Plastic Piping Materials for Geothermal & Geoexchange Ground Loops
The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry
- PPI was formed in 1950 to develop test methods for plastic pressure pipes
- Today: Non-profit trade association serving North America

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

Members: PPI members share a common interest in broadening awareness and creating opportunities that expand market share and extend the use of plastics pipe in all of its many applications

www.plasticpipe.org
The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry
- Today, PPI’s five divisions focus on solutions for multiple applications:
  - Building & Construction Division
  - Corrugated Plastic Pipe
  - Energy Piping Systems Division
  - Municipal & Industrial Division
  - Power & Communications Division

PCD: HDPE Conduit for fiber optic
EPSD: Gas distribution piping
MID: HDPE water mains
The Plastics Pipe Institute

PPI’s 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 and cooling, snow and ice melting, district heating and cooling, and ground source geothermal piping systems.

Piping Materials: CPVC, HDPE (Geo), PEX, PE-RT, & PP
The Plastics Pipe Institute

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BCD involvement with industry groups:
Presentation Outline

This presentation will:

1. Describe the plastic piping materials used for geothermal/geoexchange systems
   - HDPE *high density polyethylene*
   - PEX *crosslinked polyethylene*
   - PE-RT *polyethylene of raised temperature resistance*
   - PP *polypropylene (PP-R and PP-RCT)*

2. Discuss the industry standards that apply to these piping materials

3. Demonstrate various manifold and header techniques

4. Introduce PPI, **PPI TN-55**, and other industry resources of piping information
1. Plastic Piping Materials for Geo Systems

The piping material is critical to the success of the geoexchange system

- Piping must provide corrosion resistance, chemical resistance, flexibility, impact resistance, resistance to slow crack growth, long-term hydrostatic strength (pressure capability), and temperature resistance

- Piping systems may experience changes in pressure up to 60 psig (415 kPa) due to thermal expansion/contraction of heat transfer fluid and the pipe itself

- Piping systems may experience changes in temperature from 25°F to 115°F (-4°C to 46°C)

- Geoexchange piping materials must also provide suitable heat transfer capabilities
Plastic Piping Materials for Geo Systems

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
- HDPE is recognized in virtually all codes and standards as an approved material for ground-coupled heat exchange piping systems (aka “ground loops”)
- Strong and tough material, suitable for applications up to 140°F (60°C)

Common types:
- PE 3608, PE 4710 (material designation codes)
Plastic Piping Materials for Geo Systems

HDPE: On the job
Plastic Piping Materials for Geo Systems

HDPE: Thermal Properties
- See PPI Handbook of Polyethylene Pipe 2nd Edition, Table E.1
- Specific Heat: 0.46 BTU / lb - °F
- Thermal Conductivity: 3.1 BTU-in/ft²-hr-°F (PE 4710)

<table>
<thead>
<tr>
<th>Thermal Property</th>
<th>PE Pipe Material Designation Code (°F)</th>
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<tbody>
<tr>
<td></td>
<td>PE2XXX</td>
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<tr>
<td>Coefficient of Thermal Expansion/Contraction (in/in · °F)</td>
<td>10 x 10⁻⁶</td>
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<tr>
<td>Specific Heat BTU / LB - °F</td>
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<tr>
<td>Thermal Conductivity (BTU · in/hr · sq. ft · °F)</td>
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</table>
Plastic Piping Materials for Geo Systems

**HDPE: Connections**

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

(socket and butt fusion joints, electrofusion fitting, socket fusion caps for testing)
Plastic Piping Materials for Geo Systems

HDPE: Connections

- **ASTM F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings** is the industry’s practice for heat fusion.
- **F2620** replaced **PPI TR-33** (now retired).
Plastic Piping Materials for Geo Systems

**HDPE: U-bends**
- HDPE U-bends can be fabricated from elbows, or
- Molded from the same polymer as the pipe material

- **U-bend fabricated with butt-fused elbows**
- **Molded HDPE U-bend already fused to pipe ends**
- **Coil of HDPE pipe with U-bend**
Plastic Piping Materials for Geo Systems

HDPE: U-bends
- HDPE U-bends can be fabricated from elbows, or
- Molded from the same polymer as the pipe material
- Examples of Molded U-bends in three sizes, factory-fused to HDPE pipes
Plastic Piping Materials for Geo Systems

PEX: Crosslinked Polyethylene
- Crosslinked polyethylene (PEX) is modified HDPE with enhanced capabilities
- PEX is a high-temperature, flexible pressure pipe, over 40 years of use globally
- Widely used for plumbing, water service, fire protection, hydronic heating and cooling, snow and ice melting and ground source geothermal/geoexchange piping systems
- Strong and tough material, suitable for applications up to 180°F (82°C) and beyond

Common types:
- PEX 1206, PEX 3306 (material designation codes)
Plastic Piping Materials for Geo Systems

PEX: On the job

Courtesy REHAU

Photo: Google
Plastic Piping Materials for Geo Systems

PEX: Thermal Properties
- See PPI TR-48/2014
- R-Value and Thermal Conductivity of PEX & PE-RT

