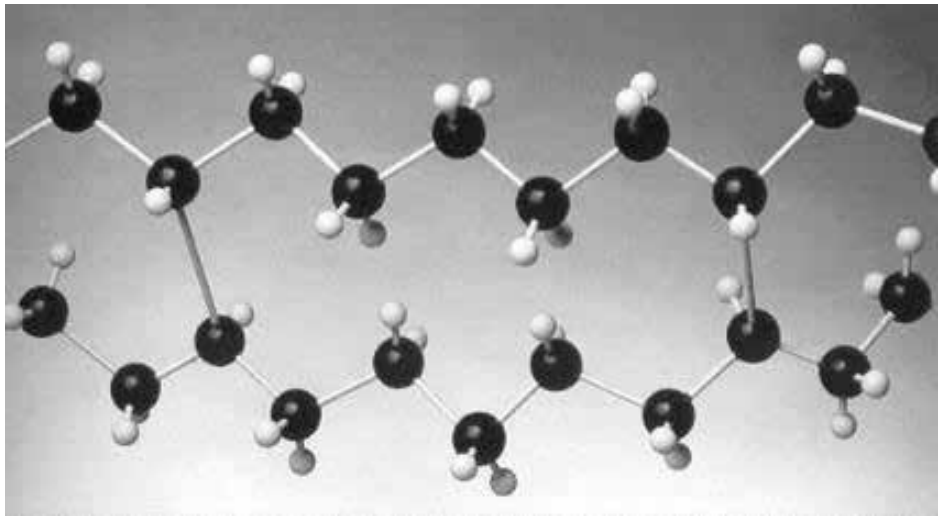


Illustration of PEX "molecule"

Recommended Piping Materials for Inside/Indoor Piping

PEX: Crosslinked (X) Polyethylene

- PEX density is slightly lower than HDPE
- Lower tensile strength = Less stiff = More flexible = Lower pressure rating for the same wall thickness
- Strong and tough material, suitable for applications up to **180°F (82°C)** and beyond
- Predominantly only available as Tubing
- Many joining options available (not butt fusion or socket fusion)

Common types:

- PEX 1206, PEX 3306 (PEX tubing material designation codes)

- *Note: PEX "code" is Not Comparable to the PE material designation code*

Recommended Piping Materials for Inside/Indoor Piping

PEX Joining

- PEX fittings work on principle of **compression** (tubing is compressed over fitting ribs)
- PEX fittings are produced from **lead-free brass alloys** and **engineered polymers**
- Butt fusion or socket fusion fittings do not work well with PEX

Collection of PEX fittings from multiple manufacturers

Recommended Piping Materials for Inside/Indoor Piping

PEX Joining

- Connections are typically via **compression fittings** or **electrofusion**

Crimp ring fitting

Copper crimp ring

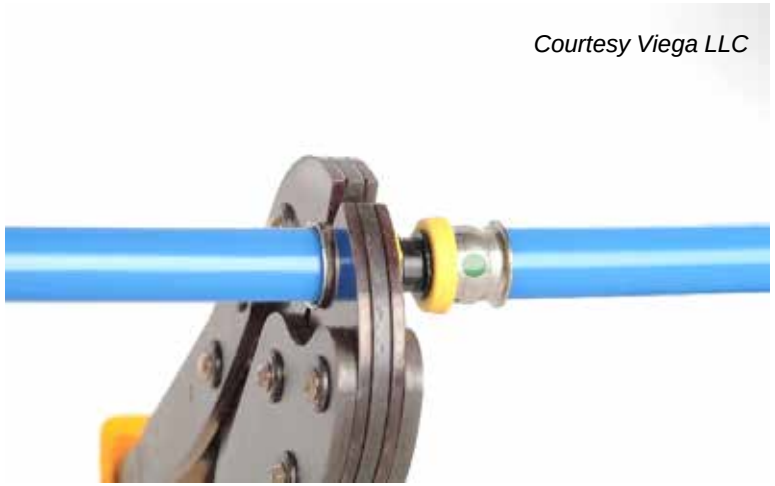
(both per ASTM F1807)

Manual crimp tool

Recommended Piping Materials for Inside/Indoor Piping

PEX Joining

- Connections are typically via **compression fittings** or **electrofusion**



Press-sleeve PEX fitting per ASTM F3347

Cold-expansion PEX fitting per ASTM F1960

Recommended Piping Materials for Inside/Indoor Piping

PEX Joining

- Connections are typically via **compression fittings** or **electrofusion**

Courtesy REHAU

Cold-expansion compression-sleeve PEX fitting per ASTM F2080

HDPE electrofusion fitting on PEX tubing per ASTM F1055

Recommended Piping Materials for Inside/Indoor Piping

PEX Summary

- Tough, durable, flexible, strong material with high temperature capabilities (**180°F** or higher)
- Ideal when high temperature resistance is needed (e.g., thermal solar contributions)
- Available in diameters up to 3 inch nominal
- Joining systems install without fusion using basic hand tools or battery-electric tools
- More expensive than PE4710, more economical than copper
- Many domestic sources

