Plastic Piping Materials for Ground Source Geothermal Systems

A presentation by the Plastics Pipe Institute

Contact

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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

2020: Over 170 members firms involved with the plastic pipe industry around the world

Website: www.plasticpipe.org

The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry

- PPI's five divisions focus on solutions for multiple applications:
  - **Building & Construction Division (BCD)**
  - Drainage
  - Energy Piping Systems
  - Municipal & Industrial
  - Power & Communications

BCD Materials: PEX, CPVC, PE-RT, PEX-AL-PEX, PP, HDPE (Geothermal)

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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.

BCD involvement with industry groups:

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Ground Source Geothermal Systems

Ground Source Geothermal

- Ground source heat pumps are the most efficient source of heating and cooling energy for any type of building (vs. VRF, boilers, chillers, etc.)

System Benefits:

- Piping loops exchange heat with the Earth
- Geothermal heat pumps can have efficiencies (COP) greater than **450%** when operating in heating mode
- Heat is rejected to the earth when cooling (high EER)
- Heat pumps are indoors, out of sight, no noise
- Low operating costs, high reliability, economical


Courtesy IGSHPA

Example of horizontal ground loops

Ground Source Geothermal Systems

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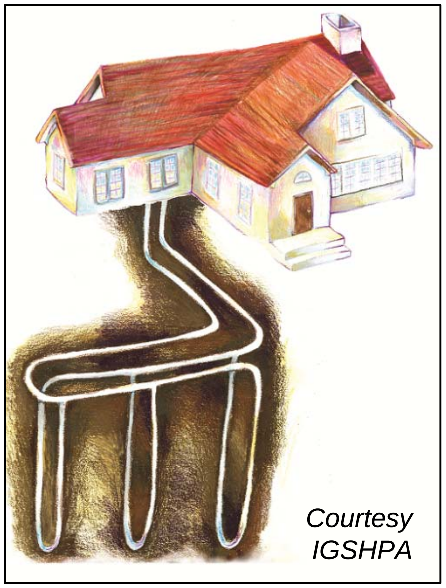

Example of vertical ground loops

Ground Source Geothermal Systems

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Example of submerged pond loop

Courtesy IGSHPA

Ground Source Geothermal Systems

Relevance

The last two **PPI BCD Project of the Year** winners have been Geothermal projects:

- **2018: Whisper Valley** Net-Zero Capable Community in Austin, TX (**REHAU**)
    - 237 homes with PEXa double U-bends in a community geo system (313,000 ft of pipe)

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Ground Source Geothermal Systems

Relevance

The last two **PPI BCD Project of the Year** winners have been Geothermal projects:

- **2019: YVR Airport** Geoexchange System in Vancouver, BC (**Versaprofiles**)
    - 841 boreholes 500 ft deep with PE4710 loops plus headers (841,000+ ft of pipe)

Presentation Outline

This presentation will:

1. Describe the **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 the industry **standards** that apply to these piping materials

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

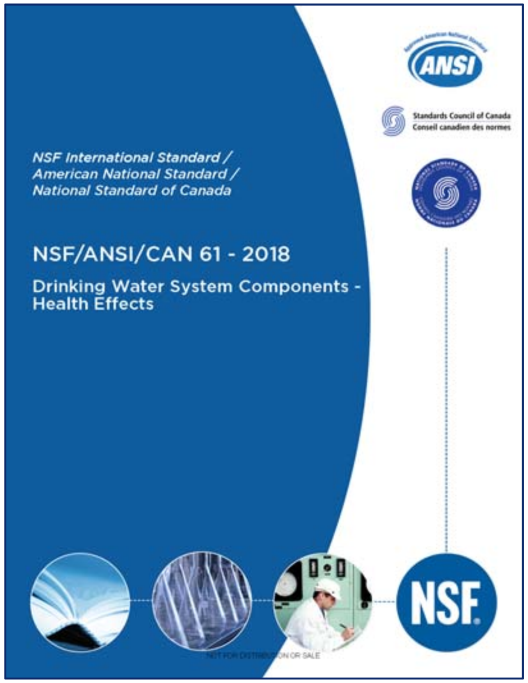
4. Introduce **PPI TN-55** and other industry resources of piping information

Plastic Piping Materials

Drinking Water Safety

- **All** plastic tubing, pipes and fittings intended for potable (drinking) water shall 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."



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Plastic Piping Materials

“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)

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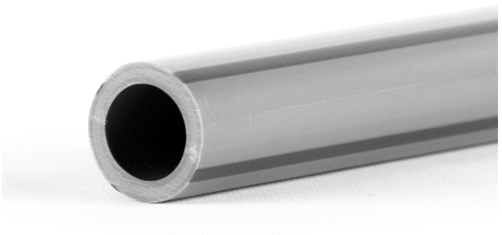


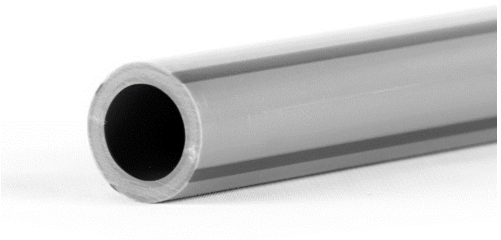
Plastic Piping Materials

Dimension Ratios

- Most* plastic pipe and tubing uses a *Standard Dimension Ratio (SDR)*
- *Standard Dimension Ratio - the ratio of outside diameter to wall thickness, calculated by dividing the average outside diameter of the tubing by the minimum wall thickness*
- 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.

- Within a *Standard Dimension Ratio*, 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*



Plastic Piping Materials

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%*
  **Certain PE 4710 materials utilize a 0.63 design factor*

- Pressure - Temperature ratings are based on an extrapolated time-to-failure prediction using a **0.50 Design Factor** on pressure; actual capability is **2x** the listed pressure

- 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, 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 25ºF to 115ºF (-4°C to 46°C)

- Geothermal 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)

Coil of HDPE piping with molded U-bend already fused to pipe ends

Plastic Piping Materials for Geo Systems

HDPE: On the job

Courtesy Versaprofiles

Plastic Piping Materials for Geo Systems

HDPE: On the job

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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/ft^2-hr-°F** (PE 4710)

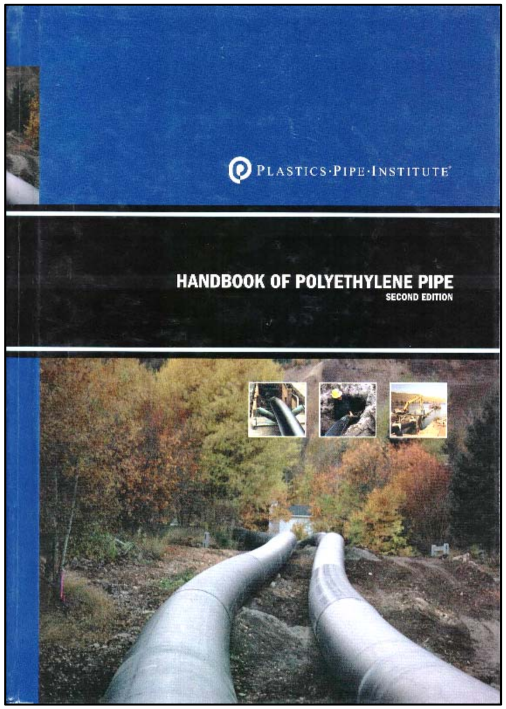


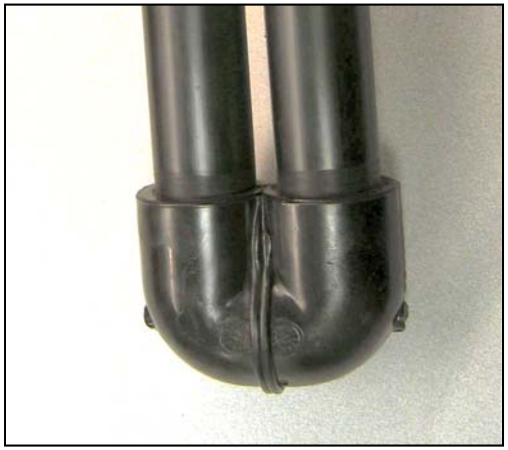
TABLE E.1
Approximate Value of Thermal Property for Temperature Range Between 32 and 120°F (0 and 49°C)

