MODEL SPECIFICATION FOR PLASTIC PIPING MATERIALS FOR GROUND SOURCE GEOTHERMAL APPLICATIONS

PPI MS-7

2023

Plastics Pipe Institute
The Voice of an Industry.

105 Decker Court • Suite 825 • Irving, Texas 75062 • 469.499.1044 • www.plasticpipe.org

Foreword

The Plastics Pipe Institute (PPI) has prepared this model specification as a service to its members and the industry. It is offered for use as a starting point and guide in developing appropriate final specifications suited to a particular project's needs.

The information in this model specification is offered in good faith and believed to be accurate at the time of its preparation but is offered "as is" without any express or implied warranty, including WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Any reference to or testing of a particular proprietary product should not be construed as an endorsement by PPI, which does not endorse the proprietary products or processes of any manufacturer. Industry members in fulfilling their own compliance responsibilities offer the information in this model specification for consideration. PPI assumes no responsibility for compliance with applicable laws and regulations.

PPI intends to revise this model specification from time to time in response to comments and suggestions from users of the document. Please send suggestions for improvements to PPI. Information on other publications can be obtained by contacting PPI directly or visiting the website.

The Plastics Pipe Institute, Inc.

https://plasticpipe.org/

This Model Specification MS-7 was first issued in May 2023.

Table of Contents

MODEL SPECIFICATION FOR PLASTIC PIPING MATERIALS FOR GROUND SOURCE GEOTHERMAL APPLICATIONS

INTRODUCTION

This Model Specification applies to plastic piping materials (e.g., pipes, tubing, and fittings) for open- and closed-loop, horizontal and vertical, direct-buried, and submerged water-based ground-source geothermal heat exchange systems, also known as "geothermal exchange," systems, "ground-coupled" systems, or "earth energy" systems. The outdoor piping in such systems may be referred to as the "geothermal ground loop", "ground heat exchanger", "ground loop heat pump piping", and other such derivations. This Model Specification includes sections for four types of plastic piping materials which have been proven for use in ground-source geothermal heat exchange systems and are approved in existing model codes:

- Section 2.2: High-density polyethylene (HDPE)
- Section 2.3: Polyethylene of raised temperature (PE-RT)
- Section 2.4: Crosslinked polyethylene (PEX)
- Section 4.2: Polypropylene (PP)

For each of these materials, this model specification provides language related to pipe and tubing materials, fittings, and joining procedures. Installation and pressure testing recommendations are also provided.

Note 1: The term "tubing" typically refers to products where the actual outside diameter (OD) is 1/8 inch (0.125") larger than the nominal size, the same as copper tube sizes (e.g., ¾ NTS). The term "pipe" typically refers to products where the actual OD matches that of steel pipe of the same nominal size, otherwise known as Iron Pipe Sizing (e.g., 4 IPS), or products in which the actual OD matches the nominal size directly (e.g., 63 mm). In both cases, specified tolerances apply, as per relevant standards.

This publication is intended for use as a guide to support designers and specifiers of ground source geothermal heat exchange systems, but it should not be used in lieu of the advice of a professional engineer.

In all cases, ground source geothermal systems, including piping, must be installed, tested, and operated in accordance with local regulations which may include the mechanical code that is enforced at the project location or other codes or regulations.

The Plastics Pipe Institute (PPI) has made every reasonable effort to ensure the accuracy of this publication, but it may not provide all necessary information, particularly with respect to special or unusual applications.

This publication may be changed without notice. Visit https://www.plasticpipe.org for the most current edition.

Note 2: The user may choose to adopt part or all this Model Specification. However, users should ensure that all parts which are used are appropriate for the intended purpose.

Note 3: Users should review PPI TN-55 “Plastic Piping Materials for Ground Source Geothermal Heating and Cooling Applications” for more information about plastic piping materials and the standards listed within this Model Specification. Users should also review relevant and applicable model codes such as ANSI/CSA/IGSHPA C448, IAPMO Uniform Mechanical Code, IAPMO Uniform Solar, Hydronics and Geothermal Code, and ICC’s International Mechanical Code.

1.0 GENERAL

1.1. Scope

This model specification applies to plastic piping materials (e.g., pipes, tubing, and fittings) for open- and closed-loop, horizontal and vertical, direct-buried, and submerged water-based ground-source geothermal heat exchange systems, also known as “geothermal exchange,” systems, “ground-coupled” systems, or “earth energy” systems. The outdoor piping in such systems may be referred to as the “geothermal ground loop”, “ground heat exchanger”, “ground loop heat pump piping”, and other such derivations.

This model specification also applies to so-called indoor piping for geothermal exchange systems, such as that which connects buried ground loop piping to heat pump/s which are typically located within buildings.

This model specification does not apply to indoor piping for hot- and cold-water plumbing distribution or to hydronic heating and cooling system piping. Specifications for those piping products should follow local regulations.

Ground loop field size, depth and spacing, as well as grouting specifications, are not covered within this model specification and are the responsibility of the geothermal system designer.

Note 4: This specification does not apply to refrigerant-filled direct exchange systems.