Recommended Piping Materials for Inside/Indoor Piping

4. PE-RT: Polyethylene of Raised Temperature Resistance

- PE-RT is modified HDPE material with enhanced capabilities to withstand higher temperatures
- Strong and tough material suitable for applications up to **180°F (82°C)**
- Same dimensions as PEX tubing; predominantly only available as Tubing
- PE-RT tubing can be joined via **heat fusion** or using most PEX **compression fittings**
- **PE-RT = HDPE material with higher temperature capabilities**
- Produced according to ASTM F2729 and/or CSA B137.18
- Recognized in all model codes for inside/indoor piping

Common type:

- PE4710 (PE material designation code)

Courtesy Legend Valve

Recommended Piping Materials for Inside/Indoor Piping

5. PP-R & PP-RCT: Polypropylene

- PP-R & PP-RCT are high-temperature plastic pressure piping materials first used for plumbing and hydronic heating in the 1980s in Europe and introduced to North America in the 2000s
- Provided in straight pipes lengths in DN (metric) diameters (e.g., 25 mm, 50 mm, 75 mm, etc.)
- Produced according to ASTM F2389 and/or CSA B137.11

Recommended Piping Materials for Inside/Indoor Piping

PP-R & PP-RCT: Two types of polypropylene pressure pipe materials

- *Random copolymerized polypropylene* (**PP-R**) is a high-temperature plastic pressure piping system first used for plumbing and hydronics, now for geothermal headers, indoor piping

- *Polypropylene random copolymer with modified crystallinity & temperature resistance* (**PP-RCT**) is a stronger grade of PP material, higher tensile strength, higher pressure rating

Recommended Piping Materials for Inside/Indoor Piping

PP-R & PP-RCT Connections

- Connections are typically via **heat fusion (socket, butt, and electrofusion)**
- Various mechanical fittings (e.g., grooved) and adapters are also available

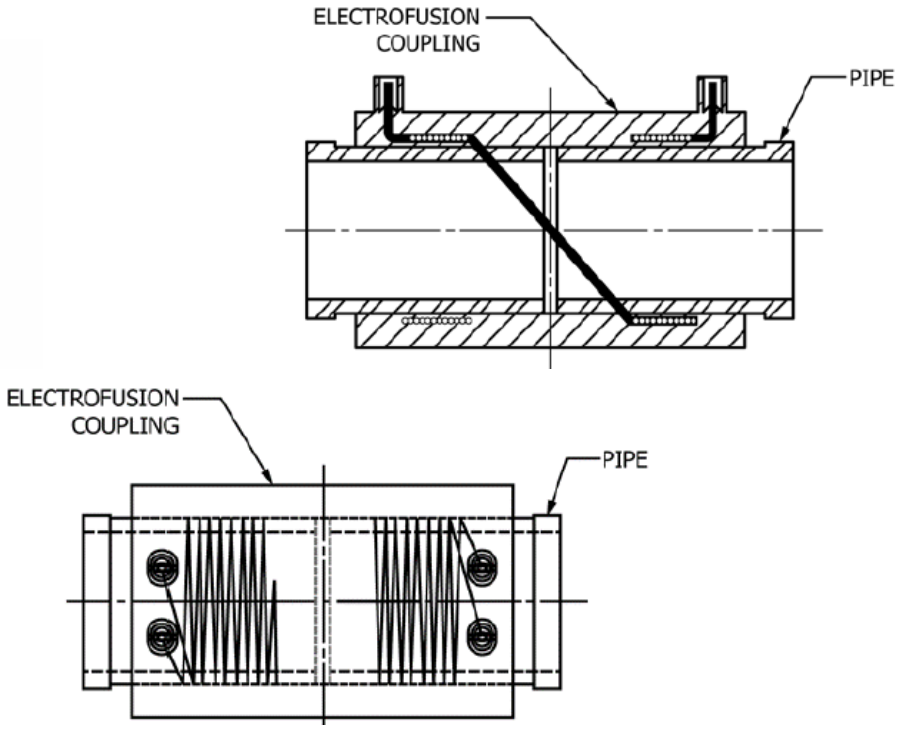
Basic fusion steps: 1. Heat 2. Press 3. Cool

Courtesy Aquatherm

Recommended Piping Materials for Inside/Indoor Piping

PP-R & PP-RCT Connections

- **Electrofusion** joints have embedded copper wires that heat the fitting, welding it to pipe ends
- A computerized machine controls the process



Recommended Piping Materials for Inside/Indoor Piping

PP Summary

- Strong rigid piping material with high temperature capabilities (typically rated for **176°F**)
- Fiber-core reinforcement layers reduce longitudinal thermal expansion/contraction
- Available in diameters from 16 mm to 710 mm (soft conversions ½ inch to 28 inch)
- Available in various wall types and thicknesses (e.g., SDR 7.4, SDR 9, SDR 11, SDR 13.5, etc.), depending on the required pressure rating
- Fusion joining with a wide variety of fittings shapes and sizes
- More economical than copper
- Several domestic sources

Recommended Piping Materials for Inside/Indoor Piping

Summary

- The plastic piping materials recommended for inside/indoor piping are:

- **CPVC** *chlorinated polyvinyl chloride*
- **HDPE** *high density polyethylene*
- **PEX** *crosslinked polyethylene*
- **PE-RT** *polyethylene of raised temperature resistance*
- **PP-R, PP-RCT** *polypropylene*

- Each of these materials provides corrosion resistance, chemical resistance, flexibility, impact resistance, resistance to slow crack growth, long-term hydrostatic strength (pressure capability), temperature resistance, and good thermal conductivity