Thermal Property	PE Pipe Material Designation Code[1]		
	PE2XXX	PE3XXX	PE4XXX
Coefficient of Thermal Expansion/Contraction[2] (in/in ·°F)	10×10^{-5}	9.0×10^{-5}	8.0×10^{-5}
Specific Heat BTU / LB - °F		0.46	
Thermal Conductivity (BTU · in /hr · sq. ft ·°F)	2.6	3.0	3.1

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

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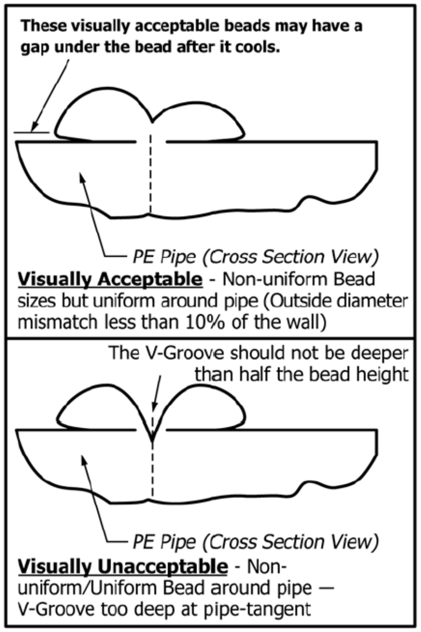
Plastic Piping Materials for Geo Systems

HDPE: Connections

- **ASTM F2620** *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings* is the industry's practice for heat fusion
- First published in 2006, latest edition 2019



Designation: F2620 – 13

An American National Standard

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

This standard is issued under the fixed designation F2620; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 standard 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 per Specification D2513 and PE potable water, sewer and industrial pipe manufactured per 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—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 and health practices and determine the applicability of regulatory limitations prior to use.*

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

2.2 *PPI Documents:*

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

TR-41 Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping[3]

2.3 *AWWA Documents:*

AWWA C901 Standard for Polyethylene (PE) Pressure Pipe and Tubing, ½ in. (13 mm) through 3 in. (76 mm), for Water Service[4]

AWWA C906 Standard for Polyethylene (PE) Pressure Pipe and Fittings, 4 in. (100 mm) through 63 in. (1575 mm), for Water Distribution and Transmission[4]

3. Summary of Practice

3.1 The principle of heat fusion joining of polyethylene (PE) pipe is to heat two prepared surfaces to a designated temperature, then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion.

3.2 The heat-fusion procedures covered in this practice are socket fusion, butt fusion, and saddle fusion.

[1] This practice is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.
Current edition approved Nov. 1, 2013. Published January 2014. Originally approved in 2006. Last previous edition approved in 2012 as F2620-12. DOI: 10.1520/F2620-13.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.

[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.

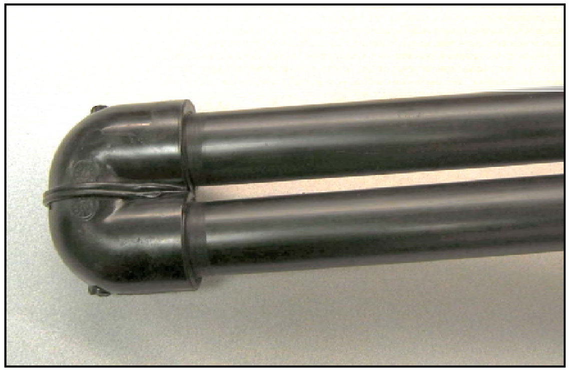
*A Summary of Changes section appears at the end of this standard

1

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

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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

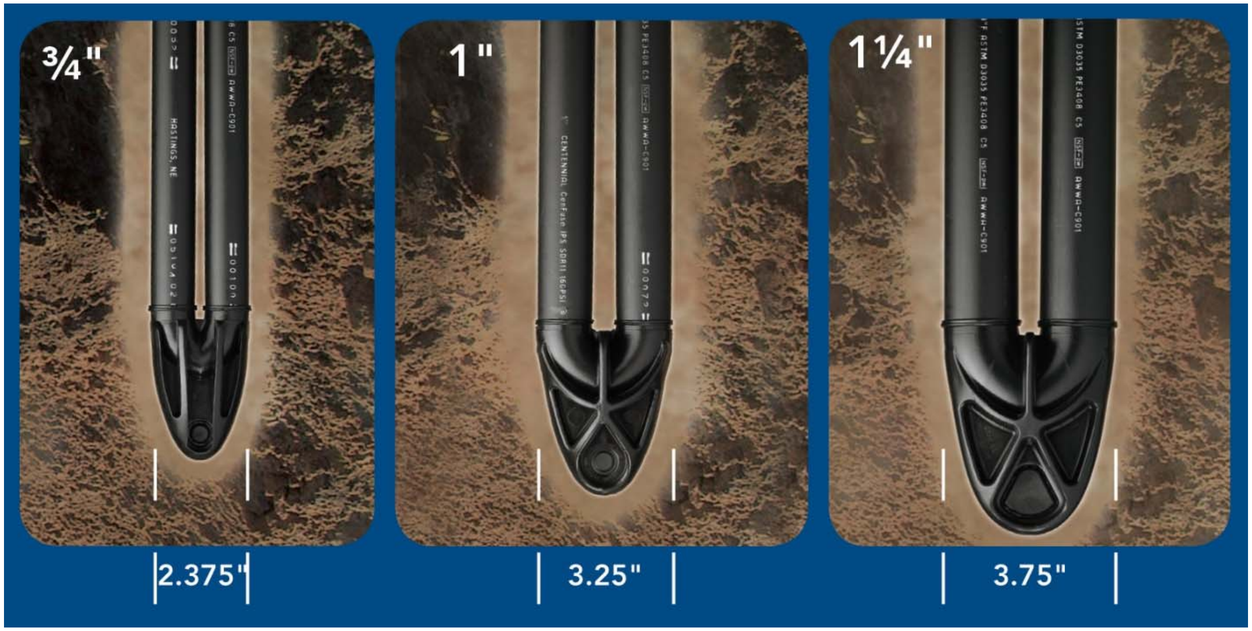


Image Courtesy Centennial Plastics

Plastic Piping Materials for Geo Systems

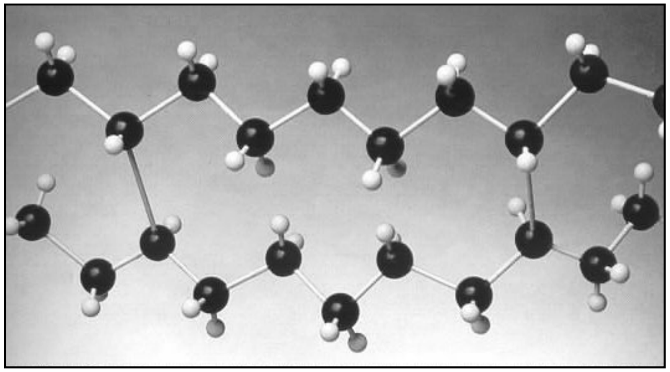
PEX: Crosslinked Polyethylene

- 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 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)

