Inside/Indoor Piping Materials

Selecting the best piping options for each project

Geothermal: The Genius Renewable

Live at Groundwater Week in partnership with NGWA

Las Vegas, NV
December 5-7, 2023
CEUs for this workshop

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Speaker Introduction

Lance MacNevin, P.Eng.
- Director of Engineering, Plastics Pipe Institute Building & Construction Division
- Staff engineer to coordinate research, publications, education, advocacy, industry outreach
- Active in the piping industry since 1993
- Serves on Technical Committees within ASHRAE, ASTM, ASPE, AWWA, CIPH, CSA, HIA-C, IAPMO, ICC, IGSHPA, NSF, RPA

PPI Represents the Plastic Pipe Industry www.plasticpipe.org
- 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
Inside/Indoor Piping Materials for Geo 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.
Inside/Indoor Piping Materials for Geo Systems

Where is Inside or Indoor piping used?

Courtesy Geo-Flo Corp.
Inside/Indoor Piping Materials for Geo Systems

Where is Inside or Indoor piping used?

Courtesy Eden Energy Equipment
Inside/Indoor Piping Materials for Geo Systems

Where is Inside or Indoor piping used?

Courtesy ISCO Industries
Inside/Indoor Piping Materials for Geo Systems

Goals for Inside/Indoor Piping

- The selected piping material must be compatible with fluids and the anticipated temperatures and pressures
- It must be reliable and durable and meet relevant standards
- It must be relatively easy to install, correctly
- It must be available and affordable
- It must be corrosion resistant, have impact resistance, and be sustainable
- It must be approved in relevant construction codes (e.g., mechanical code, acceptable to the AHJ)

This presentation explains five types of plastic piping used to construct reliable indoor piping systems.
Inside/Indoor Piping Materials for Geo Systems

Plastic Piping Systems are Sustainable because…

- No mining operations for the ore
- Lower costs to the environment for production
- Reduced water consumption & reduced air pollution for manufacturing
- Less energy to produce plastics as compared with copper and steel
- Lower thermal conductivity = reduced heat transfer through pipe walls
- Lighter weight, easier to transport on trucks and on jobsites (worker safety)
- Smooth wall, excellent flow characteristics reduce pumping costs
- Plastic piping systems provide proven long life and durability
- Fully recyclable (most plastics)

Plastic Pipes:
Better materials.
Longer life.
More value.
Inside/Indoor Piping Materials for Geo Systems

Presentation Outline

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) [2024 version already published]
- 2021 IAPMO Uniform Mechanical Code (UMC) [2024 version already published]
- 2021 IAPMO Uniform Solar, Hydronics and Geothermal Code (USHGC)
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.
8.1.2 Interior piping systems design elements

8.1.3 Interior piping material

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

- **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>
<thead>
<tr>
<th>MATERIAL</th>
<th>STANDARD (see Chapter 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylonitrile butadiene styrene (ABS) plastic pipe</td>
<td>ASTM D1527; ASTM F2806</td>
</tr>
<tr>
<td>Chlorinated polyvinyl chloride (CPVC) plastic pipe</td>
<td>ASTM D2846; ASTM F441; ASTM F442</td>
</tr>
<tr>
<td>Chlorinated polyvinyl chloride/aluminum/chlorinated polyvinyl chloride (CPVC/AL/CPVC)</td>
<td>ASTM F2855</td>
</tr>
<tr>
<td>Copper or copper-alloy pipe</td>
<td>ASTM B42; ASTM B43; ASTM B302</td>
</tr>
<tr>
<td>Copper or copper-alloy tube (Type K, L or M)</td>
<td>ASTM B75; ASTM B88; ASTM B135; ASTM B251</td>
</tr>
<tr>
<td>Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX) pressure pipe</td>
<td>ASTM F1281; CSA CAN/CSA-B-137.10</td>
</tr>
<tr>
<td>Cross-linked polyethylene (PEX) tubing</td>
<td>ASTM F876; ASTM F3253; CSA B137.5</td>
</tr>
<tr>
<td>Ductile iron pipe</td>
<td>AWWA C115/A21.15; AWWA C151/A21.51</td>
</tr>
<tr>
<td>Lead pipe</td>
<td>FS WW-P-3258</td>
</tr>
<tr>
<td>Polyethylene/aluminum/polyethylene (PE-AL-PE) pressure pipe</td>
<td>ASTM F1282; CSA B137.9</td>
</tr>
<tr>
<td>Polypropylene (PP) plastic pipe</td>
<td>ASTM F2389</td>
</tr>
<tr>
<td>Polyvinyl chloride (PVC) plastic pipe</td>
<td>ASTM D1785; ASTM D2241</td>
</tr>
<tr>
<td>Raised temperature polyethylene (PE-RT)</td>
<td>ASTM F2623; ASTM F2769; CSA B137.18</td>
</tr>
<tr>
<td>Steel pipe</td>
<td>ASTM A53; ASTM A106</td>
</tr>
<tr>
<td>Steel tubing</td>
<td>ASTM A254</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>TABLE F 104.2</th>
<th>PLASTIC GROUND SOURCE LOOP PIPING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MATERIAL</strong></td>
<td><strong>STANDARD</strong></td>
</tr>
<tr>
<td>Cross-linked polyethylene (PEX)</td>
<td>ASTM F876, CSA B137.5, CSA C448, NSF 358-3</td>
</tr>
<tr>
<td>High Density Polyethylene (HDPE)</td>
<td>ASTM D2737, ASTM D3035, ASTM F714, AWWAC901, CSA B137.1, CSA C448, NSF 358-1</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>ASTM F2389, CSA B137.11, NSF 358-2</td>
</tr>
<tr>
<td>Polyethylene Raised Temperature (PE-RT)</td>
<td>ASTM F2623, ASTM F2769, CSA B137.18, CSA C448, NSF 358-4</td>
</tr>
</tbody>
</table>