3. PPI Resources for the Geo Industry

PPI Resources

- As a non-profit trade association intending to support the geothermal industry, PPI members wish to support specifiers, designers, and installers with helpful tools
- All support tools are available at no charge on PPI website www.plasticpipe.org/buildingconstruction

PPI Resources for the Geo Industry

Please visit our website for:

- Application information on Geothermal Ground Loop Piping Systems, links to other tools

See Also

- PPI TN-54 General Guidelines for Squeezing Off Polyethylene Pipe in Water, Oil and Gas Applications
- PPI TN-55 Plastic Piping Materials for Ground Source Geothermal Heating and Cooling Applications
- BCD Plastic Pipe Design Calculator
- PPI Presentation: Plastic Piping Materials for Ground Source Geothermal Systems
- PPI Handbook of Polyethylene Pipe (Ch. 13) HVAC Applications for PE Pipe
- ANSI/CSA/IGSHPA C448 Design and installation of ground source heat pump systems for commercial
- ASTM F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
- ASTM F3190 Standard Practice for Heat Fusion Equipment (HFE) Operator Qualification on Polyethyle
- International Ground Source Heat Pump Association IGSHPA
- The Geothermal Exchange Organization GEO
- NSF 358 Certification Programs for Geothermal Piping Systems
- Meline/Kavanaugh Paper: Geothermal Heat Pumps—Simply Efficient
- Heat Pump Basis by Professor Eugene Silberstein
- Geothermal Heat Pumps in K-12 Schools: A Case Study of the Lincoln, NE Schools

PPI Resources for the Geo Industry

Please visit our website for:

- A specific webpage for each piping material

PPI Resources for the Geo Industry

Please visit our website for:

- Technical literature on many piping topics

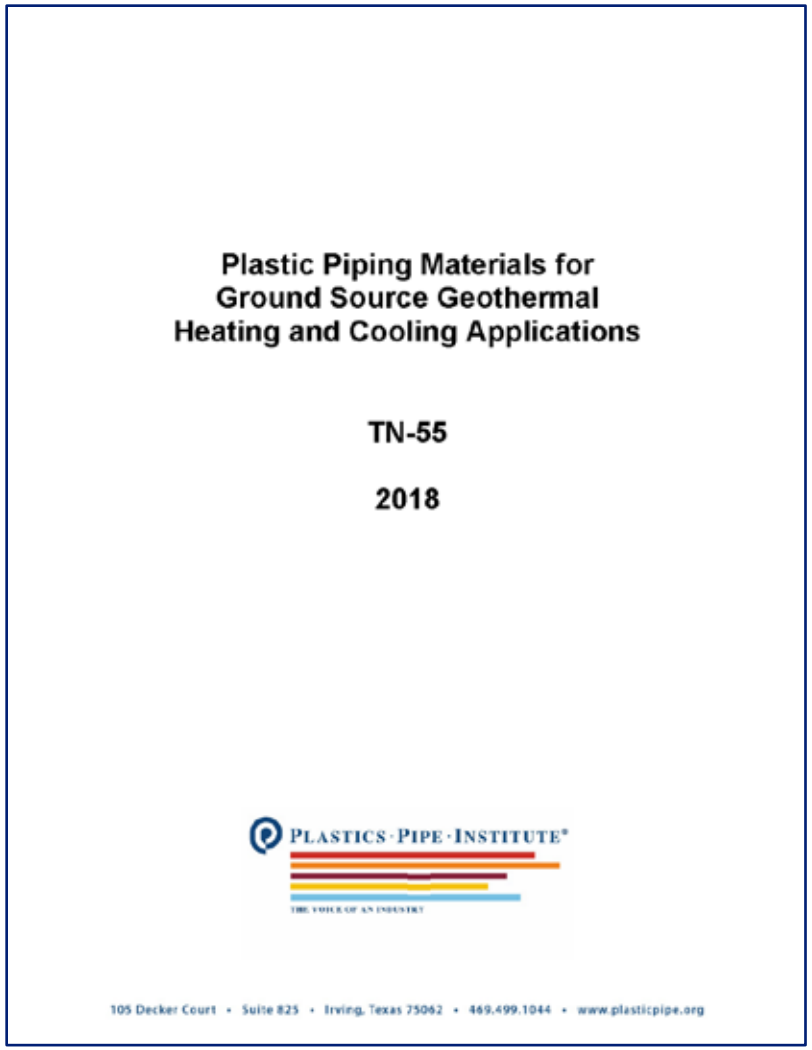
PPI Resources for the Geo Industry

PPI TN-55

- Published in March 2018 as a guide to the industry
- Contains general installation information and piping details