Illustration of PEX "molecule"



Plastic Piping Materials for Geo Systems

PEX: On the job

Plastic Piping Materials for Geo Systems

PEX: On the job

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Plastic Piping Materials for Geo Systems

PEX: Thermal Properties

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

Material	Thermal Conductivity BTU•in/(ft^2•hr•°F)	Thermal Conductivity W/(m•°K)
PEX	2.86	0.41
PE-RT	3.15	0.46

R-Value and Thermal Conductivity
of PEX and PE-RT

TR-48/2014

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Plastic Piping Materials for Geo Systems

PEX: Connections

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

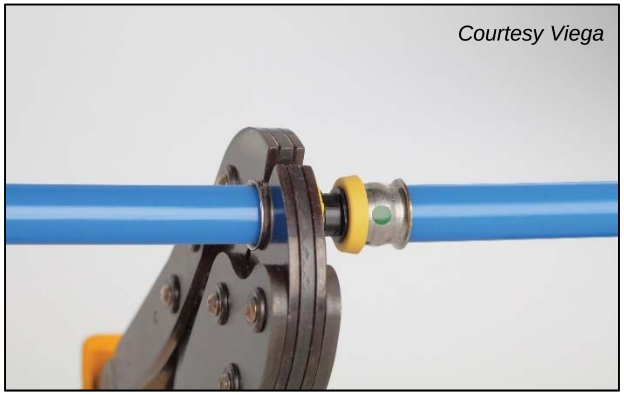
Cold-expansion compression-sleeve PEX fitting as per ASTM F2080

HDPE electrofusion fitting on PEX tubing as per ASTM F1055

Plastic Piping Materials for Geo Systems

PEX: Connections

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



Press-sleeve PEX fitting as per ASTM F3347

Cold-expansion PEX fitting as per ASTM F1960

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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:

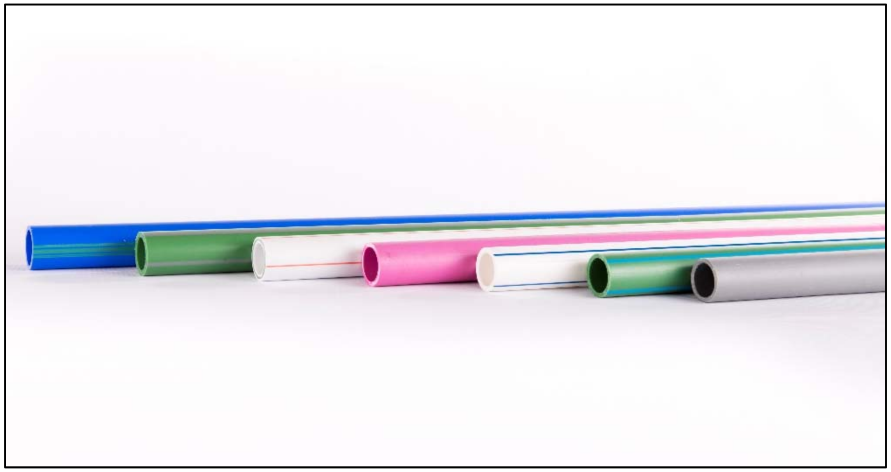
- PE 2708, PE 4710 (material designation codes)

Coil of PE-RT tubing

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



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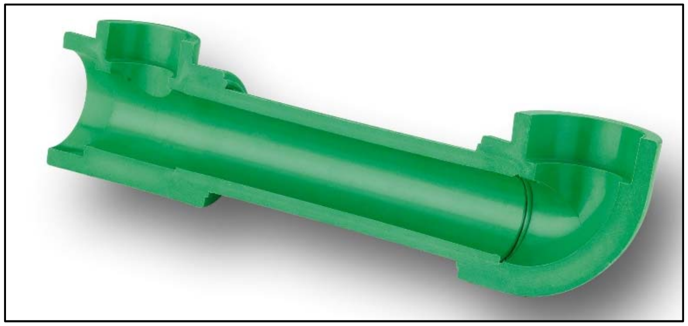
Plastic Piping Materials for Geo Systems

PP: Connections

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



Courtesy Aquatherm

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

Double U-bends

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), and temperature resistance, as well as good thermal conductivity

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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

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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?

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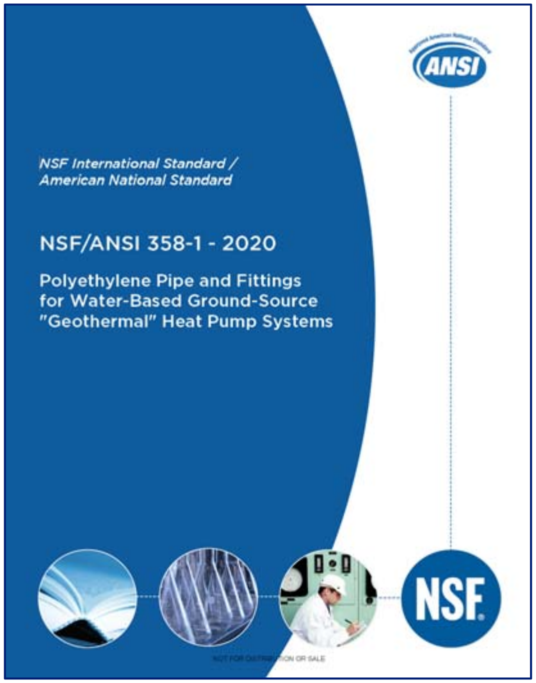
Industry Standards for Plastic Piping

NSF 358 Standards

- A series of standards specifically for the geothermal ground loop industry
- Incudes special test requirements:
  - Compatibility with **antifreeze mixtures**
  - Tensile **pull-out tests** for connections
- Pipe manufacturers can get their products certified to **358-x**

- ***NSF 358-1 HDPE***
- ***NSF 358-2 PP***
- ***NSF 358-3 PEX***
- ***NSF 358-4 PE-RT***



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***

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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***

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Industry Standards for Plastic Piping

