Plastic 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](http://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](https://plasticpipe.org/BuildingConstruction)
Ground Source Geothermal Systems

Ground Source Geothermal

- Ground source heat pumps are the **most efficient** source of heating and cooling energy for buildings
- The **Ground Loop Pipe** is the heat exchanger with the Earth (a.k.a the “ground-coupled heat exchanger”)
- There are multiple methods of installing group loop pipes, depending on sight location, hydrology, etc.

Images
Courtesy
IGSHPA

Horizontal ground loops  Vertical pipes in boreholes  Submerged pipes in water
Ground Source Geothermal Systems

Relevance
Two recent PPI BCD Project of the Year winners have been Geothermal projects:
- 2018: Whisper Valley Net-Zero Capable Community in Austin, TX
  - 237 homes with PEXa double U-bends in a community geo system (313,000 feet of pipe)
Ground Source Geothermal Systems

Relevance
Two recent PPI BCD Project of the Year winners have been Geothermal projects:
- 2019: YVR Airport Geoexchange System in Vancouver, BC
  - 841 boreholes 500 ft deep with PE 4710 loops plus headers (841,000+ feet of pipe)
Ground Source Geothermal Systems

Relevance
Princeton University (NJ) Geothermal conversion
- Princeton is phasing out steam generation for heating and instead implementing a new low-temperature heating water energy system driven by electric heat pumps, thermal storage and geo-exchange, which captures heat from inside campus buildings in the summer and stores that energy in the ground until it is needed again in the winter.”
Presentation Outline

This presentation will:

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

2. Discuss geothermal industry **standards** and codes

3. Demonstrate various **manifold** and **header** techniques

4. Introduce **PPI TN-55** and industry resources of piping information
Prologue: Plastic Piping Materials - General

Drinking Water Safety

- **All** plastic tubing, pipes and fittings intended for potable (drinking) water must meet the requirements of **NSF/ANSI/CAN Standard 61** *Toxicological Evaluation for Materials in Contact with Drinking Water* (“Health Effects”)

1.1 **Purpose** “This Standard establishes minimum health effects requirements for the chemical contaminants and impurities that are indirectly imparted to drinking water from products, components, and materials used in drinking water systems.”
Prologue: Plastic Piping Materials - General

“Tubing vs. Pipe”

- “Tubing” the actual Outside Diameter is 1/8 inch larger than the nominal size
- “Pipe” 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

- 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, more common in Geothermal
- Example: 1 inch CTS Tubing OD = 1.125” (28.6 mm)
  1 inch IPS Pipe OD = 1.315” (33.4 mm) 15% larger
Prologue: Plastic Piping Materials - General

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

- Examples:
  - PEX tubing is SDR 9 (wall thickness is 1/9 of the OD)
  - CPVC tubing is SDR 11 (wall thickness is 1/11 of the OD)
  - HDPE pipe may be SDR 9, SDR 11, SDR 13.5, etc. (wall thickness is 1 / 13.5 of the OD [7.4%])

- For the same SDR, each diameter of the pipe type (e.g., ¾, 1, 2) has the same pressure capability & rating

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

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Prologue: Plastic Piping Materials - General

Pipe Design Factor / Safety Factor

- All plastic tubing, pipes and fittings have inherent safety factors for the intended applications based on prescribed Design Factors within product standards

- Mandatory Design Factors reduce the listed operating pressures by up to 50%*
  *Most PE 4710 materials utilize a 0.63 design factor

- Pressure-Temperature ratings are based on an extrapolated time-to-failure prediction using a Design Factor -
  - Actual burst pressure capability is above the listed long-term pressure rating

- Plastic systems demonstrate Long-term Hydrostatic Strength (LTHS) through established test methods such as ASTM D2837 and listings according to PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB) and Hydrostatic Design Stresses (HDS) for Thermoplastic Piping Materials
1. Plastic Piping Materials for Geo Systems

