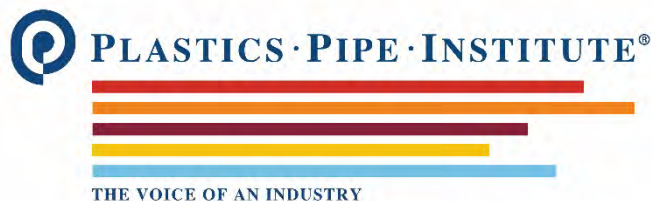


Plastic Piping Materials for Geothermal/Geoexchange Heating and Cooling Applications

TN-55

2018



Foreword

PLASTIC PIPING MATERIALS FOR GEOTHERMAL/GEOEXCHANGE HEATING AND COOLING APPLICATIONS

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The purpose of this technical note is to provide information regarding the types of plastic piping materials used in ground-source geothermal/geoexchange heating and cooling applications, including various types of designs and installations, as well as information on appurtenances such as headers and manifolds.

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PLASTIC PIPING MATERIALS FOR GEOTHERMAL/GEOEXCHANGE HEATING AND COOLING APPLICATIONS

1.0 INTRODUCTION

Geothermal or geexchange heating and cooling systems, also referred to as “ground source”, “ground-coupled” or “earth energy” heat pump systems, are “...self-contained, electrically-powered systems that take advantage of the Earth's relatively constant, moderate ground temperature to provide heating, cooling, and domestic hot water more efficiently and less expensively than would be possible through other conventional heating and cooling technologies” according to IGSHPA, the *International Ground Source Heat Pump Association*.

The three primary categories of geothermal or geexchange heating and cooling systems are commonly referred to as closed-loop, open-loop and direct-exchange:

- Closed-loop systems utilize plastic piping systems for the ground-coupled heat exchanger piping system, and are the primary focus of this technical note.
- Open-loop systems utilize ground water or surface water for the purpose of extracting or rejecting heat, as the water is circulated through a mechanical heat pump. While open-loop systems utilize the types of plastic pipes included in this Technical Note, these systems are not the focus of this document.
- Direct-exchange systems utilize copper tubing embedded in the ground with refrigerant circulating directly within this buried copper tubing. These systems will not be addressed in this Technical Note.

1.1 Closed-Loop Geothermal Systems

Closed-loop geothermal systems utilize plastic pipes and fittings that are buried in the ground in a variety of configurations, or submerged in water. The network of pipe and fittings, sometimes referred to as the *ground-coupled heat exchanger*, or simply the *ground loop*, is usually connected to a mechanical fluid-source heat pump unit¹. The ground-coupled heat exchanger is the thermal energy source during heating cycles and the thermal sink during cooling cycles.

A basic closed-loop geothermal or geexchange system typically includes:

- 1.1.1 Mechanical Components: Packaged mechanical heat pump with integrated electronic controls, circulating pumps and valves, typically installed indoors

¹ In special circumstances, direct heat-transfer systems may be designed without a mechanical heat pump or with the ability to bypass the heat pump, whereby the same fluid that passes through the ground heat exchangers also passes through the hydronic distribution pipe (e.g. a radiant heating or cooling slab). The fluid is moved by an electrical circulating pump.

1.1.2 Ground-Coupled Heat Exchanger Piping: Plastic pipe and fittings which are:

- Buried in a horizontal plane (e.g. trenches)
- Dropped in a vertical configuration (e.g. boreholes)
- Installed in a vertical large diameter hole (e.g. helix)
- Drilled or pushed into an angled configuration (e.g. inclined)
- Submerged in a surface body of water (e.g. pond, lake)
- Encased in structural building piling systems (e.g. energy piles)

1.1.3 Heat Transfer Fluid: Water, water/antifreeze solution, or brine solution

This Technical Note will provide relevant information on each of these categories, with a focus on ground loop piping materials. Other terms for a ground loop heat exchanger are the “ground loop” or the “source heat exchanger”.

2.0 MECHANICAL COMPONENTS

Mechanical components (i.e. heat pumps) should be designed and certified for closed-loop ground-coupled heating and cooling applications, and meet the requirements of all applicable codes and regulations.

Water-to-air heat pumps are typically connected to ducted air distribution systems within a building.

Water-to-water heat pumps are typically connected to hydronic distribution systems within a building. A hydronic system is a heat distribution/absorption system in which the final heat-transfer medium is a fluid such as water. Examples include radiant heating, radiant cooling, baseboard radiators, panel radiators, fan-assisted convectors, and ducted fan coils, which transfer the heat energy to/from the distribution air.

Water source heat pumps should be certified in accordance with AHRI/ASHRAE ISO Standard 13256-1 for water-to-air heat pumps, and AHRI/ASHRAE ISO Standard 13256-2 for water-to water heat pumps.

Circulating pumps, often packaged as tandem units with integrated connections, fill ports, etc. (also known as flow centers) are designed, built and sized specifically for the ground loop network and heating/cooling loads of each geothermal system.

