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PPI Statement AF

Projected Design Life of Plastic Piping Used in Geothermal Ground Heat Exchangers (GHX)

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1. Introduction

Geothermal heating and cooling systems, also referred to as "ground source", "geothermal exchange", “geoexchange”, 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.

Closed-loop geothermal systems utilize plastic pipes and fittings that are buried in the ground or submerged in water in a variety of configurations. The network of pipe and fittings, referred to as the “ground heat exchanger (GHX)”, “geothermal ground loop”, “ground-coupled heat exchanger”, or simply the “ground loop”, is usually connected to a mechanical fluid-source heat pump unit known as a ground source heat pump (GSHP). The ground heat exchanger is the thermal energy source during heating cycles and the thermal sink during cooling cycles. The heat pump transfers thermal energy to or from the ground heat exchanger to heat or cool the building as needed, and sometimes for the production of domestic hot water and/or other energy needs.

This Statement is intended to address questions about ground heat exchanger piping longevity – specifically, the design life for approved piping materials HDPE, PE-RT, and PEX, which have proven to be exceptionally reliable, delivering decades of dependable service in these applications.

Due to operational variables, which are unique for each ground heat exchanger application, PPI conservatively projects that the design life of GHX plastic piping materials, when specified correctly and installed according to industry and manufacturers’ guidelines, is typically in excess of **fifty (50) years**. In some ground source heat pump systems, the actual service life of the GHX piping may be far in excess of this value.

Please see below for details of the approved piping materials, definitions of design life and service life, and how this PPI projection was developed.

2. Ground Heat Exchanger (GHX) Piping

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

Ground heat exchanger plastic pipes and fittings may be:

- 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)
- Submerged in a surface body of water (e.g., pond, lake)
- Drilled or pushed into an angled configuration (e.g., inclined)
- Encased in structural building piling systems (e.g., energy piles)

Note 1: See PPI TN-55 for more information about ground heat exchanger installation types.

The following Canadian and US model codes include approvals for specific piping materials which are approved for use as ground heat exchangers:

- CSA/ANSI/IGSHPA C448 Design and installation of ground source heat pump systems for commercial and residential buildings
- ICC International Mechanical Code (IMC)
- ICC International Residential Code (IRC)
- IAPMO Uniform Mechanical Code (UMC)
- IAPMO Uniform Solar, Hydronic and Geothermal Code (USHGC)

Three types of plastic piping materials are approved in the model codes listed above for ground heat exchangers:

- High-density polyethylene (HDPE)
- Polyethylene of raised temperature resistance (PE-RT)
- Crosslinked polyethylene (PEX)

Polypropylene (PP-R, PP-RCT) is approved in these codes for indoor piping, headers, and manifolds. Each of these piping types belongs to the family of piping materials known as polyolefins.

2.1 HDPE Piping

High density polyethylene is a plastic resin made by the copolymerization of ethylene and a small amount of another hydrocarbon. HDPE is a tough, durable piping material with unique performance properties that allow for its use in a broad range of applications, utilizing a variety of different construction techniques.

HDPE piping systems have been used for municipal and industrial water applications for over 75 years and are the most common type of piping material used for GHX applications, with decades of proven service. HDPE GHX piping is currently produced from compounds with pipe material designation codes of PE3608 or PE4710 and a color and ultraviolet stabilizer code of C or E, per ASTM D3350. It is typically produced using carbon black, which provides long-term UV protection.

HDPE piping is recognized in all model codes and standards as an approved material for GHX systems. It is produced in both nominal pipe size (NPS) and nominal tubing size (NTS) dimensions and is available in several standard dimension ratios (SDRs) or wall thicknesses. It is typically joined with molded or fabricated fittings, produced using the same material, using butt fusion, socket fusion, or electrofusion heat fusion methods.

2.2 PE-RT Piping

Polyethylene of raised temperature resistance is a high-density polyethylene (HDPE) material with enhanced capabilities to withstand higher temperatures. PE-RT is a HDPE resin in which the molecular architecture has been designed such that a sufficient number of tie chains are incorporated to allow operation at elevated or raised temperatures (RT), "tieing" together the crystalline structures in the polymer, resulting in improved properties such as elevated temperature strength and performance.

PE-RT piping was first introduced in Europe in the 1980s and has since delivered over forty (40) years of successful use around the world with extensive testing for durability and material performance in a variety of hydronic and potable water applications. It was introduced into North America in 2003 and was first approved for GHX piping systems in 2015. PE-RT is typically produced in nominal tubing size (NTS) dimensions and SDR 9 wall thickness.

2.3 PEX Piping

Crosslinked polyethylene is a high-temperature, flexible pressure pipe introduced in Europe in the early 1970s and has since delivered over fifty (50) years of successful use around the world, including extensive testing for durability and material performance. PEX is a high-density polyethylene (HDPE) material which has undergone a change in molecular structure using a chemical or a physical process whereby the polymer chains are chemically linked, denoted by the X.