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity ( \text{BTU} \cdot \text{in}/(\text{ft}^2 \cdot \text{hr} \cdot \text{°F}) )</th>
<th>Thermal Conductivity ( \text{W}/(\text{m} \cdot \text{°K}) )</th>
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<tr>
<td>PEX</td>
<td>2.86</td>
<td>0.41</td>
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<tr>
<td>PE-RT</td>
<td>3.15</td>
<td>0.46</td>
</tr>
</tbody>
</table>
Plastic Piping Materials for Geo Systems

PEX: Connections
- Connections are typically via compression fittings or electrofusion

Cold-expansion compression-sleeve PEX fitting as per ASTM F2080
HDPE electrofusion fitting on PEX tubing
Plastic Piping Materials for Geo Systems

PEX: U-bends
- PEX U-bends may be factory-formed from continuous pipe using heat, or
- Fabricated using special s/s fittings approved for direct burial

PEX U-bend encased in resin tip (two)

PEX U-bend with compression-sleeve fittings
Double U-bend configuration
Plastic Piping Materials for Geo Systems

PE-RT: Polyethylene of Raised Temperature Resistance
- PE-RT is HDPE material with enhanced capabilities to withstand higher temperatures
- PE-RT has a 35-year history of successful use in the European market
- Strong and tough material suitable for applications up to 180°F (82°C)
- PE-RT piping can be joined via heat fusion or compression fittings

Common types:
- PE 3608, PE 4710 (material designation codes)
Plastic Piping Materials for Geo Systems

PP: Polypropylene
- There are two types of PP pressure piping materials:
- *Random copolymerized polypropylene (PP-R)* is a high-temperature plastic pressure piping system first used for plumbing and hydronics, now for geothermal
- *Polypropylene random copolymer with modified crystallinity & temperature resistance (PP-RCT)* is a stronger grade of PP material, higher tensile strength

*Courtesy Pestan*  
*Courtesy Aquatherm*
Plastic Piping Materials for Geo Systems

**PP: Connections**
- Connections are typically via heat fusion
- Various mechanical fittings and adapters are also available
Plastic Piping Materials for Geo Systems

Plastic Piping Material Applications
- Each of these materials may be used for geoexchange ground loops and energy piles
- HDPE and PEX are sometimes supplied for double-U-bend configurations

PEX in a rebar cage - structural pile
Plastic Piping Materials for Geo Systems

Summary

- The four plastic piping materials used for geothermal/geoexchange systems are:
  - HDPE  \textit{high density polyethylene}
  - PEX  \textit{crosslinked polyethylene}
  - PE-RT \textit{polyethylene of raised temperature resistance}
  - PP  \textit{polypropylene (PP-R and PP-RCT)}

- 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, as well as good thermal conductivity.
2. Industry Standards for Plastic Piping

Importance of proper standards

- Each of these piping materials delivers long-term reliability, proven through decades of use around the world

- The life expectancy of these plastic piping materials, when installed according to industry and manufacturers’ guidelines, is typically well in excess of **fifty (50) years**

- Long-term pressure ratings are based on **ASTM Test Method D2837** with materials listed according to **PPI TR-3**

- Piping materials are specified through rigorous product standards with detailed testing requirements for materials and performance, as well as strict industry **certification programs** to ensure consistent quality control
Industry Standards for Plastic Piping

Importance of proper standards

- Project specifications that cite inappropriate pipe standards can cause confusion with manufacturers, the supply chain and installers
- Specifying an out-of-date or inappropriate standard for geothermal pipes may violate requirements of relevant mechanical codes while potentially increasing costs
- Project specifications that combine inappropriate or incompatible requirements, sometimes pulled from various sources with the best intentions, can create the need for products that don’t exist!
- Sometimes referred to as “Frankenstein specs”

Is this really what was intended?
Industry Standards for Plastic Piping

HDPE: High density polyethylene

Suggested language:

- All HDPE pipe and fittings shall be manufactured from a PE compound with a minimum pipe material designation code of PE3608 when evaluated in accordance with ASTM D3350, and a minimum hydrostatic design stress (HDS) value of 800 psi at 73°F (23°C)

- HDPE pipe shall comply with one or more of the following product standards:
  ASTM D3035, ASTM F714, or CSA B137.1

- All HDPE pipe and fittings shall meet the requirements of NSF 358-1
Industry Standards for Plastic Piping

PEX: Crosslinked Polyethylene

Suggested language:

- All PEX tubing shall be manufactured with a minimum pipe material designation code of PEX1206 when evaluated in accordance with ASTM F876 and a minimum Hydrostatic Design Stress (HDS) value of 630 psi at 73°F (23°C)

- PEX tubing shall comply with one or more of the following product standards:  
  * ASTM F876, F2788 or CSA B137.5

- All PEX tubing and fittings shall meet the requirements of NSF 358-3
Industry Standards for Plastic Piping

PE-RT: Polyethylene of Raised Temperature

Suggested language:

- All PE-RT tubing shall be manufactured from a PE compound with a minimum pipe material designation code of PE3608 when evaluated in accordance with ASTM D3350, and a minimum hydrostatic design stress (HDS) value of 630 psi at 73°F (23°C)

- PE-RT tubing shall comply with one or more of the following product standards: ASTM F2623, F2769, or CSA B137.18

- All PE-RT tubing and fittings shall meet the requirements of NSF 358-4
Industry Standards for Plastic Piping

PP: Polypropylene

Suggested language:

- All PP pipe and fittings shall be manufactured from a PE compound with a minimum required strength (MRS) of 10 MPa (1,450 psi) at 68°F (20°C) when evaluated in accordance with ISO 9080.