1.2. Definitions

Antifreeze: An additive used in water-based heat transfer fluids to decrease the freezing temperature of the fluid to protect piping systems against freezing

Bend radius: the measure of pipe curvature from a center point to the mid-line of the pipe diameter when a pipe is bent

Borehole: a hole into the earth at any angle that is typically drilled, bored, cored, driven, hydraulically advanced, or otherwise constructed into the earth

Borehole heat exchanger: a borehole with a piping loop installed within for the purpose of exchanging heat with the earth

Closed-loop heat exchange system: a continuous, sealed, underground or submerged ground heat exchanger (i.e., ground loop) through which heat-transfer fluid (e.g., water plus antifreeze) passes to and returns from a heat pump

Electrofusion: a heat fusion joining process where the heat source is an integral part of fitting, such that when an electrical current is applied, heat is produced that melts and permanently joins two or more plastic components (e.g., pipe and fitting)

Heat fusion: a method of joining two similar materials (e.g., HDPE-HDPE) by the application of heat to melt the mating surfaces and then pressing them together with sufficient force to become one monolithic piece

Ground heat exchanger: (also known as ground loop, vertical loop ground heat exchanger, horizontal loop ground heat exchanger, submerged heat exchanger): a continuous, sealed, underground or submerged network of piping serving as the ground heat exchanger through which a heat-transfer fluid passes to and returns from a heat pump

Note 5: Ground heat exchangers may be vertically, diagonally, or horizontally configured or submerged in surface water.

Ground loop: the underground or submerged piping network of a ground loop heat exchanger through which the heat transfer fluid is circulated and thermal energy is exchanged with the earth

Ground source heat pump (GSHP) system: a heat pump system that is connected to a ground loop heat exchanger

Note 6: Other terms used in the industry include “earth energy heat exchange system”, “ground loop heat pump system”, “geothermal heat pump”, “geothermal exchange”, “ground coupled heat pump”, and “water source heat pump”.

Grout: a bentonite material or fluid mixture pumped into annular cavities between pipes and the earth to seal the cavity and conduct heat between the pipe and earth

HDPE: High-density polyethylene (pipe and fitting material)

Header: a pipe assembly that connects multiple parallel pipe circuits to supply or return piping; also called a “manifold”

Horizontal loop: an installation of ground heat exchanger piping that does not penetrate an aquifer and that can be inserted into a trench, open excavation, or installed by a horizontal directional drilling (HDD) method

Hydrostatic pressure: static pressure created by pressurizing a non-moving fluid inside a closed vessel, including pipes

IGSHPA: International Ground Source Heat Pump Association

Indoor piping: piping that is installed in geothermal system vaults or mechanical rooms and used to transition from buried ground loop piping to indoor mechanical systems. May include headers and manifolds when installed in indoor spaces. Sometimes referred to as “interior piping”

Open-loop (surface water or ground water) system: a system designed to utilize ground water or surface water for the purpose of exchanging thermal energy by circulation through a mechanical heat pump

PEX: Crosslinked polyethylene (piping material)

PE-RT: Polyethylene of raised temperature resistance (piping material)

PP: Polypropylene in one of two types known as PP-R and PP-RCT (piping material)

PP-R: Polypropylene random copolymer

PP-RCT: Polypropylene random copolymer with modified crystallinity & temperature resistance

Standard dimension ratio (SDR): a specific ratio of the average specified outside diameter to the minimum specified wall thickness (OD/t) for outside diameter-controlled plastic pipe, the value of which is derived by adding one to the pertinent number selected from the ANSI Preferred Number Series 10.

U-Bend assembly: A 180-degree directional change in a ground loop pipe, typically used at the bottom of a vertical borehole, that is fabricated or formed using a one-piece molded fitting attached to HDPE pipes via butt fusion, approved fittings for PE-RT or PEX pipe and tubing, or jointless hot-forming techniques

Vertical borehole: a vertical hole into the earth at any angle typically drilled, bored, cored, driven, hydraulically advanced, or otherwise constructed into the earth for the purpose of containing ground loop pipes for exchanging heat with the earth and not for the purpose of producing water

Vertical borehole heat exchanger: a vertical borehole with a piping loop installed within for the purpose of exchanging heat with the earth

1.3. Referenced Standards

Where all or part of a national or international standard specification by standards development organizations such as ASTM, CSA, or NSF is incorporated by reference in this Specification, the reference standard shall be the latest edition and revision.

- ANSI/CSA/IGSHPA C448 *Design and installation of ground source heat pump systems for commercial and residential buildings*
- ASTM D2683 *Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing*
- ASTM D2774 *Standard Practice for Underground Installation of Thermoplastic Pressure Piping*
- ASTM D3035 *Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter*
- ASTM D3261 *Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing*
- ASTM D3350 *Standard Specification for Polyethylene Plastics Pipe and Fittings Materials*
- ASTM F645 *Standard Guide for Selection, Design, and Installation of Thermoplastic Water-Pressure Piping Systems*
- ASTM F714 *Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter*
- ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*

- ASTM F877 *Standard Specification for Cross-linked Polyethylene (PEX) Hot-and Cold-Water Distribution Systems*
- ASTM F1055 *Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing*
- ASTM F1290 *Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings*
- ASTM F1807 *Standard Specification for Metal Insert Fittings Utilizing Copper Crimp Ring for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing*
- ASTM F1960 *Standard Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Crosslinked Polyethylene (PEX) Tubing*
- ASTM F2080 *Standard Specification for Cold Expansion Fittings with Metal Compression-Sleeves for Cross-linked Polyethylene (PEX) Pipe and SDR9 Polyethylene of Raised Temperature (PE-RT) Pipe*
- ASTM F2159 *Standard Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing*
- ASTM F2164 *Standard Practice for Field Leak Testing of Polyethylene (PE) and Cross-linked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure*
- ASTM F2389 *Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems*
- ASTM F2620 *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*
- ASTM D2737 *Standard Specification for Polyethylene (PE) Plastic Tubing*
- ASTM F2769 *Standard Specification for Polyethylene of Raised Temperature (PE-RT) Plastic Hot- and Cold-Water Tubing and Distribution Systems*
- ASTM F3347 *Standard Specification for Metal Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing*