**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.
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
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**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>STANDARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-Linked Polyethylene (PEX)</td>
<td>ASTM F876, ASTM F3253, CSA B137.5, CSA/IGSHPA C448, NSF 358-3</td>
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</table>

**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.
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
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

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Flame Spread Rating (according to ASTM E84)</th>
<th>Smoke Developed Rating (according to ASTM E84)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mason Alley-K</td>
<td>&lt; 25</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>Armaflex Composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johns Manville Micro-Lok</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johns Manville Micro-Lok HP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary:
- ANSI/CSA/IGSHPA C448 is being updated – changes have yet to be approved
- The 2024 ICC International Mechanical Code (IMC) no longer allows Lead pipes
- The 2024 IAPMO Uniform Mechanical Code (UMC) has 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/Indoor 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: NTS 1 Tubing OD = 1.125” (28.6 mm)
  IPS 1 Pipe OD = 1.315” (33.4 mm) 15% larger
Recommended Piping Materials for Inside/Indoor Piping

**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
- SDR is also known as “wall type”
- For the same SDR, each diameter of the pipe type (e.g., $\frac{3}{4}$, 1, 2) has the same pressure capability & rating
- **Examples:**
  - **PEX tubing** is SDR 9 (wall thickness is $\frac{1}{9}$ 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 $\frac{1}{11}$ of the OD = 9% of the OD

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

Annual Conference, December 5 - 7, 2023 – Las Vegas, NV
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 hydronic piping

Three types of CPVC for various applications:

- Hydronics
- Fire protection
- Plumbing
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
- Produced according to ASTM D2846, F441, F442 and/or CSA B137.6

Common types: CPVC 4120-05, CPVC 4120-06 (material designation codes)
Recommended Piping Materials for Inside/Indoor Piping

CPVC Configurations
- CPVC is provided in straight lengths as both **Tubing** and **Pipe**
- 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

Courtesy Lubrizol (x3)
Recommended Piping Materials for Inside/Indoor Piping

CPVC Joining
- CPVC pipe & fittings are joined via:
  1. Solvent cement (most common)
  2. Push-fit fittings
  3. Grooved mechanical fittings
  4. Flanged connections
Recommended Piping Materials for Inside/Indoor Piping

CPVC Joining
- CPVC pipe & fittings are joined via:
  1. Solvent cement (most common)
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Solvent Cement is Not Glue
- 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 and chemicals
- Each CPVC manufacturer should test for and publish chemical compatibility

Resource: PPI TR-19
Recommended Piping Materials for Inside/Indoor Piping

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

**Resource: FBC™ System Compatible Program**
- 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](https://www.lubrizol.com/CPVC/FBC-System-Compatible-Program)