The piping material is critical to the success of the ground loop system

- Piping must provide corrosion resistance, chemical resistance, flexibility, impact resistance, toughness, resistance to slow crack growth (SCG), 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)

- Geothermal piping materials must also provide suitable heat transfer capabilities

- The ground loop piping must be a multi-talented top performer!
Plastic Piping Materials for Geo Systems

Four types of plastic piping materials are used for ground source geothermal systems:

- HDPE  \( \text{high density polyethylene} \)
- PEX  \( \text{crosslinked polyethylene} \)
- PE-RT  \( \text{polyethylene of raised temperature resistance} \)
- PP  \( \text{polypropylene (PP-R and PP-RCT)} \)
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 loops.

- Strong and tough material, suitable for applications up to 140°F (60°C).

**Common types:**
- PE 3608, PE 4710 (thermoplastic material designation codes).

Coil of HDPE piping with molded U-bend already fused to pipe ends.
Plastic Piping Materials for Geo Systems

What is PE?

- **Polyethylene** (PE): A thermoplastic produced from polymerization of ethylene

- **Ethylene** is a derivative of ethane, a constituent within natural gas or derived from oil

- **Ethane** is a very clean molecule, energy efficient in production

- PE is non-polar, making it slippery (low surface polarity)

- Saturated bonds resist most chemical attack

- PE is an environmentally-friendly polymer
Plastic Piping Materials for Geo Systems

What is HDPE?

- **High Density** Polyethylene (PE) is a grade of PE

- **Density** shall be $> 0.94 \text{ g/cm}^3$ (pure water = 1.0 g/cm$^3$)

- **Crystalline structures** consist of folded chains, providing **stiffness** and **tensile strength**

- **Amorphous phase** consists of tie molecules, providing **flexibility**, **impact resistance**, **stress crack resistance** and **abrasion resistance**

- HDPE pipe materials are **blends** of these phases
Plastic Piping Materials for Geo Systems

What is HDPE?

- This unique polymeric structure of HDPE yields a **Visco-Elastic** material

  - **Viscous**: Requires time to deform and to recover deformation
  - **Elastic**: Immediate recoverable deformation

- HDPE materials are **blended** or “tuned” for ideal combinations of material properties

- Typical Maximum Operating Temp. is **140°F (60°C)** for pressure pipe

- Pressure ratings of pipes must be de-rated above **80°F (27°C)**
Plastic Piping Materials for Geo Systems

What do “PE 3408”, “PE 3608”, and “PE 4710” mean?

- Thermoplastic pipe material designation codes (e.g., PE 3608, PE 4710) 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”

PE 4710 vs. PE 3408:
- 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
Plastic Piping Materials for Geo Systems

HDPE with higher Slow Crack Growth (SCG) resistance

- **PE 3408**: Minimum 10 hours SGC Resistance using PENT test (ASTM F1473)

- **PE 4710**: Minimum 500 hours SGC Resistance using PENT test (ASTM F1473)
  - At least 50 times improvement (10 hours x 50 = 500)

- Many of today’s commercially-available PE 4710 materials exceed **2,500 hours** PENT testing

- Excellent slow crack growth resistance
- Resistance to abrasion, scratches, gouges, notches
Plastic Piping Materials for Geo Systems

HDPE: On the job
Plastic Piping Materials for Geo Systems

HDPE: On the job

Courtesy Versaprofiles

Courtesy Versaprofiles
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 for PE 4710

<table>
<thead>
<tr>
<th>Thermal Property</th>
<th>PE2XXX</th>
<th>PE3XXX</th>
<th>PE4XXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of Thermal Expansion/Contraction (in/in - °F)</td>
<td>10 x 10⁻³</td>
<td>9.0 x 10⁻³</td>
<td>8.0 x 10⁻³</td>
</tr>
<tr>
<td>Specific Heat BTU / LB - °F</td>
<td>0.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Conductivity (BTU · in /hr · sq. ft · °F)</td>
<td>2.6</td>
<td>3.0</td>
<td>3.1</td>
</tr>
</tbody>
</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 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 Practice F2620**