- ASTM F3348 *Standard Specification for Plastic Press Insert Fittings with Factory Assembled Stainless Steel Press Sleeve for SDR9 Crosslinked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing*

- AWWA C901 *Polyethylene (PE) Pressure Pipe and Tubing, 3/4 in. (19 mm) through 3 in. (51mm) for Water Service*

- AWWA C904 *Crosslinked Polyethylene (PEX) Pressure Tubing, ½ in. Through 3 in. for Water Service*

- CSA B137.1 *Polyethylene Pipe, Tubing, and Fittings for Cold Water Pressure Services*

- CSA B137.5 *Crosslinked Polyethylene Tubing Systems for Pressure Applications*

- CSA B137.11 *Polypropylene (PP-R and PP-RCT) Pipe and Fittings for Pressure Applications*

- CSA B137.18 *Polyethylene of Raised Temperature (PE-RT) Tubing Systems for Pressure Applications*

- NSF/ANSI 14 *Plastics Piping System Components and Related Materials*

- NSF/ANSI/CAN 61 *Drinking Water System Components – Health Effects*

- NSF/ANSI 358-1 *Polyethylene Pipe and Fittings for Water-Based Ground-Source "Geothermal" Heat Pumps Systems*

- NSF/ANSI 358-2 *Polypropylene Pipe and Fittings for Water-Based Ground-Source "Geothermal" Heat Pump Systems*

- NSF/ANSI 358-3 *Crosslinked Polyethylene (PEX) Pipe and Fittings for Water- Based Ground-Source (Geothermal) Heat Pump Systems*

- NSF/ANSI 358-4 *Polyethylene of Raised Temperature (PE-RT) Pipe and Fittings for Water- Based Ground-Source (Geothermal) Heat Pump Systems*

- PPI TR-4 *PPI HSB Listings of HDB, HDS, SDB, PDB, MRS Ratings and CRS for Thermoplastic Piping Materials or Pipe*

1.4. Engineered and Approved Plans

When required by regulations and codes, geothermal ground loop piping installation and construction shall be performed in accordance with engineered construction plans for the work prepared under the direction of a Professional Engineer.

1.5. Licenses and Permits

A licensed and bonded contractor shall perform all ground loop piping construction work. The Contractor shall secure all necessary permits before commencing construction.

1.6. Inspections

All work shall be inspected by an Authorized Representative of the Owner who shall have the authority to halt construction if, in the representative's opinion, these specifications, local regulations, or standard construction practices are not being followed. Whenever any portion of these specifications is violated, the Project Engineer or his Authorized Representative shall, by written notice, order further construction to cease until all deficiencies are corrected.

1.7. Pipe Warranty

The pipe manufacturer shall provide a written warranty on the pipe as agreed upon between the manufacturer and the owner.

1.8. Piping Installer Qualifications

1.8.1. Ground Loop Contractor Qualifications

The ground loop contractor shall be certified for geothermal ground loop installations. At a minimum, the project superintendent or lead worker shall be certified according to a recognized certification program such as the International Ground Source Heat Pump Association (IGSHPA) Accredited Installer (AI) program and the National Ground Water Association (NGWA) Certified Vertical Closed Loop Driller (CVCLD) designation.

Contractors not meeting the requirements in ground heat exchanger installation and commissioning may be approved by the design engineer upon submittal and satisfactory review of documented comparable experience.

1.8.2. Fusion Technician Qualifications

Each fusion technician shall be thoroughly familiar with heat fusion procedures and must have had formal training at an authorized training session resulting in certification. Technicians shall hold current and correct certification for the fusion type (i.e., butt, socket, or electrofusion) and the pipe diameter range to be installed.

2.0 **GROUND LOOP PIPING PRODUCTS**

2.1. Pipe, Tubing, and Fitting Materials for Ground Loops

Acceptable plastic pipe, tubing, and fitting materials for the underground portion of a ground-source heat exchange system (i.e., the ground loop) shall include high-density polyethylene (HDPE), polyethylene of raised temperature (PE-RT), and crosslinked polyethylene (PEX), as specified below.

2.2. High-density Polyethylene (HDPE) Pipe, Tubing, and Fittings

2.2.1. HDPE Pipe and Tubing

HDPE pipe and tubing shall:

a) be certified to the requirements of CSA B137.1, ASTM D2737, ASTM D3035, or ASTM F714;

b) be manufactured from a PE compound that has a pipe material designation code of PE4710 when evaluated in accordance with ASTM D3350 and a color and ultraviolet stabilizer code of C or E. Code E compounds shall be stabilized against deterioration from unprotected exposure to ultraviolet rays for not less than 3 years, as evidenced by meeting the test criteria specified in AWWA C901;

c) be listed 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);

d) be certified to the requirements of NSF Standard 358-1;

e) be certified to the requirements of NSF/ANSI/CAN 61; and

f) meet the dimension ratio and pressure rating requirements specified in Table 1.