PP: Polypropylene

Suggested 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***

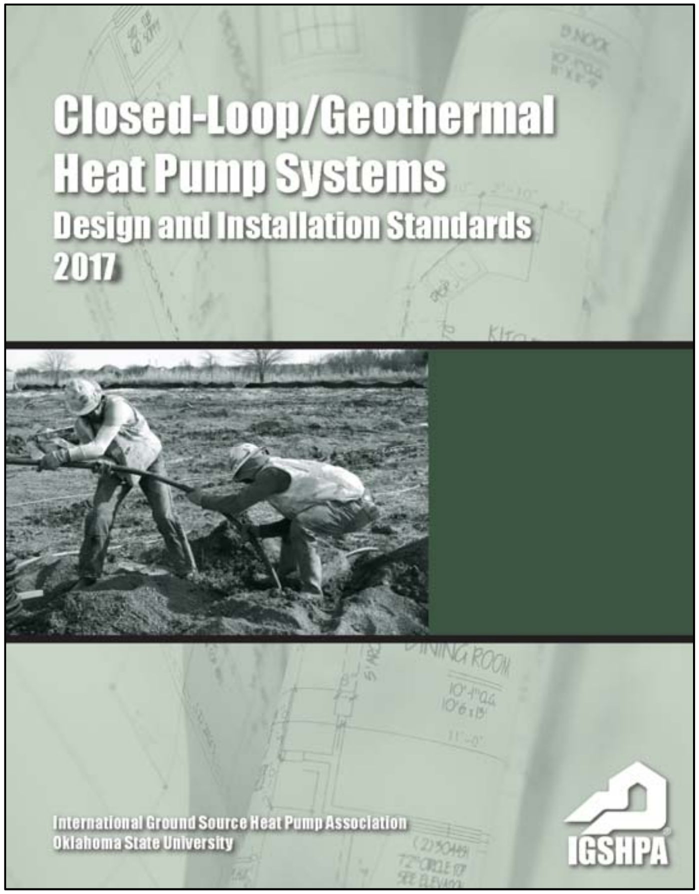
Industry Standards for Plastic Piping

IGSHPA Design & Installation Standards

- Updated regularly over the years

- Includes HDPE & PEX

- Planning to be "retired" soon



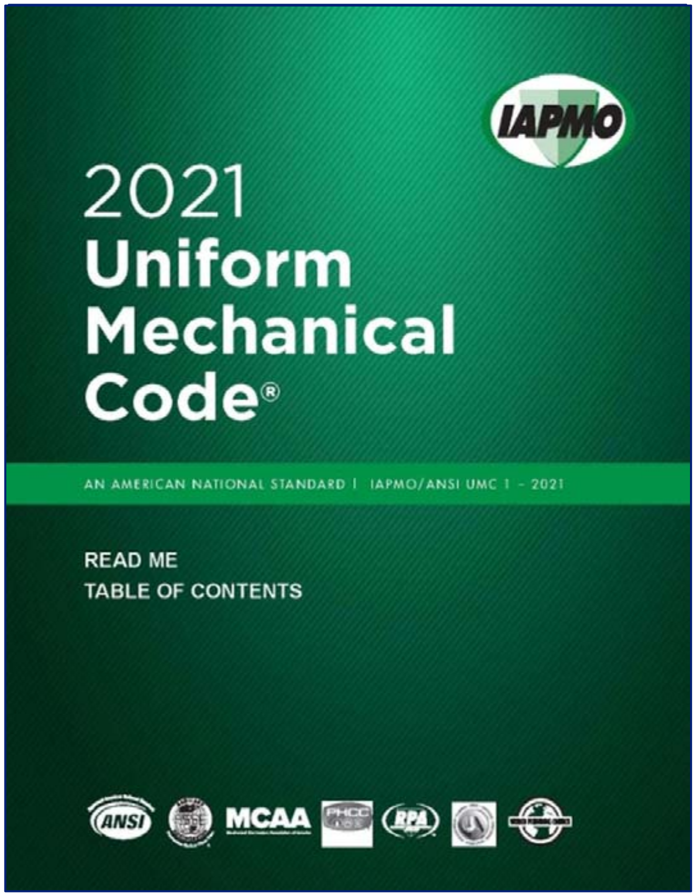
Industry Standards for Plastic Piping

IAPMO Uniform Mechanical Code

- Latest 2021 edition published in March 2020

- **Appendix F** is Geothermal Energy Systems

- Contains ***Installation***, ***Piping Requirements***, ***Testing***, and more



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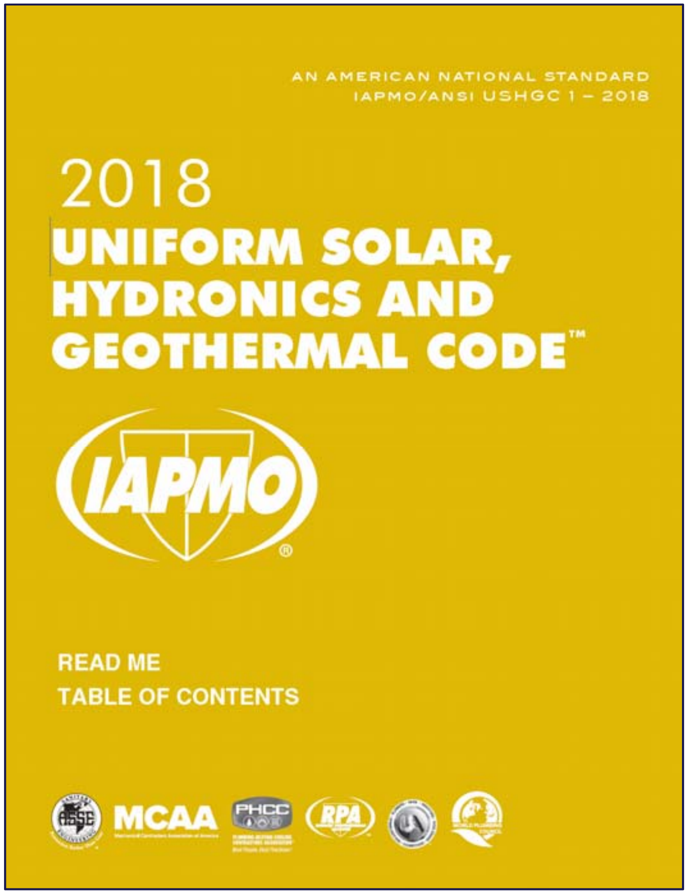
Industry Standards for Plastic Piping

Uniform Solar, Hydronics & Geo Code

- Latest 2018 edition published in September 2018

- **Chapter 7** is Geothermal Energy Systems

- Contains ***Installation***, ***Piping Requirements***, ***Testing***, and more



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Industry Standards for Plastic Piping

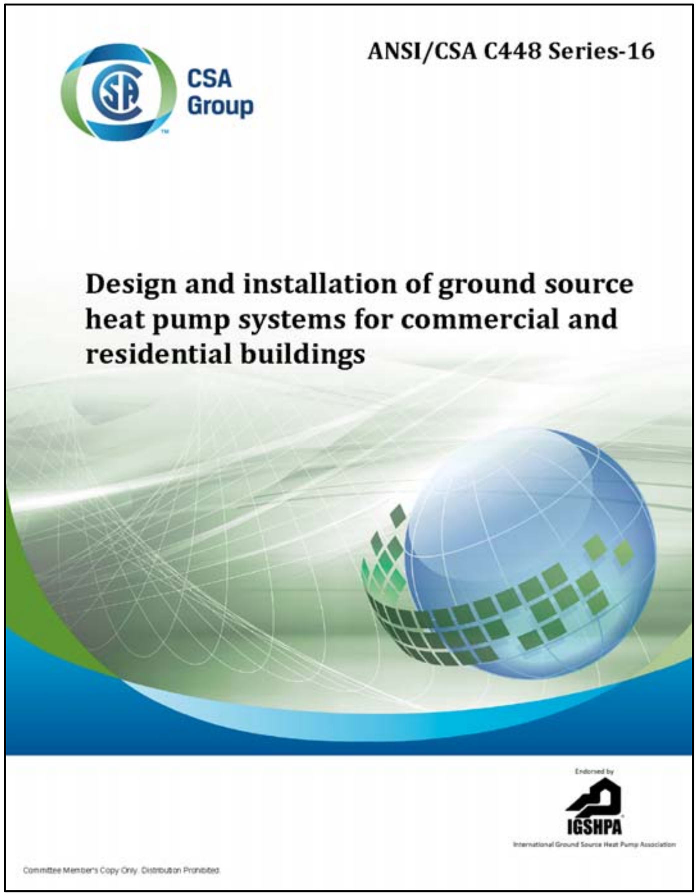
ANSI/CSA/IGSHPA C448-16

- 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

- This Standard was developed by a Bi-national Technical Committee 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 IAPMO UMC or USHGC or 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)