- CPVC is compatible with Methanol
- CPVC is not compatible with polypropylene glycol antifreeze
Recommended Piping Materials for Inside/Indoor Piping

CPVC Summary
- Strong rigid piping material with high temperature capabilities (rated for 200°F)
- Available in various wall types and thicknesses (e.g., SDR 11, SDR 13.5, Schedule 40/80, etc.) depending on the required pressure rating
- Recognized in all model codes for inside/indoor hydronic piping
- Available in wide range of CTS and IPS diameters
- Wide variety of fitting shapes and sizes available
- More economical than copper
- Easy installation, no open flame
- Be careful with chemical compatibility
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 exposures up to 140°F (60°C)
- Good chemical resistance, corrosion resistant, economical
- Produced according to ASTM D2239, ASTM D3035, ASTM F714 and/or CSA B137.1
- Recognized in IAPMO model codes for inside/indoor piping (not approved in the ICC IMC)

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) fittings are produced according to ASTM Standard F1055
- Butt and Socket fusion joints shall be installed in accordance with ASTM Standard Practice F2620
- Electrofusion joints shall be installed in accordance with ASTM Standard Practice F1290
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](#)).
Recommended Piping Materials for Inside/Indoor Piping

**HDPE Summary**
- Tough, durable, flexible, strong material
- Proven over 40+ years in ground loop and hydronic applications
- Wide range of diameters and wall types
- Mechanical fittings (e.g., grooved) are options
- Available in various wall types and thicknesses (e.g., SDR 9, SDR 11, SDR 13.5, etc.) depending on the required pressure rating
- Material has its temperature limitations
- Good chemical compatibility
- Recognized in IAPMO codes for hydronic piping; not yet approved in ICC IMC for hydronic piping
- Heat fusion requires training, equipment, preparation, and attention to detail [obtain certification]
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 heating 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
   - Excellent chemical compatibility

   - PEX is widely used for plumbing, water service, fire protection, hydronic distribution, radiant 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
- Strong and tough material, suitable for applications up to 180°F (82°C) and beyond
- PEX density is slightly lower than HDPE and more flexible
- Lower tensile strength = Less stiff = Lower pressure rating for the same wall thickness
- Predominantly available as Tubing (CTS)
- 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: Configurations
- Available in coils or straight lengths, depending on the customer preference, the diameter, and application
- Copper tube size diameters from ¼ to 4 nominal
- PEX is available in natural, white, or colors such as red, white, blue, black, gray, orange, etc.

 Courtesy Wavin/Bow (x3)

 Courtesy REHAU
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 (both per ASTM F1807)

Copper crimp ring

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

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)
- Recognized in all model codes for inside/indoor hydronic piping
- Better chemical resistance than HDPE or CPVC
- Available in diameters up to 4 inch nominal
- Joining systems install without flame or fusion using basic hand tools or battery-electric tools
- Available with oxygen diffusion barrier (when needed)
- Excellent chemical compatibility
- More expensive than PE4710, more economical than copper

Courtesy Viega
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)**
   - Predominantly available as Tubing with the same dimensions as PEX tubing
   - PE-RT tubing can be joined via heat fusion or using most PEX compression fittings
   - Produced according to ASTM F2623, ASTM F2769, and/or CSA B137.18
   - Recognized in all model codes for inside/indoor piping
   - Good chemical compatibility (similar to HDPE)

**Common type:**
- PE4710 (PE material designation code)
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 pipe lengths in DN (diameter nominal) dimensions (e.g., 25 mm, 50 mm, 75 mm, etc.)
- Produced according to ASTM F2389 and/or CSA B137.11
- Recognized in all model codes for inside/indoor piping
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 for the same wall thickness.
Recommended Piping Materials for Inside/Indoor Piping

PP-R & PP-RCT Connections
- Connections are typically via heat fusion (socket, butt, saddle, and electrofusion)
- Various mechanical fittings (e.g., grooved) and flanged adapters are also available

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, no corrosion
- Good chemical compatibility
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), and temperature resistance
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](http://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

### Industry Codes & Standards
- ANSI/CSA/IGSHPA C448 Design and installation of ground source heat pump systems for commercial and residential buildings
- 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 Polyethylene (PE) and Polyamide (PA) Pipe and Fittings
- NSF 358 Certification Programs for Geothermal Piping Systems