Note 7: See the applicable product standard or manufacturer's published information for specific dimensions and availability.

2.2.2. HDPE Pipe and Tubing Markings

HDPE pipe and tubing shall be marked in accordance with the applicable product standard specified in Section 2.2.1.a of this Specification.

In addition, the following marking requirements shall apply:

a) "Geothermal" or "Geo" and the Standard designation "CSA C448", shall be used to indicate the intended service; and

b) “NSF 358-1”

2.2.3. HDPE Pipe and Tubing Fittings

Fittings for use with the HDPE pipe and tubing shall:

a) be certified to the requirements of

   i) ASTM D2683 for PE socket-type heat fusion fittings;

   ii) ASTM D3261 for PE butt-type heat fusion fittings, including saddle fittings; or

   iii) ASTM F1055 for PE electrofusion-type fittings, including saddle fittings;

b) be manufactured from a PE compound that has a pipe material designation code of PE4710 when evaluated in accordance with ASTM D3350 and a color and ultraviolet stabilizer code of C or E. Code E compounds shall be stabilized against deterioration from unprotected exposure to UV rays for not less than three years, as evidenced by meeting the test criteria specified in AWWA C901;

c) be certified to the requirements of NSF Standard 358-1;

d) be certified to the requirements of NSF/ANSI/CAN 61; and

e) meet the minimum pressure rating requirements specified in Table 1.

2.2.4. HDPE U-bends

All HDPE U-bend assemblies shall be factory-fabricated.

2.2.5. Installation of HDPE Fittings

The following shall apply for installation:

a) Butt-fusion, socket-fusion, and saddle fusion joints and fittings for HDPE pipe and tubing shall be installed in accordance with ASTM F2620 and the instructions of the pipe or tubing and fitting manufacturer/s.

b) As recommended in ASTM F2620, consult the pipe or fitting manufacturer for applicable procedures for butt fusion joining of pipes and fittings that have the same outside diameter but a different wall thickness (i.e., DR).

c) Electrofusion joints and fittings for PE pipe and tubing shall be installed in accordance with ASTM F1290 and the instructions of the pipe or tubing and fitting manufacturer(s).

2.2.6. HDPE Transition Fittings

HDPE transition fittings to adapt to ferrous and non-ferrous metals or plastics other than those listed in this Specification shall be:

a) Polyethylene fusion transition fittings with threads or flanges.

b) Polyethylene fusion transition fittings with threads or barbs for adaptation to approved high strength hose or tubing.

c) Self-restrained HDPE-to-grooved system mechanical couplings for transitions of HDPE pipe conforming to ASTM D3035 and ASTM F714 in SDR 11 to SDR 17 dimension ratios, or PE-RT pipe conforming to ASTM D3350 with a cell class PE445574C in accordance with ASTM F2619 or ASTM F714 in SDR 11 to SDR 17 dimension ratios for nominal diameters 2 to 14 for connections to grooved steel pipe, fittings, and valves.

2.2.7. Barbed Fittings

Barbed fittings utilizing mechanical clamps shall not be connected directly to polyethylene pipe in buried locations.

2.2.8. Accessibility of mechanical connections

All mechanical connections shall be accessible.

2.3. Polyethylene of Raised Temperature Resistance (PE-RT) Tubing and Fittings

2.3.1. PE-RT Tubing

PE-RT tubing shall:

a) be certified to the requirements of CSA B137.18 or ASTM F2769;

b) be manufactured from a PE compound that has a pipe material designation code of PE3608, or PE4710 when evaluated in accordance with ASTM D3350;

c) be listed by The Plastics Pipe Institute's Hydrostatic Stress Board (HSB) in PPI TR-4 with the minimum Hydrostatic Design Stress (HDS) value of 630 psi at 73°F (23°C);

d) be certified to the requirements of NSF Standard 358-4;

e) be certified to the requirements of NSF/ANSI/CAN 61; and

f) meet the dimension ratio and pressure rating requirements specified in Table 1.

Note 8: See the applicable product standard or manufacturer's published information for specific dimensions and availability.

Note 9: For submerged piping systems with still, clear water and with pipes that are close to the surface (e.g., less than 3 feet), there is a possibility of excessive ultraviolet (UV) exposure to PE-RT tubing over years of operation. Consult with the piping manufacturer to ensure that their piping material is recommended for submerged systems.

2.3.2. PE-RT Tubing Markings

PE-RT tubing shall be marked in accordance with the applicable standard specified in Section 2.3.1.a of this Specification.

PE-RT tubing shall be marked with the standard designation/s of the fitting system/s for which the tubing is recommended for use by the tubing manufacturer such as “D2683”, “D3261”, “F1055”, “F1807”, “F1960”, “F2080”, or “F2159” as applicable.

In addition, the following marking requirements shall apply:

a) “Geothermal” or “Geo”, and the Standard designation “CSA C448”, shall be used to indicate the intended service; and

b) “NSF 358-4”

2.3.3. PE-RT Fittings

Underground and underwater joints and fittings for polyethylene of raised temperature tubing used in ground heat exchanger systems shall:

a) be certified to ASTM D2683, ASTM D3261, ASTM F1055, ASTM F1807, ASTM F1960, ASTM F2080, ASTM F2159, ASTM F3347, or ASTM F3348 for use with PE-RT tubing and be approved by the manufacturer for direct burial.

b) be certified to dezincification resistance and stress corrosion cracking resistance requirements of NSF/ANSI 14;

c) be certified to the requirements of NSF/ANSI/CAN 61;

d) meet the minimum pressure requirements specified in Table 1;

e) be installed in accordance with the fitting manufacturer’s instructions; and

f) be marked in accordance with the relevant fitting standard specification as per Section 2.3.3.a

2.3.4. Electrofusion fittings with PE-RT tubing

Polyethylene electrofusion fittings shall be qualified for use with PE-RT tubing according to ASTM F1055.