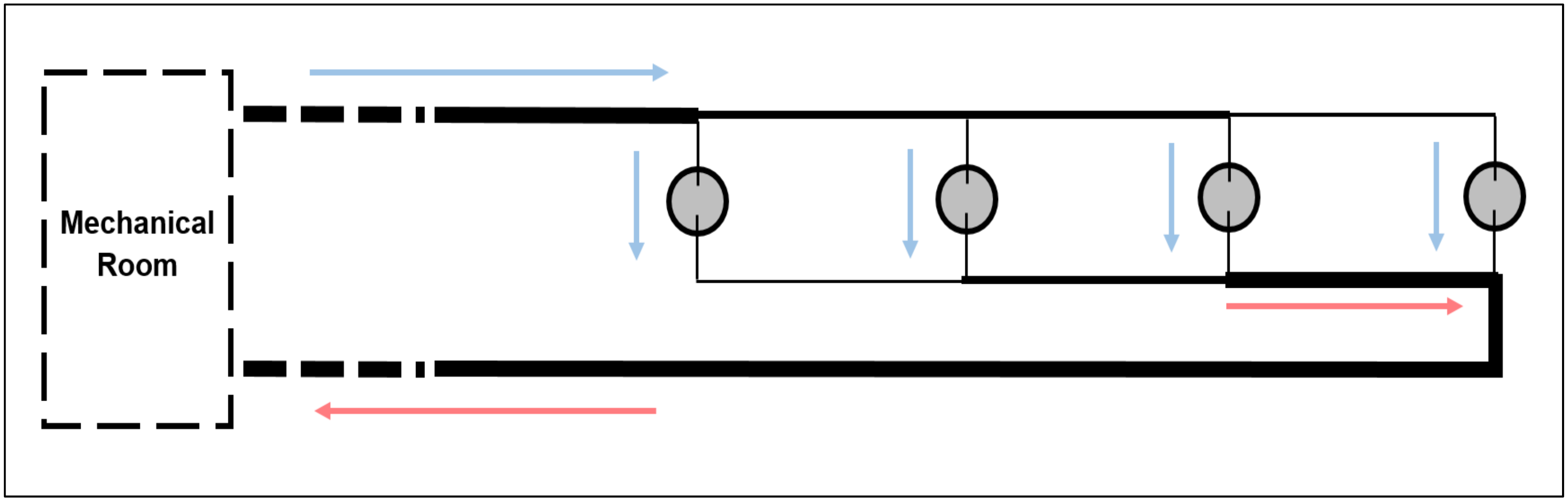
2. **Series** (generally avoided due to high pressure losses)

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

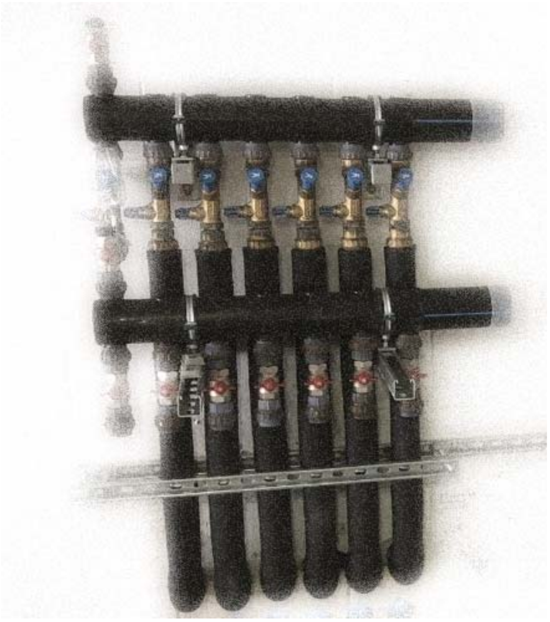
Manifolds and Headers

- 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
- Typically contains a supply header and 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

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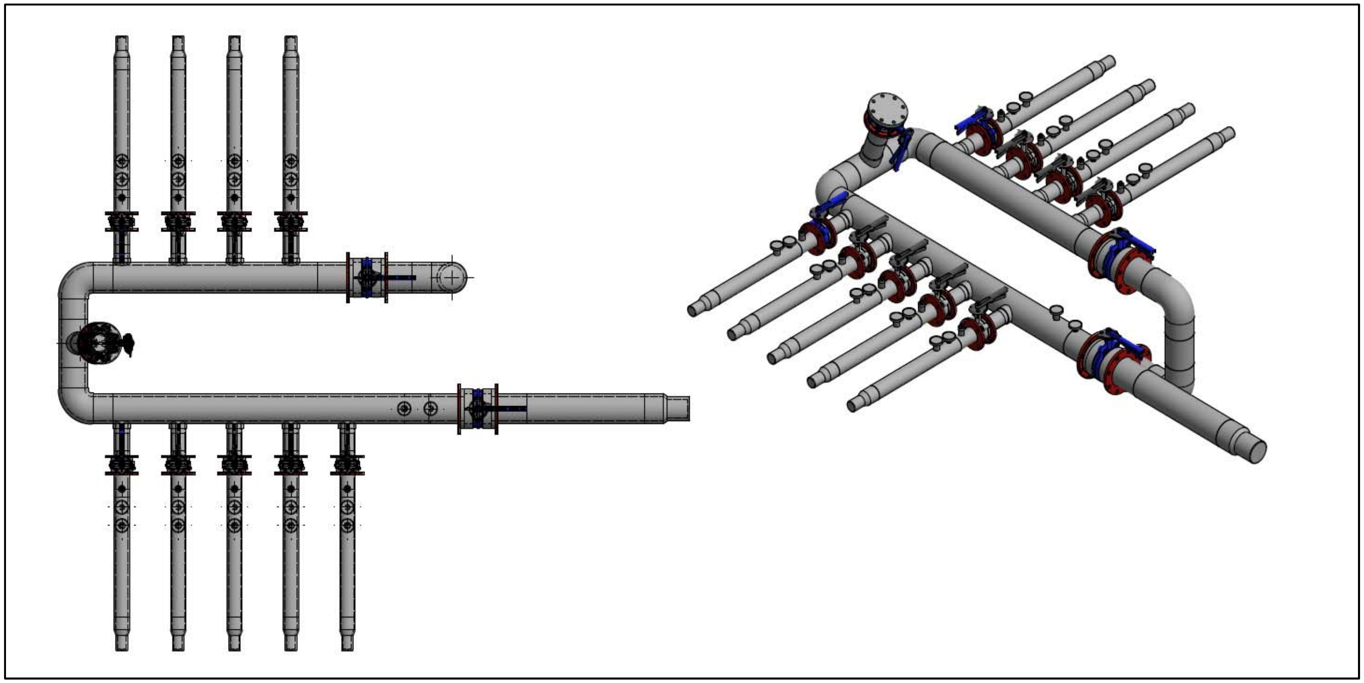
Manifold and Header Techniques