![Socket and Butt fusion joints](image1)
![Electrofusion fitting](image2)
![Socket fusion caps for testing](image3)
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 (Based somewhat on PPI TR-33)
- First published in 2006, latest edition **2020**
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 diameters, factory-fused to HDPE pipes

Image Courtesy
Centennial Plastics
Plastic Piping Materials for Geo Systems

**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
Plastic Piping Materials for Geo Systems

PEX: Crosslinked (X) Polyethylene

- Crosslinked polyethylene (PEX) is actually modified HDPE with enhanced capabilities for temperature

- Crosslinking creates a three-dimensional matrix of connected molecules

- PEX is a high-temperature, flexible pressure pipe, over 40 years of global usage in pressure applications

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

- Approved for geo ground loops in North America since 2008

Illustration of PEX “molecule”
Plastic Piping Materials for Geo Systems

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
- Currently only available as a Tubing for geothermal applications

Common types:
- PEX 1206, PEX 3306 (PEX tubing material designation codes)

- Note: PEX “code” is Not Comparable to the PE material designation code

Illustration of PEX “molecule”
Plastic Piping Materials for Geo Systems

PEX: On the job
Plastic Piping Materials for Geo Systems

PEX: On the job

Courtesy REHAU

Photo: Google
Plastic Piping Materials for Geo Systems

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

- PE 4710 Thermal Conductivity = 3.1

- PEX Thermal Conductivity = 2.86 (92% of HDPE)

- PE-RT Thermal Conductivity = 3.15 (101% of HDPE)

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Plastic Piping Materials for Geo Systems

PEX: Connections
- Connections are typically via compression fittings or electrofusion
- Butt fusion or socket fusion fittings do not work well with PEX

Press-sleeve PEX fitting as per ASTM F3347
Cold-expansion PEX fitting as per ASTM F1960
Plastic Piping Materials for Geo Systems

PEX: Connections
- Connections are typically via compression fittings or electrofusion
- Butt fusion or socket fusion fittings do not work well with PEX

Cold-expansion compression-sleeve
PEX fitting as per ASTM F2080

HDPE electrofusion fitting on PEX tubing
as per ASTM F1055
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

*Courtesy REHAU*

*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

**PEX: Summary**

- Tough, durable, flexible, strong material with high temperature capabilities (180°F or higher)

- Ideal when solar thermal generation (higher temperature) is combined with ground loop storage

- Approved for geo ground loops in North America since 2008 (in use in Europe before that)

- Compression fittings install without fusion using basic hand tools or battery-electric tools
Plastic Piping Materials for Geo Systems

**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)

- PE-RT tubing can be joined via heat fusion or most PEX compression fittings

- PE-RT = HDPE material with higher temperature capabilities

**Common types:**
- PE 2708, PE 4710 (PE material designation codes)
Plastic Piping Materials for Geo Systems

PE-RT: Thermal Properties
- PPI TR-48/2014 *R-Value and Thermal Conductivity of PEX and PE-RT*
- PE 4710 Thermal Conductivity = 3.1
- PEX Thermal Conductivity = 2.86 (92% of HDPE)
- PE-RT Thermal Conductivity = 3.15 (101% of HDPE)

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Plastic Piping Materials for Geo Systems

PP: Polypropylene
- Two types of PolyPropylene 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 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

Various colors for different applications
Collection of PP pipes and fittings
Plastic Piping Materials for Geo Systems

PP: Connections
- Connections are typically via heat fusion
- Various mechanical fittings (e.g., grooved) and adapters are also available
Plastic Piping Materials for Geo Systems

PP: Connections
- **Electrofusion** joints have embedded copper wires that heat the fitting, welding it to pipe ends
- A computerized machine controls the process
Plastic Piping Materials for Geo Systems