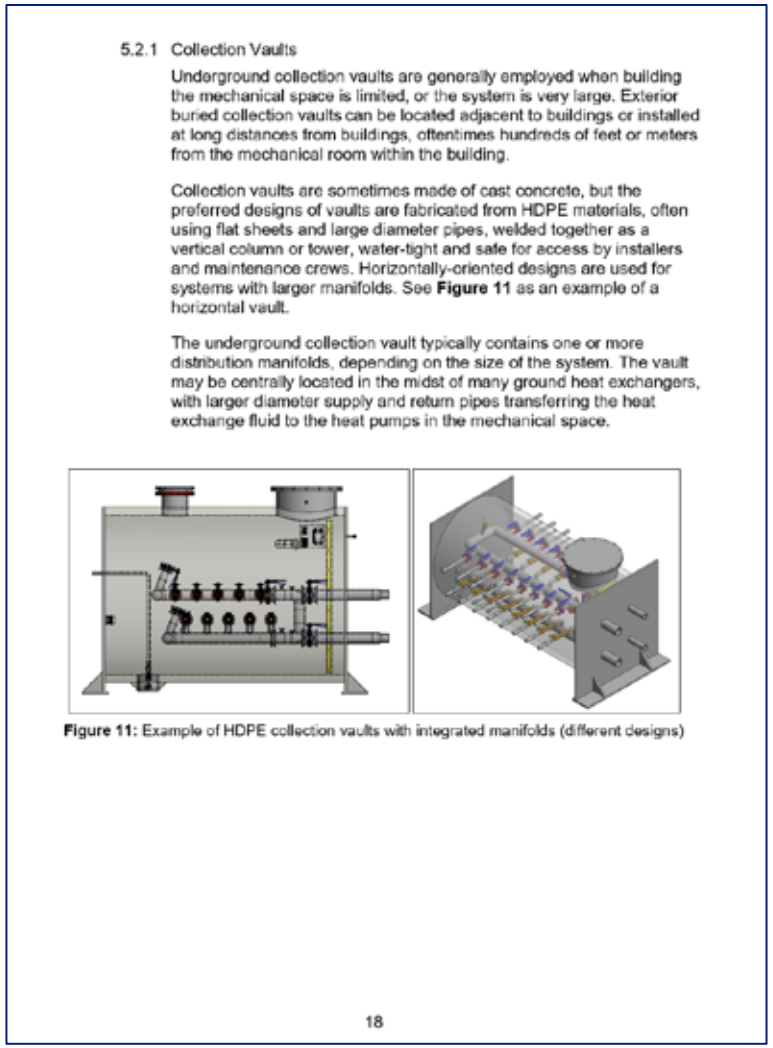
Chapters:

1.0 Introduction
2.0 Mechanical Components
3.0 Ground Loop Heat Exchange Piping Systems
4.0 Ground Loop Heat Exchange Piping Materials
5.0 Headers and Distribution Manifolds
6.0 Heat Transfer Fluid
7.0 Standards, Codes and Regulations



PPI Resources for the Geo Industry

PPI TN-55 Content



5.2.1 Collection Vaults

Underground collection vaults are generally employed when building the mechanical space is limited, or the system is very large. Exterior buried collection vaults can be located adjacent to buildings or installed at long distances from buildings, oftentimes hundreds of feet or meters from the mechanical room within the building.

Collection vaults are sometimes made of cast concrete, but the preferred designs of vaults are fabricated from HDPE materials, often using flat sheets and large diameter pipes, welded together as a vertical column or tower, water-tight and safe for access by installers and maintenance crews. Horizontally-oriented designs are used for systems with larger manifolds. See **Figure 11** as an example of a horizontal vault.

The underground collection vault typically contains one or more distribution manifolds, depending on the size of the system. The vault may be centrally located in the midst of many ground heat exchangers, with larger diameter supply and return pipes transferring the heat exchange fluid to the heat pumps in the mechanical space.

Figure 11: Example of HDPE collection vaults with integrated manifolds (different designs)

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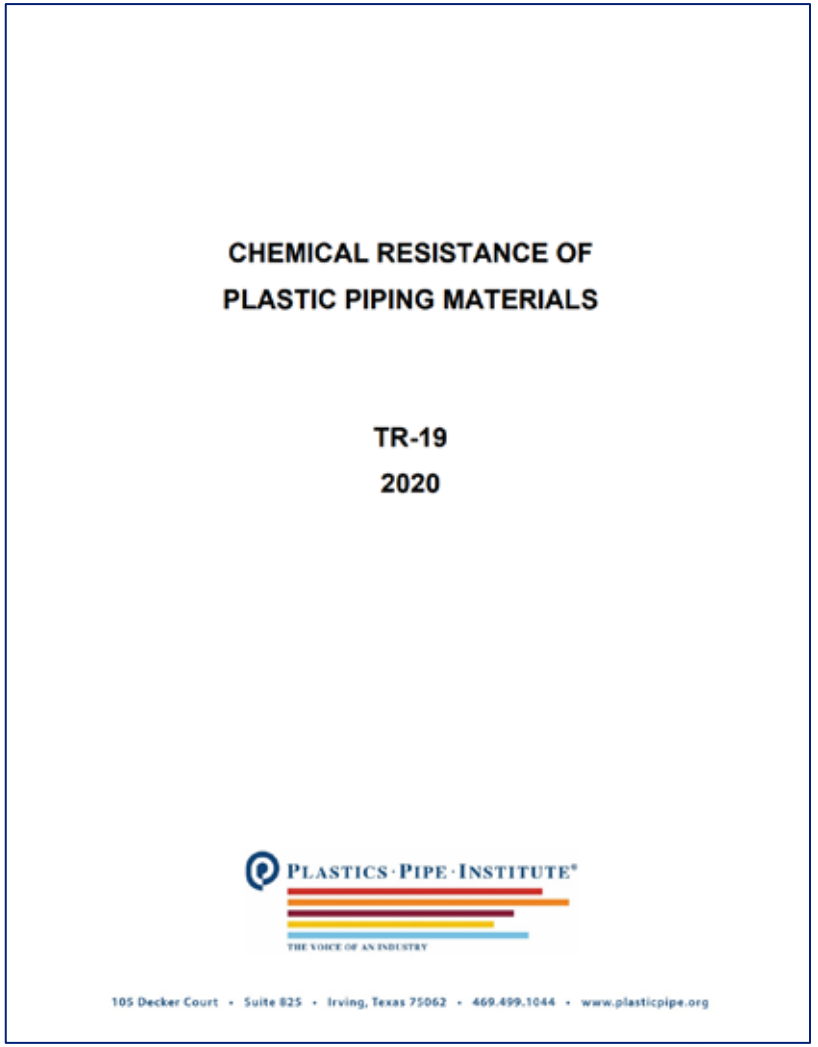
PPI Resources for the Geo Industry