Manifolds and Headers

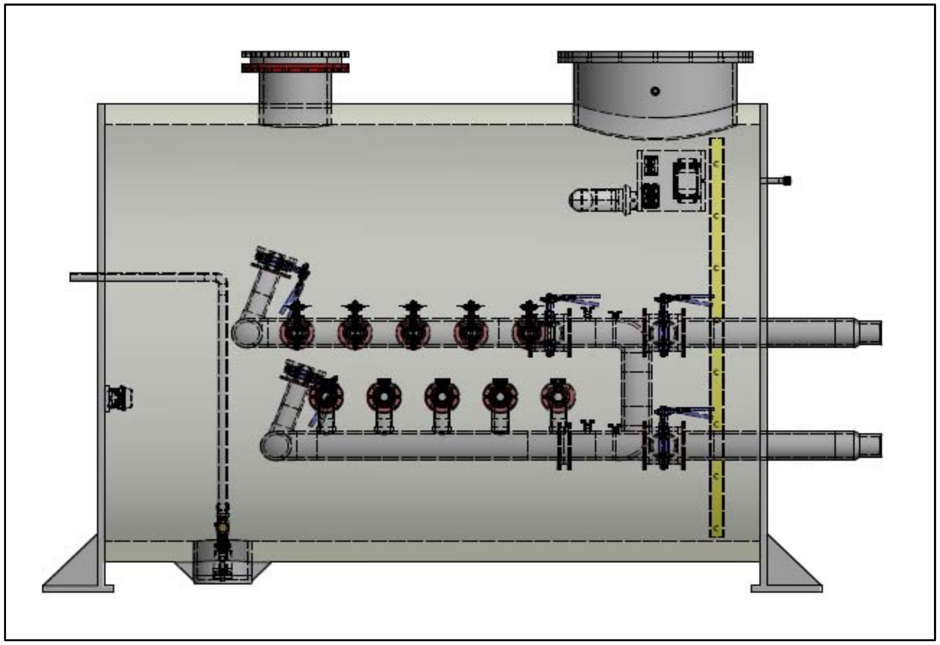
- Example of a **distribution manifold** with shut-off valves on supply and return headers and balancing valves on supply header (two views of the same design)

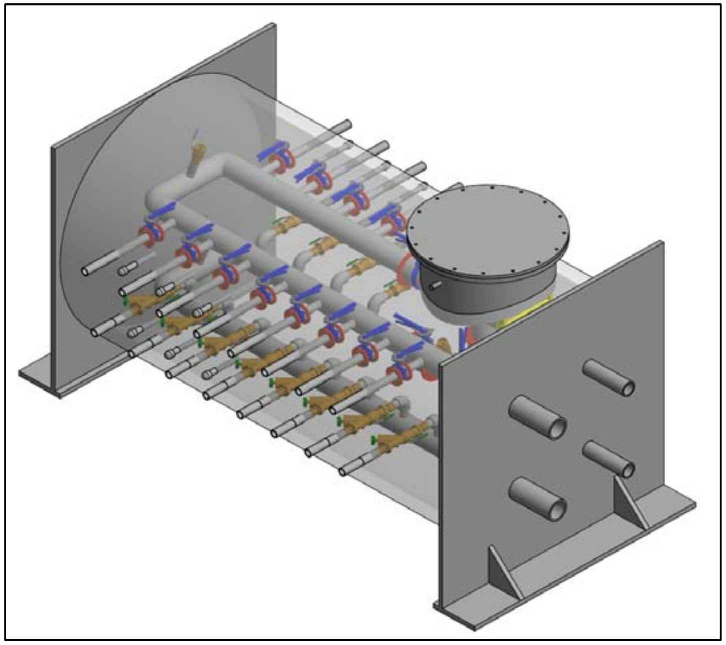


Manifold and Header Techniques

Manifolds and Headers

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





Manifold and Header Techniques

Manifolds and Headers

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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
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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

Plastic Piping Materials for Ground Source Geothermal Heating and Cooling Applications

TN-55

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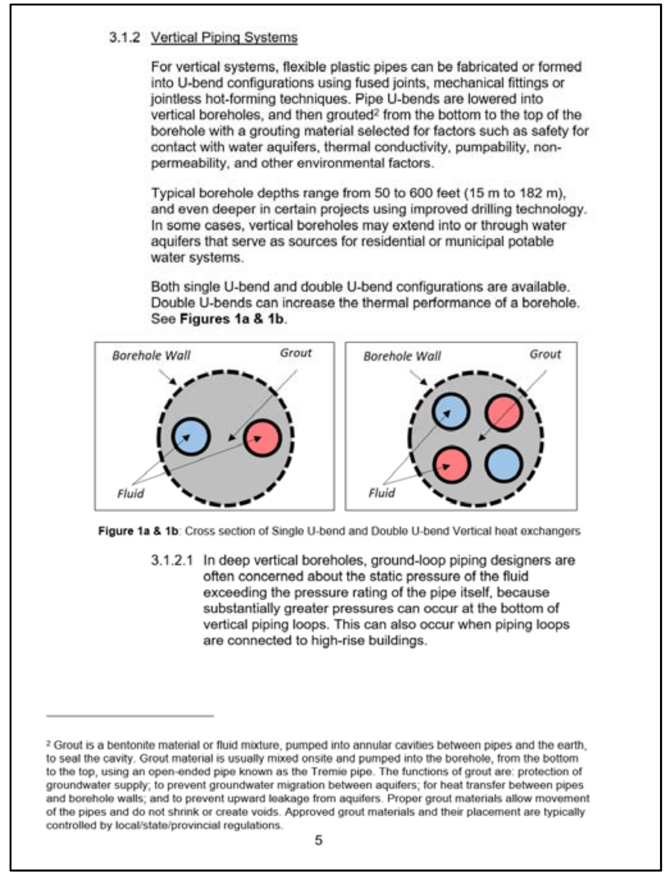
PPI TN-55 and Other Resources

PPI TN-55 Content



3.1.2 Vertical Piping Systems

For vertical systems, flexible plastic pipes can be fabricated or formed into U-bend configurations using fused joints, mechanical fittings or jointless hot-forming techniques. Pipe U-bends are lowered into vertical boreholes, and then grouted[2] 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, pumpability, 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 drilling 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 1a & 1b**.

Figure 1a & 1b: Cross section of Single U-bend and Double U-bend Vertical heat exchangers

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.

[2] Grout is a bentonite material or fluid mixture, pumped into annular cavities between pipes and the earth, to seal the cavity. Grout material is usually mixed onsite and pumped into the borehole, from the bottom to the top, using an open-ended pipe known as the Tremie pipe. The functions of grout are: protection of groundwater supply; to prevent groundwater migration between aquifers; for heat transfer between pipes and borehole walls; and to prevent upward leakage from aquifers. Proper grout materials allow movement of the pipes and do not shrink or create voids. Approved grout materials and their placement are typically controlled by local/state/provincial regulations.

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For example, when the fluid is water, the static pressure applied to fluid within the piping system is equivalent to 4.3 psig per 10 ft. (30 kPa per 3 m) of elevation, or 43 psig per 100 ft. (300 kPa per 30 m) of elevation. For antifreeze fluids with higher densities, this value is incrementally higher.

However, in a properly grouted borehole, the pressure of the grout surrounding the pipe will balance the static pressure of the fluid inside. In some installations, pipes pass through an aquifer, in which case the water surrounding the pipe balances the static pressure of the fluid inside.

3.1.3 Pipe-in-Pipe Coaxial Vertical Systems

Instead of placing two vertical pipes adjacent to each other connected with a U-bend at the bottom of the borehole, a pipe-in-pipe coaxial vertical system utilizes one pipe inside a larger vertical pipe in a concentric arrangement. See **Figure 2**.

There are several configurations available for this type of installation, but the objective is to improve the thermal performance of a vertical borehole by increasing the surface area of the external larger coaxial pipe, and therefore, reducing borehole thermal resistance of heat transfer from the ground to the pipe's surface. Installation techniques are different, as compared to the continuous pipe loops typically used in vertical boreholes, and borehole diameters may need to be larger to accommodate the external pipe.