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

- PEX in rebar cage/structural pile
- PEX Double U-bend being prepared for installation
- HDPE Double U-bend going down the Borehole
Plastic Piping Materials for Geo Systems

Summary
- The four plastic piping materials used for geothermal ground loop systems are:
  - HDPE  *high density polyethylene*
  - PEX  *crosslinked polyethylene*
  - PE-RT  *polyethylene of raised temperature resistance*
  - PP  *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), temperature resistance, and good thermal conductivity
2. Industry Standards for Plastic Piping, Geo Codes

Importance of proper standards

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

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

- Piping materials are specified through rigorous product standards with detailed testing requirements for materials and performance

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

- Strict industry **certification programs** to ensure consistent quality control
Industry Standards for Plastic Piping, Geo Codes

Importance of proper standards

- 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 cite inappropriate pipe standards can cause confusion with manufacturers, the supply chain, and installers

- 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”
Industry Standards for Plastic Piping, Geo Codes

**NSF 358 Standards**

- A series of standards specifically for geothermal ground loop piping
- Includes special test requirements:
  - Compatibility with antifreeze mixtures
  - Tensile **pull-out tests** for connections
- Pipe manufacturers pay to have their products tested and certified to **358-x** (the appropriate version for the type of pipe)

- Four versions of **NSF 358**:
  - NSF 358-1 HDPE
  - NSF 358-2 PP
  - NSF 358-3 PEX
  - NSF 358-4 PE-RT
Industry Standards for Plastic Piping, Geo Codes

HDPE: High density polyethylene

Suggested specification language:

- All HDPE pipe and fittings shall be manufactured from a PE compound with a minimum pipe material designation code of **PE 3608** (or **PE 4710**) 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, Geo Codes

PEX: Crosslinked Polyethylene

Suggested specification language:

- All PEX tubing shall be manufactured with a minimum pipe material designation code of PEX 1206 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, ASTM F2788, or CSA B137.5

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

PE-RT: Polyethylene of Raised Temperature

Suggested specification language:

- All PE-RT tubing shall be manufactured from a PE compound with a minimum pipe material designation code of **PE 3608** when evaluated in accordance with ASTM D3350, and a minimum hydrostatic design stress (HDS) value of **800 psi** at 73°F (23°C)

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

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

PP: Polypropylene

Suggested specification language:

- All PP pipe and fittings shall be manufactured from a PP 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, Geo Codes

ANSI/CSA/IGSHPA C448-16

- C448 is the ANSI designated bi-national consensus standard for the design and installation of ground source heat pump systems

- First published in February 2016 (2nd edition is in development)

- C448 was developed by a Bi-national Technical Committee comprised of the industry's leaders from Canada and USA

- Contains *Piping Requirements, Equipment, Design, Installation, Testing, Heat Transfer Fluids, Decommissioning* and much more
Industry Standards for Plastic Piping, Geo Codes

IAPMO’s Uniform Mechanical Code

- Latest 2021 edition published in March 2020

- **Appendix F** is *Geothermal Energy Systems*

- Contains *Installation, Piping Requirements, Testing*, more
Industry Standards for Plastic Piping, Geo Codes

IAPMO’s Uniform Solar, Hydronics and Geothermal Code

- Latest 2021 edition published in March 2021
- Chapter 7 is Geothermal Energy Systems
- Contains Installation, Piping Requirements, Testing, more
Industry Standards for Plastic Piping, Geo Codes

Summary

- Using industry standards helps to ensure proper design and installation of geothermal systems

- Each of the plastic piping materials used for ground loops can be clearly specified using standards

- 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
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

Manifold and Header systems are typically piped in one of three (3) distinct configurations:

1. **Reverse-Return**: Typically preferred for balanced flow

2. **Series**: Generally avoided due to high pressure losses

3. **Parallel or “Home run”**: Each ground loop is piped individually to a central header or manifold located in an outdoor (e.g., buried) collection vault or in the building mechanical room or space
Manifold and Header Techniques

In-ground Header Example
- Example of typical Reverse-Return in-ground (buried) header system employing several pipe diameters to connect four (4) vertical boreholes.
- Pressure drop through all four pathways must be balanced to ensure that flow is equal through all four borehole loops (unequal flow = unequal heat transfer and other issues).