### Research Reports
- 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
- ASHRAE Journal - A Simple Approach to Affordable GSHPs (Dr. Steve Kavanaugh)
- ASHRAE Journal - Paving a Path for Zero Energy Schools (Ray Beaufait, P.E.)
- Concepts for varying flow rate in geothermal earth loops - Max COP Tracking, Part 1 (John Siegenthaler)

### Geothermal in the Media
- IRS: Frequently asked questions about energy efficient home improvements and residential clean energy property credits - December 2022
- US DOE: Making Our Homes More Efficient: Clean Energy Tax Credits for Consumers - December 2022
- US Department of Energy Announces $13 million to Support Community Geothermal Heating and Cooling Solutions - April 2023
- CNBC Visits 1 Java St. (Brooklyn, NY) to Talk Geothermal - April 2023
- Fast Company: In this Massachusetts Neighborhood, Nearly Every Home is Switching to Geothermal Energy - June 2023
PPI Resources for the Geo Industry

Please visit our website for:
- A specific webpage for each piping material

CPVC tubing comes in SDR11 (90% standard density CPVC pipe). High density polyethylene (HDPE) is used in various applications, including Construction Division. PEX tubing comes in hydostatic pressure for appropriate pressure. PE-RT tubing comes in 73°F (1379 kPa at 23°C) tubing and pipe are suitable for high temperature applications. Polypropylene (PP) is a versatile piping material that is used in a wide range of applications. Two types of PP are used for pressure piping systems: PP-R (polypropylene random copolymer) and PP-RT (polypolypropylene random copolymer with modified crystallinity and temperature resistance). With their high temperature and pressure capabilities, PP-R and PP-RT pipes are suitable for demanding pressure piping applications, such as pressure piping (plumbing, hydronics) in commercial high-rise buildings.

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PPI Resources for the Geo Industry

Please visit our website for:
- Technical literature on many piping topics
PPI Resources for the Geo Industry

Model Specifications
- PPI MS-7 and PPI MS-8
- Attend PPI’s second presentation on Thursday, Dec. 7 at 9:15 am!
- How to Use PPI MS-7
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 TR-19

- First published in 1973; latest update 2023
- Provides chemical resistance to over 600 chemicals and most types of plastic pipes and fittings
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

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

* 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.

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**PPI Resources for the Geo Industry**

**Plastic Piping Design Calculator – Pipe Weight / Volume**
- Free online sizing tool at [www.plasticpipecalculator.com](http://www.plasticpipecalculator.com)

![Image of BCD Plastic Pipe Design Calculator Ver 3.0](image)

- **Input**
  - Length Of Pipe: 160 ft

- **Results**
  - Dry Weight: 369.2 lb, 167.5 kg
  - Filled Weight: 1117.9 lb, 507.1 kg
  - Volume Of Fluid In Pipe: 86.2 US Gallons, 326.2 L
  - Volume Of Mixture Fluid: 43.1 US Gallons, 163.1 L

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PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Thermal Expansion / Contraction
- Free online sizing tool at www.plasticpipecalculator.com

![Plastic Piping Design Calculator](BCD_Plastic_Pipe_Design_Calculator_Ver_3.0.png)

**Input**

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

**Results**

- Length of Tube Expansion: 7.7 in (195 mm)

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PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Expansion Arm / Loop
- Free online sizing tool at www.plasticpipecalculator.com

BCD Plastic Pipe Design Calculator Ver 3.0
EXPANSION ARM/LOOP

Input

Expansion Type:
- Arm
- Loop

Results

<table>
<thead>
<tr>
<th>Description</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length Lₐ</td>
<td>16.6 in</td>
<td>422 mm</td>
</tr>
<tr>
<td>Length L₂</td>
<td>33.3 in</td>
<td>845 mm</td>
</tr>
<tr>
<td>Expansion Length ΔL</td>
<td>7.7 in</td>
<td>195 mm</td>
</tr>
</tbody>
</table>
PPI Resources for the Geo Industry

Plastic Piping Design Calculator – Static Water Column Pressure
- Free online sizing tool at www.plasticpipecalculator.com

*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.
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 Geo Systems

Presentation Summary

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
Inside/Indoor Piping Materials for Geo Systems

Thank you!
Inside/Indoor Piping Materials

Selecting the best piping options for each project

Geothermal: The Genius Renewable

Live at Groundwater Week in partnership with NGWA

Las Vegas, NV
December 5-7, 2023