PPI TR-19

- First published in 1973; latest update 2020
- Provides chemical resistance to over 600 chemicals and most types of plastic pipes and fittings

Table 1: Plastic Materials Identification

ABS	acrylonitrile-butadiene-styrene
CPVC	chlorinated polyvinyl chloride
PP	polypropylene
PP-R [1]	polypropylene random copolymer
PP-RCT [1]	polypropylene random copolymer with modified crystallinity and temperature resistance
PVC	polyvinyl chloride
PE	polyethylene (representative of medium density polyethylene [MDPE] and high density polyethylene [HDPE]; not representative of low density polyethylene [LDPE])
PE-RT [2]	polyethylene of raised temperature resistance
PB	Polybutylene
PVDF	polyvinylidene fluoride
PEX	crosslinked polyethylene
PA11/ PA12	polyamide 11 / polyamide 12
PSU	Polysulfone
PPSU	Polyphenylsulfone



PPI Resources

PPI TR-19

- First published in 1973; la
- Provides chemical resista
  and most types of plastic

Table 1: Plastic

ABS	acrylonitrile-butadiene-st
CPVC	chlorinated polyvinyl chlo
PP	polypropylene
PP-R [1]	polypropylene random c
PP-RCT [1]	polypropylene random c temperature resistance
PVC	polyvinyl chloride
PE	polyethylene (representa and high density polyeth polyethylene [LDPE])
PE-RT [2]	polyethylene of raised te
PB	Polybutylene
PVDF	polyvinylidene fluoride
PEX	crosslinked polyethylene
PA11/ PA12	polyamide 11 / polyamid
PSU	Polysulfone
PPSU	Polyphenylsulfone

******May not be fully applicable to pressurized applications******

Chemical Formula	Concentration	ABS	CPVC	PP (PP-R, PP-RCT)	PVC	PE (MDPE, HDPE, PE-RT)	PB	PVDF	PEX	PA (PA11, PA12)	PSU	PPSU
Methanol (Methyl Alcohol)	5%	---	R to 180	---	---	---	---	R to 140	---	---	---	---
CAS# 67-56-1	Liquid	---	N	R to 180	R to 140	R to 140	R to 140	L to 176	R to 140	---	R to 73	---
CH_3 OH												
Methoxyethyl Oleate												
CAS# 111-10-4	--	---	N	---	R to 73	---	---	---	---	---	---	---
CH_3 OCH_2 CH_2 $OOCC_{17}H_{33}$												
Methyl Acetate												
CAS# 79-20-9	--	N	N	R to 140	N	L to 120	---	---	L to 120	---	---	---
CH_3 CO_2 CH_3												
Methyl Acrylate												
CAS# 96-33-3	Tech Pure	---	N	---	---	R to 140	---	---	R to 140	---	---	---
CH_2 =$CHCOOCH_3$												
Methylamine												
CAS# 74-89-5	--	---	N	N	N	---	---	---	---	---	---	---
CH_3 NH_2												
Methyl Bromide												
CAS# 74-83-9	--	---	N	N	N	L to 73	---	---	L to 73	R to 68	---	---
CH_3 Br												
Methyl Butyl Ketone												
CAS# 591-78-6	Liquid	---	N	---	---	---	---	L to 122	---	---	---	---
$CH_3CO(CH_2)_3CH_3$												
Methyl Cellosolve												
CAS# 109-86-4	--	---	N	R to 73	N	L to 120	---	---	L to 120	---	---	---
$HOCH_2$ CH_2 OCH_3												
Methyl Chloride												
CAS# 74-87-3	Dry	N	N	N	N	L to 120	N	---	L to 120	R to 68	---	---
CH_3 Cl												
Methyl Chloroform												
CAS# 71-55-6	--	N	N	L to 73	N	L to 120	---	---	L to 120	---	---	---
CH_3CCl_3												

PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Pressure Drop / Head Loss

- Free online sizing tool at www.plasticpipecalculator.com

Plastic Pipe Design Calculator

PRESSURE DROP / HEAD LOSS

Input

Is this a Geothermal Application? ☑

Pipe/Tubing Selection[1]

Pipe/Tubing Material: HDPE - PE 4710

Sizing Type (CTS/IPS/Metric): IPS (ASTM D3035/CSA B137.1)

Wall Type (SDR/Schedule): SDR 11

Nominal Pipe/Tubing Size[2]: 1 1/4

More information on HDPE

Calculate

Results

Flow Regime:	Turbulent	
Pressure Drop:	7.0 Psi	48.5 kPa
Head Loss:	16.2 ft water	
Velocity*:	2.1 ft/s	0.6 m/s