Legend:
- Boreholes (4)
- Flow direction
- Line thickness indicates relative pipe diameter
- Connection details at tees and elbows are not shown

Not to scale
Manifold and Header Techniques

In-ground Header Example
- Example of typical Reverse-Return in-ground (buried) header system employing several pipe diameters to connect four (4) vertical boreholes
- Pressure drop through all four pathways must be balanced to ensure that flow is equal through all four borehole loops (unequal flow = unequal heat transfer and other issues)
Manifold and Header Techniques

Manifolds

- **Parallel distribution manifolds** (also called mechanical manifolds) are typically located in building mechanical spaces or in exterior collection vaults, buried in the earth.

- Manifold assembly typically contains a supply and return Manifold, mounted closely together in pairs.

- Manifolds may include shut-off valve (common) and/or balancing valves (rare).

- 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
- **Parallel distribution manifolds** (also called mechanical manifolds) are typically located in building mechanical spaces or in exterior collection vaults, buried in the earth

- Examples:
  - Polypropylene (PP-R) valved manifolds located in small outdoor vaults backfilled with soil
  - Polypropylene (PP-R) valved manifolds located in concrete vault
Manifold and Header Techniques

**Manifolds**
- 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)

*Courtesy ISCO Industries*
Manifold and Header Techniques

Manifolds
- Example of HDPE collection vaults with integrated manifolds (two different designs)

Courtesy ISCO Industries
Manifold and Header Techniques

**Manifolds**
- Example of HDPE *collection vaults* with integrated manifolds (two different designs)

*Courtesy ISCO Industries*
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
- Manifold and header systems are typically piped in one of three (3) distinct configurations:
  1. Reverse-Return headers
  2. Series headers
  3. Parallel or “Home run” manifolds
4. PPI TN-55 and Other Resources

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
PPI TN-55 and Other Resources

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 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

3.1.2 Vertical Piping Systems

For vertical systems, flexible plastic pipes can be fabricated or formed into U-bend configurations using bending, mechanical forming or forming hot-forming techniques. Pipe U-bends are lowered into vertical boreholes, and then grouted from the bottom to the top of the borehole with a grouting material selected for factors such as safety for contact with water aquifers, thermal conductivity, permeability, non-permeability, and other environmental factors. Typical borehole depths range from 50 to 600 feet (15 m to 182 m), and even deeper in certain projects using improved driving technology. In some cases, vertical boreholes may extend into or through water aquifers that serve as sources for residential or municipal potable water systems.

Both single U-bend and double U-bend configurations are available. Double U-bends can increase the thermal performance of a borehole. See Figures 6a & 6b.

3.1.2.1 In deep vertical boreholes, ground loop piping designers are often concerned about the static pressure of the fluid exceeding the pressure rating of the pipe itself, because substantially greater pressures can occur at the bottom of vertical piping loops. This can also occur when piping loops are connected to high-rise buildings.

Figure 6a & 6b: Cross section of Single U-bend and Double U-bend Vertical heat exchangers.

3.1.2.2 Grout is a cementitious material or bleed mixture, pumped into annular cavities between pipes and the earth, to seal the cavity. Grout material is usually mixed onsite and pumped into the annulus from the bottom to the top, using a cementing pipe known as the Terrier pipe. The function of grout is protection of groundwater supply, to prevent groundwater migration between aquifers, for load bearing between pipes and borehole walls, and to prevent upward transfer from aquifers. Proper grout materials allow movement of the pipes and do not drain or create voids. Approved grout materials and their placement are typically controlled by local code enforcement regulations.
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5.2 Distribution Manifolds

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. When the individual ground loops are connected to such a centralized distribution manifold, then the ground loops are in parallel, also known as a network.