Crosslinking of polyethylene into PEX for pipes results in improved properties such as elevated temperature strength and performance, chemical resistance, and resistance to slow crack growth.

PEX was introduced into 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 other applications. PEX was first approved for GHX piping systems in 2008. PEX is produced in nominal tubing size (NTS) dimensions and SDR 9 wall thickness. PEX piping is available in other dimensions.

2.4 GHX Piping Standards

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, performance, and reliability.

Relevant product standards are:

- **HDPE**: ASTM D2737, ASTM D3035, ASTM F714, CSA B137.1
- **PE-RT**: ASTM F2769, CSA B137.18
- **PEX**: ASTM F876, ASTM F2788, CSA B137.5

Note 2: See PPI TN-55 *Plastic Piping Materials for Ground Source Geothermal Heating and Cooling Applications* and PPI MS-7 *Model Specification for Plastic Piping Materials for Ground Source Geothermal Applications* for more information about standards for ground heat exchanger piping materials including pipes, tubing, and fittings.

3. GROUND HEAT EXCHANGER PIPING DESIGN LIFE

3.1 Thermoplastic Piping Test Methods

HDPE, PE-RT, and PEX piping materials deliver long-term reliability proven over decades of use around the world. Long-term pressure ratings for these piping materials are developed based on testing in accordance with **ASTM Test Method D2837** *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products.*

According to D2837-25, "The HDB is a material property and is obtained by evaluating stress rupture data derived from testing pipe made from the subject material" and, "The LTHS* is determined by analyzing stress versus time-to-rupture (that is, stress-rupture) test data that cover a testing period of not less than 10,000 hours and that are derived from sustained pressure testing of pipe made from the subject material. The data is analyzed by linear regression to yield a best-fit log-stress versus log time-to-fail straight-line equation." **Long-term hydrostatic strength*

LTHS data that is generated for the D2837 evaluation is extrapolated to 100,000 hours and 50 years in accordance with Appendix X2 *Least Squares Calculations for Long-Term Hydrostatic Strength*. This test method allows for extrapolations up to fifty (50) years. Piping materials and pipes are third-party listed according to policies such as **PPI TR-3** *Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), Minimum Required Strength (MRS) Ratings, and Categorized Required Strength (CRS) for Thermoplastic Piping Materials or Pipe.*

3.2 Predicting GHX Piping Design Life and Service Life

The **design life** for a piping material can be defined as the length of time that it is projected to operate reliably in a standard and approved application, while the **service life** is the length of time that a piping material actually operates while in service.

While some HDPE PE4710 piping materials have a projected design life of 100 years or more in certain applications where internal water pressures, loads, and temperatures are relatively constant (e.g., municipal water systems), the piping used in GHX applications experiences several more variables in operation which can reduce its service life, including:

- Potential damage during installation in boreholes or other installed methods (e.g., excessive bending or kinking, point loads, scratches and gouges, exposure to heat and stress from equipment, etc.)
- Changes in internal hydrostatic pressure which varies with fluid temperature, elevation, etc.
- Wide range of fluid temperatures (e.g., minimums <32ºF and maximums >100ºF)
- Cyclic pressure changes when system pumps are activated and deactivated
- Exposure to fluids such as various types of antifreeze mixtures and additives
- Installation variables (e.g., horizontal, vertical, inclined, horizontal directional drilling/HDD, etc.)
- Static water column pressure (i.e., internal pressure caused by vertical column of internal fluid) in deep boreholes, if there are any voids in grouting

Due to these operational variables, which are unique for each ground heat exchanger application, and considering typical safety factors which are applied by GSHP system designers, PPI conservatively projects that the design life of HDPE, PE-RT, and PEX GHX plastic piping materials, when specified correctly and installed according to industry and manufacturers' guidelines, is typically in excess of **fifty (50) years**.

In some ground source heat pump systems, the actual service life of the GHX piping may be far in excess of this value, depending on specific factors such as operating pressures and temperatures. However, blanket statements about projected piping design life in excess of fifty years for GHX applications cannot reliably be made.

4. CONCLUSION

Polyolefin piping materials (e.g., HDPE, PE-RT, and PEX) are safe, reliable, and well-proven, with decades of experience for ground heat exchanger (GHX) applications. The manufacturing of these piping materials and their associated fittings is tightly controlled through rigorous standards, code compliance, and third-party certification programs.

When these piping materials are used in ground heat exchanger applications, they experience a wide range of temperatures and pressures, as well as operational and installation variables. The uniqueness of each GHX application makes it difficult to accurately predict an extended design life for these materials as a category.

When specified correctly and installed according to industry and manufacturers' guidelines, the design life for these approved GHX piping materials is typically in excess of **fifty (50) years**, and in some ground source heat pump systems, the actual service life of the ground heat exchanger piping may be far in excess of this value.

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