2.3.5. PE-RT U-bends

All PE-RT U-bend assemblies shall be factory-fabricated.

2.4. Crosslinked Polyethylene (PEX) Pipe, Tubing, and Fittings

2.4.1. PEX Pipe and Tubing

PEX pipe and tubing shall:

a) be certified to the requirements of CSA B137.5, ASTM F876, or ASTM F2788;

b) have a minimum material designation code as per CSA B137.5, ASTM F876, or ASTM F2788 of “PEX1206”;

c) be listed by The Plastics Pipe Institute’s Hydrostatic Stress Board (HSB) in PPI TR-4 with the minimum Hydrostatic Design Stress (HDS) value of 630 psi at 73°F (23°C);

d) be certified to the requirements NSF 358-3;

e) be certified to the requirements of NSF/ANSI/CAN 61; and

f) meet the dimension ratio and pressure requirements specified in Table 1.

Note 10: See the applicable product standard or manufacturer’s published information for specific dimensions and availability.

Note 11: For submerged piping systems with still, clear water and with pipes that are close to the surface (e.g., less than 3 feet), there is a possibility of excessive ultraviolet (UV) exposure to PEX tubing over years of operation. Consult with the piping manufacturer to ensure that their piping material is recommended for submerged systems.

2.4.2. PEX U-bends

All PEX U-bend assemblies shall be factory-fabricated.

2.4.3. PEX Pipe and Tubing Markings

PEX pipe and tubing shall be marked in accordance with the applicable standard specified in 2.4.1.a of this Specification.

Pipe and tubing shall be marked with the standard designation/s of the fitting system/s for which the pipe or tubing is recommended for use by the pipe or tubing manufacturer, such as “F1055”, “F1807”, “F1960”, “F2080”, “F2159”, “F3347”, or “F3348” as applicable.

In addition, the following marking requirements shall apply:

a) “Geothermal” or “Geo”, and the Standard designation “CSA C448”, shall be used to indicate the intended service; and

b) “NSF 358-3”

2.4.4. PEX Pipe and Tubing Fittings

Underground and underwater joints and fittings for PEX plastic pipe and tubing used in ground heat exchanger systems shall:

a) be certified to ASTM F1807, ASTM F1960, ASTM F2080, ASTM F2159, ASTM F3347, or ASTM F3348 for use with PEX tubing, and ASTM F2829 for PEX pipe, and shall be approved for direct burial by the manufacturer;

b) be certified to the dezincification resistance and stress corrosion cracking resistance requirements of NSF/ANSI 14;

c) be certified to the requirements of NSF/ANSI/CAN 61;

d) meet the minimum pressure requirements specified in Table 1;

e) be certified to meet the performance requirements of ASTM F877 for PEX tubing and ASTM F2829 for PEX pipe;

f) be installed in accordance with the fitting manufacturer’s instructions; and

g) be marked in accordance with the relevant fitting standard specification as per Section 2.4.3.a

2.4.4.1. Electrofusion fittings with PEX pipe and tubing

Polyethylene electrofusion fittings shall be qualified for use with PEX pipe according to ASTM F3373 and shall be qualified for use with PEX tubing according to ASTM F1055.

Table 1: Requirements for HDPE, PE-RT and PEX Pipe, Tubing, and Fittings for Ground Loop Applications

	Vertical installations[1]		Horizontal installations[2]	
Nominal pipe size[3]	Minimum pipe pressure rating[4] psi (kPa)	Maximum dimension ratio[5]– all pipe & tubing	Minimum pipe pressure rating[4] Psi (kPa)	Maximum dimension ratio[5] – all pipe & tubing
3/4	160 (1103)	SDR 13.5	160 (1103)	SDR 13.5
1	160 (1103)	SDR 13.5	125 (862)	SDR 13.5
1 1/4	160 (1103)	SDR 13.5	125 (862)	SDR 13.5
1 1/2	160 (1103)	SDR 13.5	125 (862)	SDR 13.5
2	160 (1103)	SDR 13.5	100 (690)	SDR 13.5
2 1/2	[6]	[6]	100 (690)	SDR 13.5
3	[6]	[6]	100 (690)	SDR 17
4	[6]	[6]	100 (690)	SDR 17
6	[6]	[6]	100 (690)	SDR 17
8 and larger	[6]	[6]	100 (690)	SDR 17

[1] Vertical installations also include diagonal, inclined, and angled installations.