- PP-R and PP-RCT pipe and fittings shall comply with one or more of the following product standards: ASTM F2389 or CSA B137.11.

- All PP pipe and fittings shall meet the requirements of NSF 358-2.
Industry Standards for Plastic Piping

ANSI/CSA/IGSHPA C448-16

- The ANSI designated Bi-national consensus standard for the design and installation of ground source heat pump systems
- First published in February 2016
- This Standard was developed by a Bi-national Technical Committee which comprised of the industry's leaders from Canada and USA
- Contains Piping Requirements and much more
Industry Standards for Plastic Piping

Summary

- It is important to properly select and specify the correct type of ground loop piping materials using current industry products and correct specific language, to avoid misunderstandings with suppliers and installers.

- Each of the plastic piping materials used for ground loops can be specifically specified.

- Use of and reference to ANSI/CSA/IGSHPA C448-16 will help to ensure proper design and installation of geothermal systems.
3. Manifold and Header Techniques

Manifolds and Headers
- Most ground source geothermal projects require more than one loop of heat exchange piping for the required heat transfer capacity
- Header systems and distribution manifolds are utilized to connect multiple piping loops

Images courtesy IGSHPA
Manifold and Header Techniques

In-ground header systems are typically piped in one of three (3) distinct configurations:

1. **Reverse-Return** (preferred for balanced flow)

2. **Series** (generally avoided due to high pressure losses)

3. **Parallel or “Home run”** (each ground loop piped individually to a central header or manifold in a collection vault or in the building mechanical room or space)
Manifold and Header Techniques

Manifolds and Headers
- Example of typical **Reverse-Return in-ground (buried) header system** employing several pipe diameters to connect four (4) vertical boreholes; flow to be equal through all four borehole loops
- Connection details at tees and elbows not shown (not to scale)
Manifold and Header Techniques

Manifolds and Headers
- Example of typical Reverse-Return in-ground (buried) header system employing several pipe diameters to connect four (4) vertical boreholes; flow to be equal through all four borehole loops
Manifold and Header Techniques

Manifolds and Headers
- **Parallel distribution manifolds** (also called mechanical manifolds) are typically located in building mechanical spaces or in exterior collection vaults, buried in the earth.
- A distribution manifold typically contains a supply header and a return header, mounted closely together in pairs.
- Manifolds may include shut-off and/or balancing valves.
- When the individual ground loops are connected to such a centralized distribution manifold, then the ground loops are in parallel, also known as **home-run**.
Manifold and Header Techniques

Manifolds and Headers
- Example of a distribution manifold with shut-off valves on supply and return headers and balancing valves on supply header (two views of the same design)
Manifold and Header Techniques

Summary
- Most ground source geothermal projects require more than one loop of heat exchange piping for the required heat transfer capacity
- Header systems and distribution manifolds are utilized to connect multiple piping loops
- In-ground header systems are typically piped in one of three (3) distinct configurations:

1. **Reverse-Return** (preferred for balanced flow)
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4. PPI TN-55 and Other Resources

PPI TN-55 Content

1.0 Introduction
2.0 Mechanical Components
3.0 Ground Loop Heat Exchange Piping Systems
   3.1.1 Horizontal Piping Systems
   3.1.2 Vertical Piping Systems
   3.1.3 Pipe-in-Pipe Coaxial Vertical Systems
   3.1.4 Helix Piping Systems
   3.1.5 Inclined or Angled Configurations
   3.1.6 Horizontal Directional Drilling (HDD)
   3.1.7 Energy Piles
   3.1.8 Submerged 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
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- Technical Reports
- Case studies
- Design information
- Educational videos
- Finding Manufacturers
- Links to other organizations
- [www.plasticpipe.org](http://www.plasticpipe.org)
PPI TN-55 and Other Resources

Plastic Pressure Piping Design Calculator
- Free online sizing tool at www.plasticpipecalculator.com

![Plastic Pressure Pipe Design Calculator](image-url)
Summary

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1. Describe the plastic piping materials used for geothermal/geoexchange systems
   - HDPE \textit{high density polyethylene}
   - PEX \textit{crosslinked polyethylene}
   - PE-RT \textit{polyethylene of raised temperature resistance}
   - PP \textit{polypropylene (PP-R and PP-RCT)}

2. Discuss the industry \textbf{standards} that apply to these piping materials

3. Demonstrate various \textbf{manifold} and \textbf{header} techniques

4. Introduce PPI, \textbf{PPI TN-55}, and other industry resources of piping information
Plastic Piping Materials for Geothermal & Geoexchange Ground Loops

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