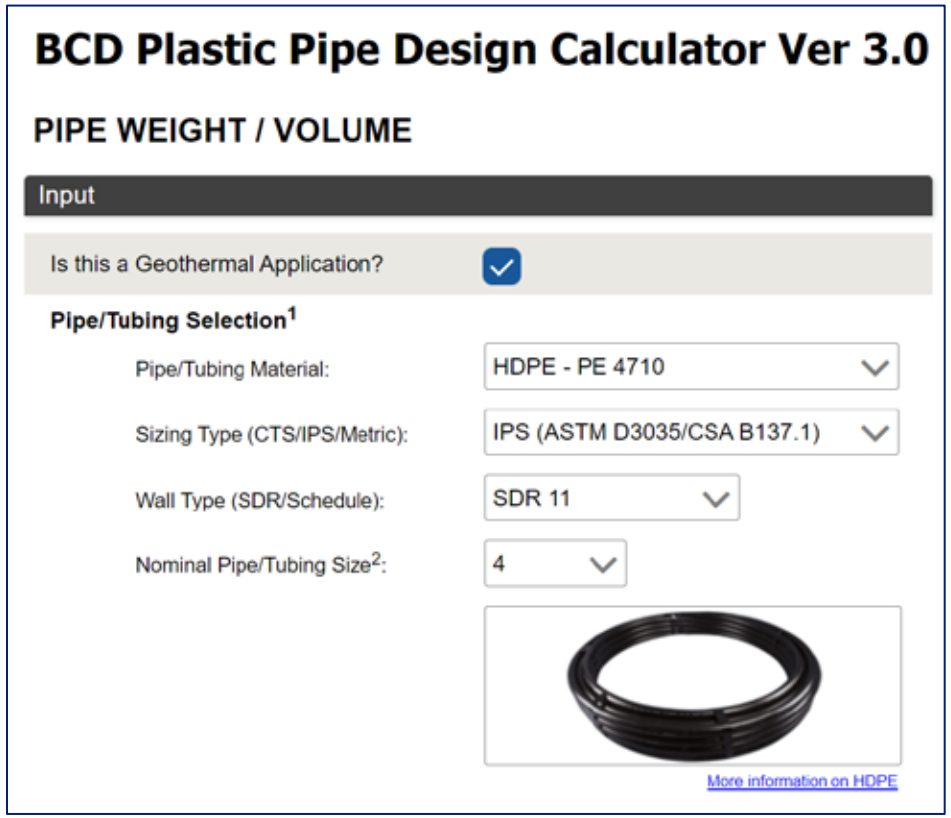
Calculation Details Print Email

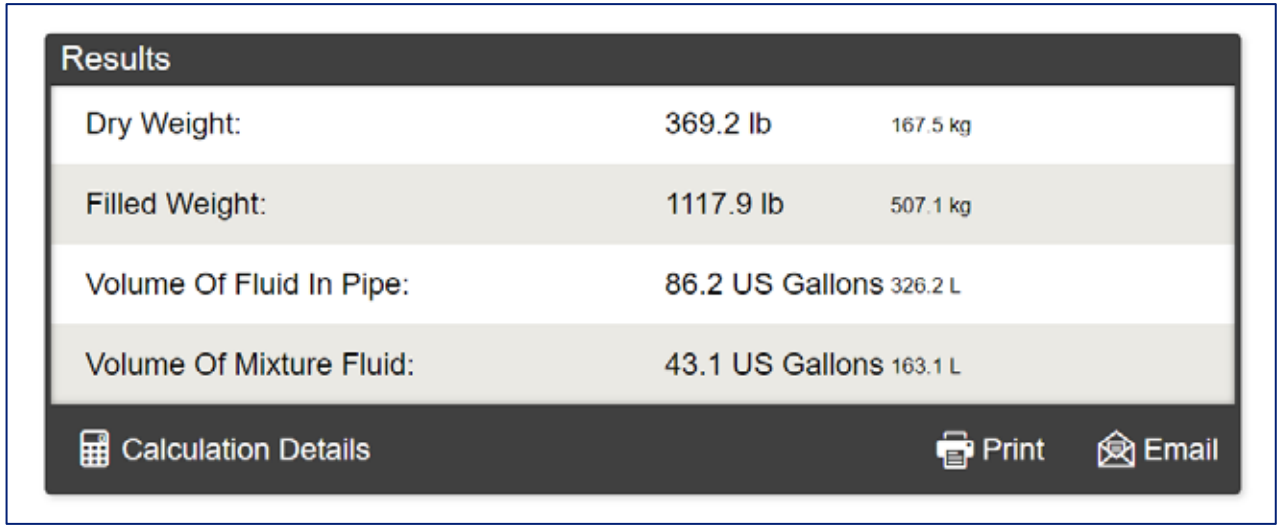
*** Values shown above are not an indication that the flow velocity is acceptable for your application. Always refer to and follow the pipe manufacturers recommended velocity limits.**

PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Pipe Weight / Volume

- Free online sizing tool at www.plasticpipecalculator.com





PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Thermal Expansion / Contraction

- Free online sizing tool at www.plasticpipecalculator.com

BCD Plastic Pipe Design Calculator Ver 3.0

THERMAL EXPANSION / CONTRACTION

Input

Is this a Geothermal Application? ☑

Pipe/Tubing Selection[1]