[2] Horizontal installations also include headers for use in vertical borehole heat exchanger systems, horizontal directional drilling (HDD) installations, and submerged heat exchangers

[3] Nominal pipe sizes indicate the nominal diameter by which a pipe is designated. The specific product dimensions (i.e., outside diameter and inside diameter) are based on referenced standards for HDPE, PEX, and PE-RT pipe and tubing materials. Actual outside and inside diameters are not the same as the nominal sizes. So-called soft metric conversions of these nominal pipe sizes may cause confusion. For instance, a specification for a “25 mm pipe” would not match any of the available HDPE, PE-RT, or PEX pipes meeting the referenced standards. Designers and specifiers should specify the nominal pipe sizes as shown in **Table 1.**

[4] Pressure ratings listed in Table 1 are for water at 73°F (23°C). Pressure ratings will be reduced for operating temperatures above 80°F (27°C) according to the materials and the relevant product standards.

[5] A numerically-lower Standard Dimension Ratio (SDR) value indicates a thicker wall for a given diameter. For example, SDR 11 pipe has a thicker wall than SDR 13.5 pipe. Therefore, a numerically lower dimension ratio (e.g., SDR 9) complies with a maximum dimension ratio of SDR 11 as listed in Table 1.
The Maximum Dimension Ratios specified in Table 1 are to ensure that pipe or tubing has a sufficiently thick wall in all diameters for the purpose of resisting typical working stress during installation, resistance to kinking and incidental mechanical damage caused by handling, uncoiling, abrasion against borehole casing, rocks, debris, etc., so that the pipe or tubing may withstand minor scratches or gouges without loss of pressure capability.

[6] Using this nominal pipe size in a vertical borehole installation is considered an exception that requires evaluation by a professional engineer.

Note 12 on the effects of borehole depth on pipe pressure: The pressure inside pipes that is caused by elevation is known as static water column pressure. Static water column pressures in vertical borehole heat exchange piping systems are increased with the depth of the borehole and the height of the building above grade, if not hydraulically-separated and should be considered when selecting the piping material, its wall type (i.e., dimension ratio or DR) its pressure rating to prevent exceeding the pressure rating of the pipe when installed in a borehole.

For example, using a density for water of 62.4 lbs per ft^3 at 40°F (4°C) ÷ 144 in^2/ft^2 = 0.433 lbs/in^2 or 0.433 pounds per square inch of added internal pressure per 1 ft of water height. 10 feet of water elevation creates 4.3 psi pressure inside piping systems, and 2.307 feet of water creates 1 psi. Antifreeze fluids added to water (e.g., ethanol, glycol) can have different densities and will result in different hydrostatic pressures.

Designers shall calculate the static water column pressure in vertical borehole installations and ensure that pressure ratings of pipes are not exceeded. The PPI **Plastic Pipe Design Calculator** at www.plasticpipecalculator.com includes a function to help estimate the Static Water Column Pressure in a geothermal vertical borehole heat exchanger. This Calculator can also be used to estimate the pressure loss through plastic piping materials as well as the volume of various types and diameters of piping materials. This function may be used to estimate antifreeze quantities.

2.5. Valves

Valves used to isolate the ground loop piping from a building or for isolating individual ground loop circuits shall be labeled and shall be locatable and accessible.

Valves shall be rated for the operating temperature and pressure rating of the ground-loop system to which they are connected and shall be compatible.

2.6. Detectable Locator Tape

Where required, detectable warning tape shall be 5 mil minimum thickness with a minimum width of 3 inches (75 mm). The background of the tape shall be blue with black lettering continuously printed with the words “Ground Loop Pipe Buried Below.”

2.7. Tracer Wire

Where required, plastic pipe with a nominal diameter of 4 inches and greater shall be installed with insulated 12 AWG solid or stranded copper wire suitable for direct burial.

2.8. Antifreeze

2.8.1. Fluid Types

When it is determined that any segment of the geothermal ground loop is subject to freezing, adequate antifreeze protection shall be included utilizing only the approved fluid types as follows:

- Propylene glycol with approved corrosion inhibitors and environmental stabilizer additives to be mixed with water
  .
- Ethanol with approved corrosion inhibitors and environmental stabilizer additives to be mixed with water.
- Methanol with approved corrosion inhibitors and environmental stabilizer additives to be mixed with water.
- Other heat transfer fluids in accordance with ANSI/CSA/IGSHPA C448 or local codes.

2.8.2. Regulatory Compliance

All antifreeze fluids shall comply with local regulations.

2.8.3. Quantity

The percent of antifreeze fluid by volume shall be determined based on the freezing point of the solution and type of mixture in accordance with the manufacturer's specifications.

2.8.4. Flammability

When using flammable heat transfer fluid (e.g., ethanol, methanol), proper caution and protocol in accordance with the manufacturer's instructions and local regulations shall be followed.

3.0 **GROUND LOOP PIPING INSTALLATION**

3.1. Piping Installation – General

The following procedures shall be utilized for installation of high-density polyethylene (HDPE), crosslinked polyethylene (PEX), and polyethylene of raised temperature (PE-RT) pipe and tubing as ground loop piping:

a) Pipe and tubing shall be inspected before installation and any sections that have cuts, gouges, kinks, or other signs of significant damage[7] shall be removed.

b) To avoid surface abrasion, pipe and tubing shall not be dragged over rough ground or obstructions.

c) Pipe and tubing shall not be bent to form a sharp angle or kink.

d) Where pipe or tubing is dispensed from an uncoiling device, it shall be mounted in such a way that stresses are minimized during installation. The pipe shall not be subjected to reverse curvature.

e) Pipe and tubing shall not be installed in contact with or close to hot surfaces in excess of their highest rated operated temperature.

f) Pipe and tubing shall be inserted into boreholes without significant damage[7].

g) The installation process shall be defined such that the internal and external hydrostatic pressures exerted on the pipe during installation can be shown not to exceed the pressure rating of the pipe (internal hydrostatic pressure) and collapse (i.e., external hydrostatic buckling) resistance of the pipe (external pressure caused by water or grout in the borehole), respectively.

h) Backfill material must be free of large stones or other dense hard objects which could damage the pipe when dropped into the trench or create concentrated pipe loading.