Larger pipes transfer fluid to and from the supply and return headers of the distribution manifold, respectively, to the heat pump equipment in the mechanical room or space.

Distribution manifolds may be built with individual balancing valves installed on the supply or return header, depending on the type of balancing valve used.

Balancing valves can correct the unbalanced head pressure loss (or head loss) at short circuits simply by adding the correct amount of resistance in the valve itself. This can correct inherently unbalanced systems to ensure optimal flow through each loop of the ground heat exchange piping. See Figure 18 as an example.

Shutoff valves are typically installed at each loop or circuit, on both supply and return headers, to allow for complete isolation for plugging, repair and maintenance.

Figure 18: Example of a distribution manifold with shut off valves on supply and return headers and balancing valves on supply header (two inlets of the sewer design)
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4.0 Ground Loop Heat Exchange Piping Materials

5.0 Headers and Distribution Manifolds

5.2.1 Collection Vaults

Underground collection vaults are generally employed when building the mechanical space is limited or the system is very large. Interior turned collection vaults can be located adjacent to buildings or installed at long distances from buildings, affecting 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, corner, or tower, lightweight 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)
PPI TN-55 and Other Resources

Please visit our website for:
- Application information on Geothermal Ground Loop Piping Systems, links to other tools

See Also
- PPI TN-55 Plastic Piping Materials for Ground Source Geothermal Heating and Cooling Applications
- 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 and residential buildings
- 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
PPI TN-55 and Other Resources

Plastic Piping Design Calculator
- Free online sizing tool (pressure loss, volume, etc.) at www.plasticpipecalculator.com
PPI TN-55 and Other Resources

International Ground Source Heat Pump Association (IGSHPA) [www.igshhpa.org](http://www.igshhpa.org)
- Non-profit trade association focused on supporting the geothermal industry
- Training, certifications, design tools

EXPERTS IN OUR FIELD

For more than three decades, the International Ground Source Heat Pump Association (IGSHPA) has worked to advance ground source heat pump (GSHP) technology on local, state, national, and international levels.

Welcome to the new IGSHPA!

Your past support of the International Ground Source Heat Pump Association has been central to the advancement of our industry. Thank you. Together, we are authoring a new chapter in the evolution of the organization and of the geothermal heat pump industry.

Last year OSU dissolved the IGSHPA Board and in June approved the transfer of IGSHPA, its intellectual property, and assets to the control of the Geothermal Exchange Organization. The new IGSHPA will be functionally and operationally independent, with GEO providing limited oversight of governance and financial solvency.
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Geothermal Exchange Organization (GEO) [www.geoexchange.org](http://www.geoexchange.org)
- Non-profit trade association focused on supporting the geothermal industry
- Advocacy, tax incentive programs, promotions

About GEO

The Geothermal Exchange Organization (GEO) is the Voice of the Geothermal Heat Pump Industry in the United States. As a non-profit trade association, we promote the manufacture, design and installation of GeoExchange® systems—the most energy efficient and environmentally friendly heating and cooling technology in the world.

Government affairs and public outreach strategies pursued by GEO are more important than ever to knocking down barriers to industry growth, maintaining progress already won, and securing new opportunities. GEO advocacy successfully increased tax credits for residential geothermal heat pump installations from $300 to 30% of system costs. And through our efforts, geothermal heat pumps are increasingly recognized as a renewable energy technology alongside wind and solar, ensuring an integral role in meeting future government energy and environmental goals.
Presentation Summary

This presentation did:

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

2. Discuss geothermal industry **standards** and codes

3. Demonstrate various **manifold** and **header** techniques

4. Introduce **PPI TN-55** and industry resources of piping information
Plastic Piping Materials for
Ground Source Geothermal Systems

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Thank you!