Pipe/Tubing Material: HDPE - PE 4710

Sizing Type (CTS/IPS/Metric): IPS (ASTM D3035/CSA B137.1)

Wall Type (SDR/Schedule): SDR 11

Nominal Pipe/Tubing Size[2]: 4

Calculate

Initial Temperature:	45	°F
Final Temperature:	125	°F
Length of Pipe:	100	ft

Results

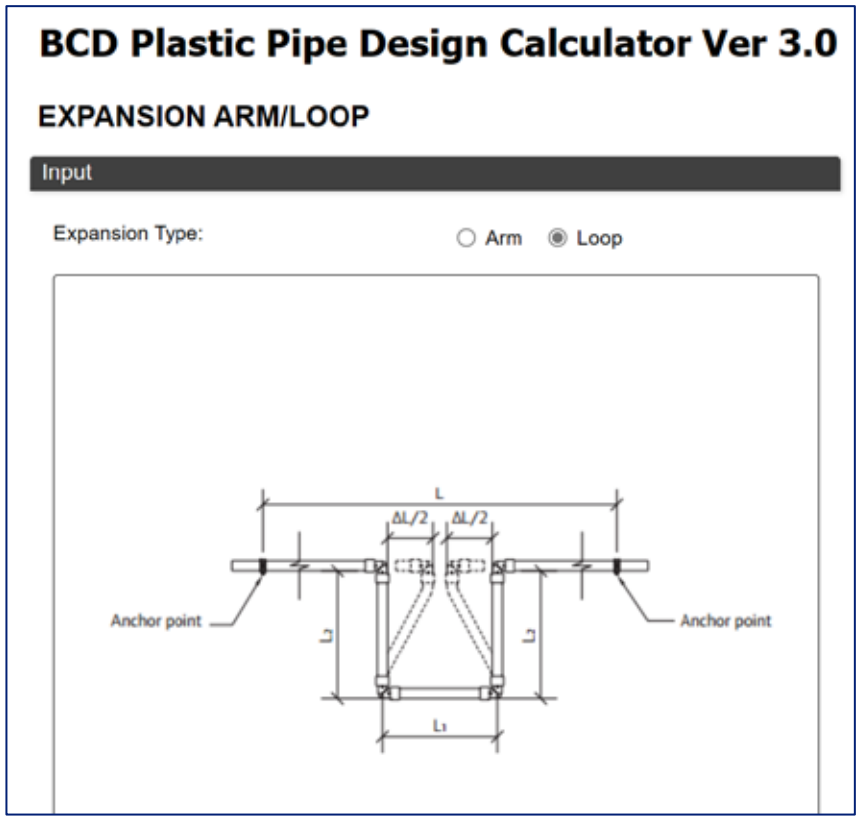
Length of Tube Expansion:	7.7 in	195 mm

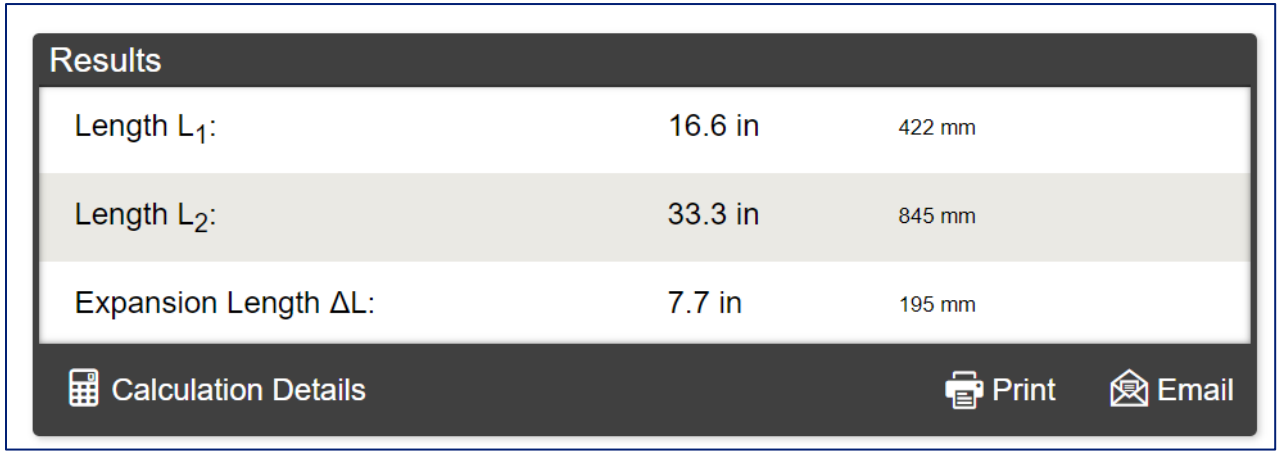
Calculation Details Print Email

PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Expansion Arm / Loop

- Free online sizing tool at www.plasticpipecalculator.com





PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Static Water Column Pressure

- Free online sizing tool at www.plasticpipecalculator.com

Pipe/Tubing Selection[1]

Pipe/Tubing Material: PP-RCT, Fiber-core Layer

Sizing Type (CTS/IPS/Metric): DN - Metric (ASTM F2389)