3.2. Bend Radius

Pipe or tubing shall not be bent to a radius less than the minimum bend radii as follows:

[7] "significant damage" is defined as a scratch, dent, or gouge of a depth greater than 10% of the minimum pipe wall thickness that is required for the pipeline's operating pressure or the minimum wall thickness required to meet structural design requirements.

3.2.1. HDPE Pipe and Tubing Bend Radius

The minimum bend radius of HDPE pipe and tubing shall be in accordance with **Table 2**. When a fitting or flange connection is present in the pipe bend, the minimum bend radius shall be one hundred times the pipe outside diameter (OD) for a distance of five times the pipe diameter on either side of the fitting location.

Table 2: MINIMUM BEND RADIUS FOR HDPE PIPE

DIMENSION RATIO (DR)	MINIMUM BEND RADIUS
7	20 x Pipe OD
9	20 x Pipe OD
11	25 x Pipe OD
13.5	25 x Pipe OD
15.5	27 x Pipe OD
17	27 x Pipe OD
Fitting/flange present in the pipe bend	100 x Pipe OD

3.2.2. PEX Tubing Bend Radius

The minimum bend radius of PEX pipe and tubing is six times the outside diameter (OD) of the tubing or in accordance with the manufacturer's installation instructions.

3.2.3. PE-RT Tubing Bend Radius

The minimum bend radius of PE-RT tubing is six times the outside diameter (OD) of the tubing or in accordance with the manufacturer's installation instructions.

3.3. Vertical Borehole Heat Exchanger Piping Installation

a) Install piping in boreholes according to ASTM D2774 or ASTM F645.

b) Clean pipe and fittings and make heat-fusion joints according to ASTM F2620, ASTM F1055 or ASTM F3373 for electrofusion fittings. Minimize the number of joints.

c) Purge, flush, and pressure test vertical loop piping before backfilling borehole heat exchangers. See Field Quality Control in Section 3.5.

d) Completely fill the borehole from bottom to top with grout, water, or other backfill material as specified. Grout material shall be pressure pumped through the appropriately sized tremie pipe and placed in the borehole column from the bottom to the top (or from end to end in a horizontally bored application).

When required, mark borehole locations with detectable locator tape.

3.3.1. Prevention of Hydrostatic Buckling or Collapse

When external pressure is applied to the outer wall of cylinder, there is the possibility of buckling or collapse of the cylinder. A pipe can be considered a cylinder in this regard.

For plastic pressure pipe and tubing materials that are installed within deep vertical boreholes, there is the theoretical possibility that external pressure caused by grout or groundwater on the outside of pipes could cause unconstrained pipe buckling or collapse. The term “unconstrained” is used when pipes are not surrounded with compacted backfill, as is the case in a borehole heat exchanger.

Extensive industry experience has provided the mathematical models to predict when such buckling could occur, allowing designers and installers to prevent such occurrences.

The calculation methods presented in the PPI *Handbook of Polyethylene Pipe* (Chapter 6) or in the ASHRAE *HVAC Applications Handbook* (Chapter 35, Geothermal Energy) may be used to illustrate that the installation process does not exceed pipe pressure or buckle/collapse resistance ratings.

3.4. Horizontal Loop Piping Installation

a) All excavations shall comply with local regulations.

b) Install piping in trenches according to ASTM D2774 or ASTM F645. All piping shall be placed at minimum depth from grade as shown on the drawings.

c) Pipe embedment material should be Class I, Class II, or Class III materials as defined by ASTM D2321 Section 6.

d) Pipe bedding shall be in conformation with ASTM D2321 Section 8. Compaction rates should be as specified by ASTM D2321.

e) Extend the horizontal piping and connect to ground-loop heat-pump piping systems at outside face of building wall in locations and pipe sizes indicated.

f) Terminate water-service piping at the building wall or inside mechanical room of building until ground-loop heat-pump piping systems are installed. Terminate piping with caps and/or isolation valves as indicated on the contract documents. Make connections to indoor pipe of heat pump systems when those systems are installed. Fill the entire piping loop with potable water that meets the required water quality.

g) Seal penetrations through building walls using a compressible sleeve seal or other approved product.

h) When required, mark borehole locations, header pipes, and horizontal runs with detectable locator tape. When required, also run tracer wire. Do not place metallic tape in the vicinity of buried gas lines. Detectable locator tape shall be at 18 inches (0.48 m) below finished grade.

i) Prepare as-built drawings, documentation, test, and inspection reports as required.

3.5. Field Quality Control For Ground Loop Piping

3.5.1. Inspection of Ground Loop Piping before Installation

All ground loop pipe and tubing shall be physically inspected at the jobsite before installation and any sections that have cuts, gouges, kinks, or other signs of significant damage[6] shall be removed.

Cap or tape each pipe end until the pipe is joined to other pipes to avoid contamination from trash, soil, small animals, and other foreign debris.

3.5.2. Pressure Testing of Ground Loop Pipes before Installation

Before installation of pipes in the ground, test pipes according to the manufacturer's recommendations.