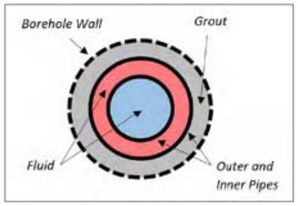

Figure 2: A cross section of a Coaxial heat exchanger (not to scale)

3.1.4 Helix Piping Systems

Certain project sites are neither ideal for horizontal systems nor traditional vertical boreholes, but may be suitable for helix piping systems. A helix system uses a wide borehole which is augured into the ground, typically 2 to 3 feet (0.6 to 0.9 m) in diameter and 16 to 20 ft. (4.9 to 6.1) deep. After the hole is dug, a tightly wound coil of pipe in a helix configuration is stretched-out into the hole.

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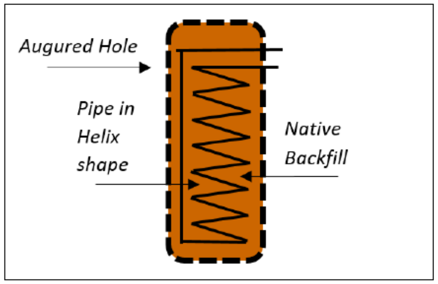

Figure 3: Side-view of a Helix piping system heat exchanger (not to scale)

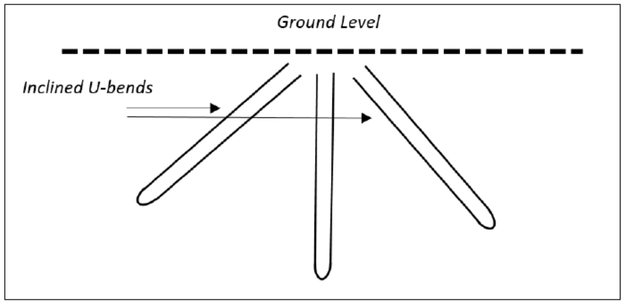

Figure 4: Side-view of an Inclined piping system heat exchanger (not to scale)

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4.0 Ground Loop Heat Exchange Piping Materials

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6.0 Heat Transfer Fluid

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PPI recommends that all HDPE piping components used for ground-coupled heat exchangers meet the requirements of industry standard ANSI/CSA/IGSHPA C448, and:

4.1.1 Be a high-density polyethylene extrusion compound with a pipe material designation code of PE 3608[3], PE 3710[4], PE 4608[4], PE 4708[4], or PE 4710, and a color and ultraviolet stabilizer code of C or E, per ASTM D3350.

4.1.2 Be listed as such by the Plastics Pipe Institute's Hydrostatic Stress Board (HSB) in PPI TR-4 with the minimum Hydrostatic Design Stress (HDS) value of 800 psi at 73°F (23°C).

4.1.3 Meet the requirements of NSF/ANSI Standard 358-1.

4.1.4 Meet the requirements of NSF/ANSI Standard 61 for open-loop systems, or if the water aquifer or reservoir into which the piping system is installed is a water source for a potable water system.

See **Table 1** for typical pressure ratings of some HDPE material grades and wall types.

Table 1: Minimum Pressure Ratings for Typical HDPE Geothermal Pipe

PE Material	DR	Pressure rating @ 73°F	Pressure rating @ 140°F
PE 3608	9	200 psi (1.4 MPa)	100 psi (0.7 MPa)
PE 3608	11	160 psi (1.1 MPa)	80 psi (0.6 MPa)
PE 3608	13.5	125 psi (0.9 MPa)	64 psi (0.4 MPa)
PE 4710	9	250 psi (1.7 MPa)	160 psi (1.1 MPa)
PE 4710	11	200 psi (1.4 MPa)	125 psi (0.9 MPa)
PE 4710	13.5	160 psi (1.1 MPa)	100 psi (0.7 MPa)
PE 4710	17	125 psi (0.9 MPa)	80 psi (0.6 MPa)

See also other PPI publications on PE materials, such as PPI's *Handbook of Polyethylene Pipe*, Chapter 13 "HVAC Applications".

[3] *PE 3608 meets the minimum requirements of ANSI/CSA/IGSHPA C448. Other PE material designation codes listed exceed the minimum requirements.*

[4] *Not all material formulations are readily available in all markets and regions. The most common HDPE materials available at the time of this publication are PE 3608 and PE 4710.*

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4.2 PEX: Crosslinked Polyethylene

Crosslinked polyethylene (PEX) is a high-temperature, flexible pressure pipe with over 40 years of successful use in the European market, including extensive testing for durability and material performance. It was first introduced in North America in the early 1980s and is widely used for plumbing, water service, fire protection, hydronic heating and cooling, snow and ice melting and ground source geothermal piping systems.

Figure 6: Coil of PEX Tubing

PPI recommends that all PEX piping components used for ground-coupled heat exchangers meet the requirements of industry standard ANSI/CSA/IGSHPA C448 and:

4.2.1 Be a crosslinked polyethylene compound with a pipe material designation code of PEX 1206[5], PEX 1306, PEX 3206, PEX 3306, PEX 5206 or PEX 5306 per ASTM F876 and CSA B137.5.

4.2.2 Be listed as such by the Plastics Pipe Institute's Hydrostatic Stress Board (HSB) in PPI TR-4 with a minimum Hydrostatic Design Stress (HDS) value of 630 psi and a minimum pressure rating of 160 psi (1,100 kPa) at 73°F (23°C).

4.2.3 Meet the requirements of ASTM F876 or CSA B137.5.

4.2.4 Meet the requirements of NSF/ANSI Standard 358-3.

4.2.5 Meet the requirements of NSF/ANSI Standard 61 for open-loop systems, or if the water aquifer or reservoir into which the piping system is installed is a water source for a potable water system.

Note 3: A PEX compound will also be listed by PPI's Hydrostatic Stress Board with a minimum Hydrostatic Design Basis (HDB) value of 800 psi at 180°F (82°C).

See also other PPI publications on PEX materials, such as PPI TN-17 "Crosslinked Polyethylene Pipe & Tubing".

[5] PEX 1206 meets the minimum requirements of ANSI/CSA/IGSHPA C448. Other PEX material designation codes listed exceed the minimum requirements.

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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

5.2 Distribution Manifold Systems

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 home-run.

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 low pressure loss (or head loss) of 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 exchanger piping. See **Figure 10** as an example

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

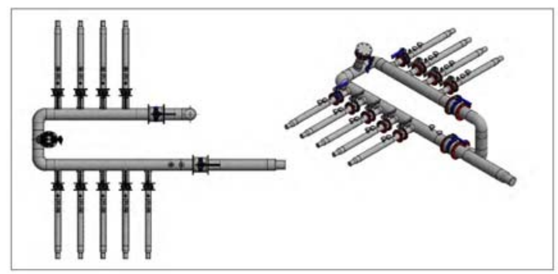

Figure 10: Example of a distribution manifold with shut-off valves on supply and return headers and balancing valves on supply header (two views of the same design)

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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.