Calculate

$P_{Surface}$ (Surface Pressure)[3]: 15 psi

Height of Water/Fluid Column: 60 ft

Fluid Type (Water or % Antifreeze[4]): 30% Propylene Glycol

Averag

Results

Static Water Column Pressure at Bottom of Vertical Column: 41.3 Psi 284.9 kPa

Calculation Details Print Email

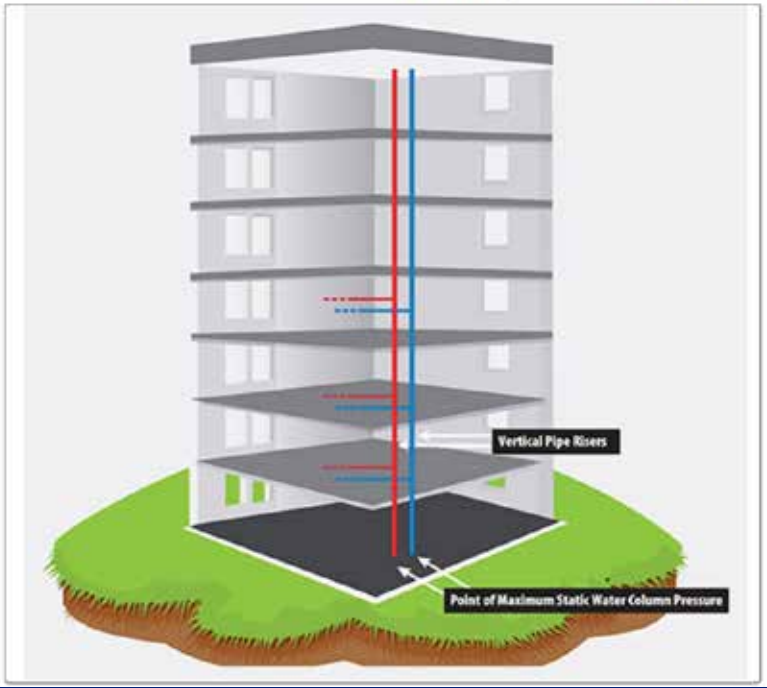
*Static Water Column Pressure is shown to help the user determine if selected pipe or tubing is appropriate to withstand the calculated internal pressure. Always refer to and follow the pipe manufacturer's recommended pressure limits.

BCD Plastic Pipe Design Calculator Ver 3.0

STATIC WATER COLUMN PRESSURE

Input

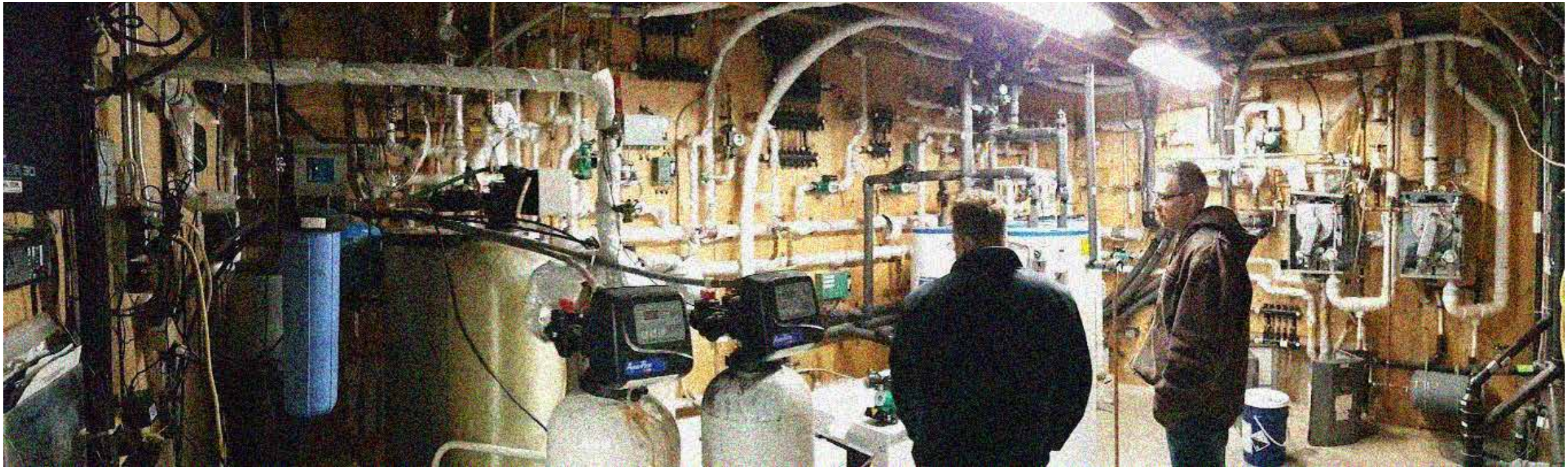
Column Type: Geothermal / Plumbing, Fire Protection, Hydronic



PPI Resources for the Geo Industry

Summary

- All support tools are available at no charge on PPI website www.plasticpipe.org/buildingconstruction
- Share your thoughts and ideas and let us know how we can support you on piping topics



Inside / Indoor Piping Materials for Geothermal Systems

Presentation Summary: This presentation addressed

1. Industry standard and code requirements for inside/indoor piping materials

2. Recommended types of piping materials for inside/indoor piping in geothermal systems

3. PPI resources for sizing and designing inside piping

Inside / Indoor Piping Materials for Geothermal Systems