3.5.3. Ground Loop Flush/Purge after Pipe Installation:

Ensure that the exterior ground loop piping has been filled with liquid and purged of air and debris, pressure tested, and filled with proper quality water and heat transfer fluid as specified.

Flushing, pigging, or other means of cleaning the system to remove dirt and debris that may damage valves, regulators, and so forth may be required before testing.

The flushing/purging flow rate shall be completed with a minimum flow rate of 2 feet per second (0.6 m/s) to remove air, but not in excess of the maximum flow velocity (pressure) recommended by the pipe and fittings manufacturer to remove debris. For pipes of nominal diameter 3 inches and larger, fluid velocity higher than 2 ft per second (0.6 m/s) may be required to adequately remove dirt and rock debris.

3.5.4. Hydrostatic Pressure Testing of Installed Pipes:

Pressure tests shall be conducted in accordance with ASTM F2164 Standard Practice for Field Leak testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure which provides information on apparatus, safety, restraints, pre-test preparation, and procedures for conducting pressure tests, and the piping manufacturer's recommendations.

The following content is from ASTM F2164-21, Section 4. Summary of Practice*:

“The section of the piping system to be tested is isolated from other parts of the system and restrained against movement to prevent catastrophic failure. Components that are not to be subjected to test pressure or could be damaged by test pressure are isolated or removed as necessary. Isolated components are vented to atmosphere. The test section is filled with the testing liquid, raised to the test pressure, and allowed to stabilize. The system is inspected or monitored for leakage, and then test pressure is relieved. If repairs or corrections are necessary, they are performed only when the test section is depressurized. If necessary, a retest is performed after a relaxation period. At the conclusion of an acceptable test, the test section may be placed in service. Purging and disposal of the test liquid from the test section may be necessary.”

3.5.4.1. Supplemental Information on Hydrostatic Testing

a) Before testing, heat fusion joints shall be completely cooled following procedures outlined in ASTM F2620 and ASTM F1055.

b) Leakage or failures are more likely to occur at joints than in piping sections.

c) Mechanical connections shall be completely assembled with all necessary seals and all fasteners installed and tightened.

d) Components that are not to be subjected to test pressure or could be damaged by test pressure shall be isolated or removed as necessary. If lower pressure-rated components cannot be removed or isolated from the test section, the maximum test pressure is the pressure rating of the lowest pressure-rated component that cannot be isolated from the test section.

e) There is no leakage allowance for HDPE, PE-RT, or PEX piping systems.

f) When HDPE, PE-RT, or PEX piping systems are first pressurized, these materials will expand slightly due to their elasticity. Make-up fluid should be added to the piping system to restore pressure to the initial setpoint.

g) Air vents should be located at all high points of the piping system to allow for the release of air.

h) The test fluid shall not be allowed to freeze during the pressure test. In freezing conditions, ensure that adequate antifreeze is used to prevent freezing.

i) Each pipeline section to be tested shall be restrained against movement in the event of catastrophic failure. Joints may be exposed for leakage examination, provided that restraint is maintained.

j) Leakage at any joint indicates a defective joint which could rupture or separate while under pressure. Immediately remove pressure and replace any leaking joints before a retest.

k) Test pressure and duration shall be in accordance with ASTM F2164.

l) Only authorized people should be in the proximity of the piping systems during the testing procedure and must be wearing the appropriate personal protective equipment (PPE).

3.5.5. Hydrostatic Test Records

The following information about hydrostatic pressure tests shall be documented:

a) A description of the test section components (e.g., circuit number/location)

b) The test liquid

c) The target test pressure in addition to test pressures recorded during the test.

d) The type of test gauge used to measure the pressure

e) Location of test gauges through the piping system

f) The test date and duration (starting time, ending time)

g) The weather conditions and ambient temperature at the site during the test

h) Any adjustments made to test pressure for elevated temperature, pipe expansion, etc.

i) Description of any leaks or failures and the corrective actions taken

j) The identification of the party conducting the test

4.0 **INDOOR PIPING PRODUCTS**

4.1. Pipe and Fitting Materials for Indoor Piping

Acceptable plastic pipe and fitting materials for the indoor portion of a ground-source heat exchange system to connect ground loop piping to the heat pump/s and other mechanical equipment shall include:

a) high-density polyethylene (HDPE) per Section 2.2 of this specification

b) polyethylene of raised temperature (PE-RT) per Section 2.3 of this specification

c) crosslinked polyethylene (PEX) per Section 2.4 of this specification

d) polypropylene (PP) per Section 4.2 of this specification

4.2. Polypropylene (PP-R and PP-RCT) Pipe and Fittings

4.2.1. PP-R and PP-RCT Pipe

PP-R and PP-RCT Pipe for indoor piping of ground heat exchange systems shall:

a) be certified to the requirements of CSA B137.11 or ASTM F2389;

b) be certified to the requirements of NSF Standard 358-2; and

c) have a pressure/temperature rating at or above the system requirements.

4.2.2. Fittings for PP-R and PP-RCT pipe

Fittings for PP-R and PP-RCT pipe used as indoor piping for ground heat exchanger systems shall:

a) be certified to CSA B137.11 or ASTM F2389 and be approved by the manufacturer for ground source heat pump applications;

b) be certified to the requirements of NSF Standard 358-2; and

c) be installed in accordance with the fitting manufacturer’s instructions.