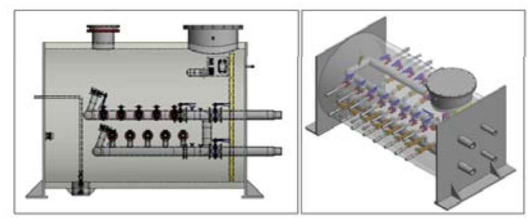

Figure 11: Example of HDPE collection vaults with integrated manifolds (different designs)

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PPI TN-55 and Other Resources

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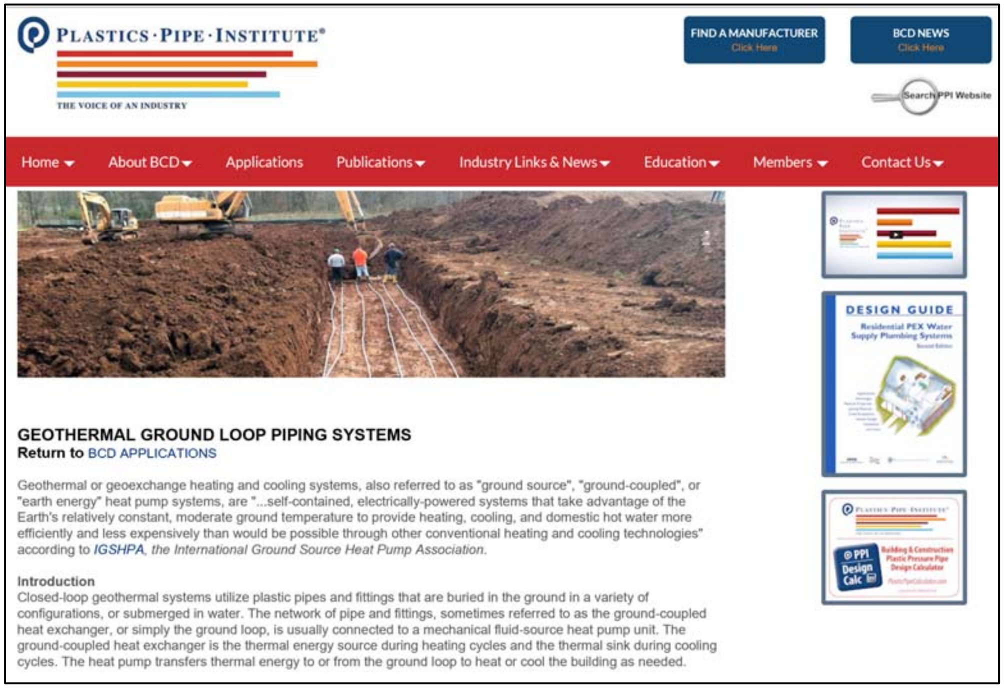

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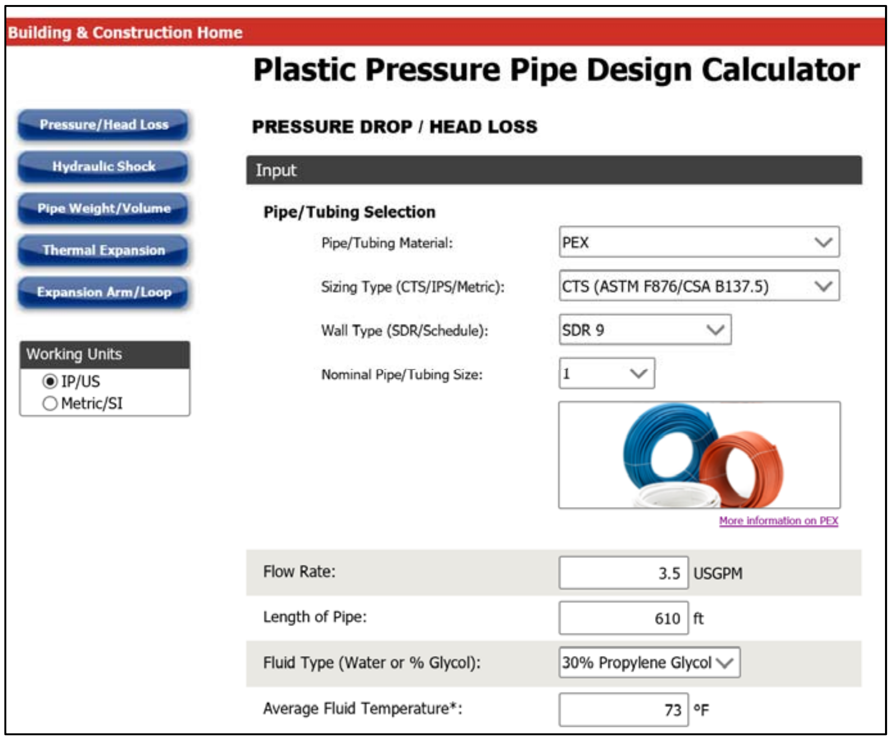
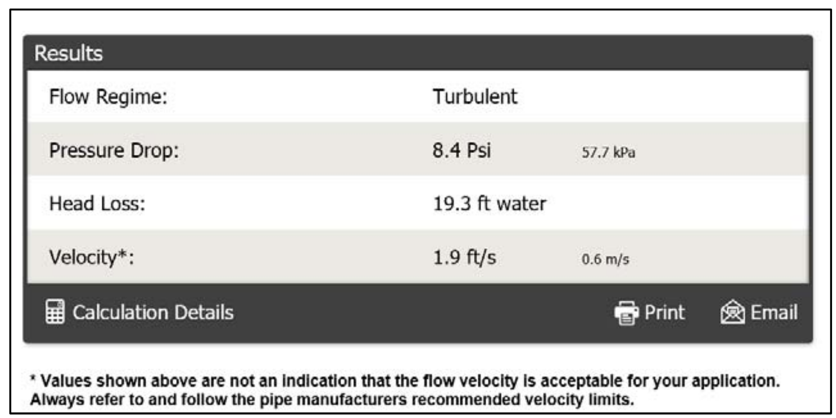
Plastic Pressure Piping Design Calculator

- Free online sizing tool at www.plasticpipecalculator.com





Summary

This presentation:

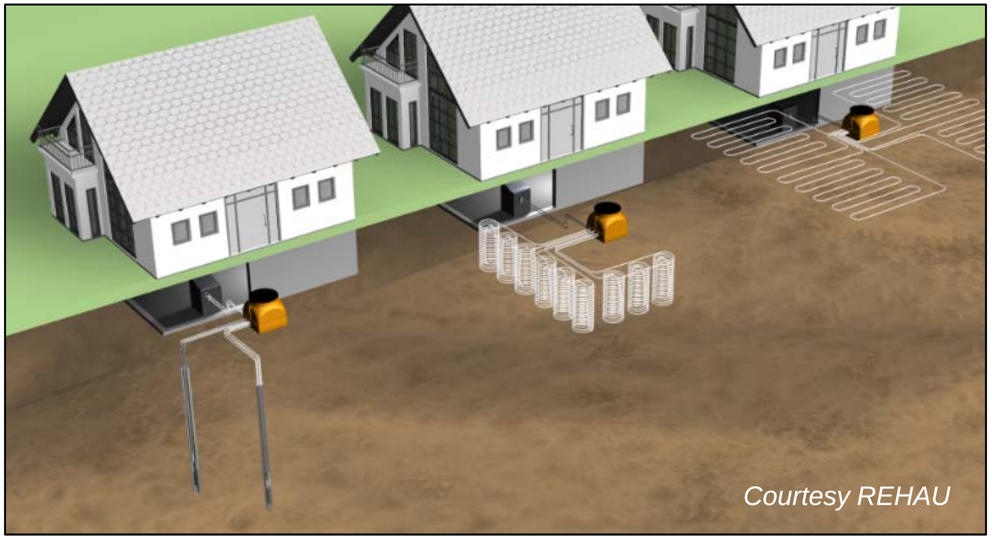
1. Described the **plastic piping materials** used for ground source geothermal systems
   - HDPE *high density polyethylene*
   - PEX *crosslinked polyethylene*
   - PE-RT *polyethylene of raised temperature resistance*
   - PP *polypropylene (PP-R and PP-RCT)*

2. Discussed the industry **standards** that apply to these piping materials

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

4. Introduced **PPI TN-55** and other industry resources of piping information

Plastic Piping Materials for Ground Source Geothermal Systems



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