3.0 GROUND-LOOP HEAT EXCHANGE PIPING SYSTEMS - INTRODUCTION

The ground-coupled heat exchanger piping system (i.e. the ground loop) may be designed to supply the total heating and cooling capacity of the building for the specific geographical location, or for partial loads. Partial-load heating systems are often supplemented with heat sources such as boilers or thermal solar collection systems. Partial-load cooling systems are often supplemented with mechanical chillers or cooling towers. In such situations, it is common for the geothermal systems to be sized to carry a base building load, typically 60 to 75% of the peak load, and for the supplement equipment to operate only when needed to meet peak loads.

The piping material is critical to the overall success of the closed-loop ground-coupled system and must provide corrosion resistance, chemical resistance, flexibility, impact resistance, resistance to slow crack growth, long-term hydrostatic strength (pressure capability), and temperature resistance. In addition, the ground loop heat exchanger materials must provide suitable heat transfer capabilities.

These piping systems may experience changes in pressure up to 60 psig (415 kPa), due to thermal expansion and contraction of the heat transfer fluid and the pipe itself over a potential operating temperature range from 25°F to 115°F (-4°C to 46°C).

Pressure and temperature cycles occur, to some degree, each time the system is operated. The typical average static pressure within the piping system at ground level is 25 psig to 40 psig (170 kPa to 275 kPa).

Typical plastic piping materials for ground loops are:

- HDPE: *High-density polyethylene*
- PEX: *Crosslinked polyethylene*
- PE-RT: *Polyethylene of raised temperature*
- PP: *Polypropylene pressure pipe*

Each of these plastic piping materials provides important long-term performance benefits for geothermal applications, including:

- a. Corrosion resistance
- b. Chemical resistance
- c. Flexibility
- d. Impact resistance
- e. Temperature resistance
- f. Long-term hydrostatic strength (pressure capability)

While all of these materials share common benefits for geothermal applications, each material has specific characteristics that influence their selection for various projects.

See Section 4.0 GROUND-LOOP HEAT EXCHANGE PIPING SYSTEMS - MATERIALS for additional information on these piping materials.

3.1 Ground-Loop Heat Exchange Piping Systems – System Types

Qualified designers should be involved with calculations and layouts for all ground-loop heat exchange system designs. Proper designs will determine the size and quantity of pipes which are required to meet design loads (in BTU, kW or tons of energy) for a specific system.

Designers often use specialized software modelling programs to ensure that heat exchange capacities will be satisfied by the ground loop piping design, even modelling the heat exchange for several years of operation to avoid overheating or overcooling the earth over time.

For a given project, the selected type of installation can be affected by several factors, such as:

- Topography and geography of the land (type of soil, amount of overburden, hills, valleys, water table, etc.)
- The type of equipment available to the installer
- Accessibility for equipment
- Available land area
- Water table levels
- Proximity to body of water
- Local regulations
- Other factors

Ground-loop heat exchange piping systems include, but are not limited to, the following installation types:

3.1.1 Horizontal Piping Systems

A horizontal piping system is typically buried at depths of 4 to 7 feet (1.2 to 2.1 m) within trenches, usually below the frost line for the location. Pipe spacing and positioning varies on factors such as soil type, thermal conductivity of the earth, width of the trench and other factors. Trench width can vary from just 2 ft. to 8 ft. (0.6 to 2.4 m) or more, depending upon factors such as the topography, soil type, equipment availability, etc.

Trench safety during installation of the pipe is an important consideration when designing trenches, and local regulation must be adhered (e.g. OSHA trenching and excavation safety requirements in 29 CFR 1926.651 and 1926.652). The amount of pipes and spacing between pipes installed within trenches can also vary.

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 grouted² 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**.

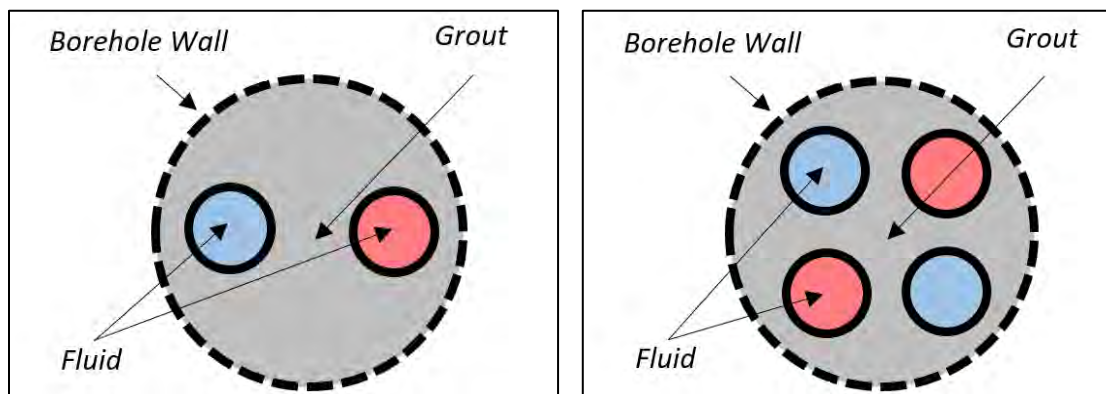


Figure 1a & 1b: Cross section of Single U-bend and Double U-bend Vertical heat exchangers

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.