Polyethylene Pipe and Fittings for Water-Based Ground-Source (Geothermal) Heat Pump Systems

1 General

1.1 Purpose

This Standard establishes the minimum physical and performance requirements for plastic piping system components. These criteria were established for the protection of property, public health and the environment.

1.2 Scope

The physical and performance requirements in this standard apply to plastic piping system components as well as non-plastic components of the ground loop heat exchanger including but not limited to pipes and fittings used in water-based ground-source heat pump systems. This standard does not cover refrigerant based ground loop heat exchangers such as direct expansion (DX) systems. This standard does not cover hydronic heating or cooling systems within buildings.

2 Normative References

The following documents contain provisions that, through reference, constitute provisions of this NSF Standard. At the time this Standard was balloted, the editions listed below were valid. All documents are subject to revision, and parties are encouraged to investigate the possibility of applying the recent editions of the documents indicated below.

Normative References for Polyethylene Pipe and Fittings for Water-Based Ground-Source (Geothermal) Heat Pump Systems:

ASTM D2447-03 Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter

ASTM D2683-10 Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing

ASTM D3035-08 Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter


ASTM D3350-10 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

ASTM F412-09 Terminology Relating to Plastic Piping Systems
3 Definitions

Terms used in this Standard that have a specific technical meaning are defined here.

3.1 compound: A mixture of polymers with other ingredients such as fillers, stabilizers, catalysts, processing aids, lubricants, modifiers, pigments, or curing agents.

NOTE – Compounds are considered materials; however, not all materials are considered compounds.

3.2 contamination: The presence of a substance not intentionally incorporated in a product.

3.3 critical dimensions: Dimensions of a product (e.g., pipes and fittings) that directly affect the fit and function, or the capacity of making a sound joint, or both.

3.4 fitting: A piping component used to join, terminate, or provide changes of direction in a piping system.

3.5 ground-source heat pump system: A terminology used to describe a variety of mechanical systems that use the ground, groundwater, or surface water as a heat source or heat sink. Systems can be further described as ground-coupled, groundwater and surface water heat pump systems.

3.6 hydrostatic design basis (HDB): One of a series of established stress values specified in ASTM D 2837 for a plastic compound, obtained by categorizing the long-term hydrostatic strength determined in accordance with ASTM D 2837.

3.7 hydrostatic design stress (HDS): The estimated maximum tensile stress a material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

3.8 joint: The location at which two pieces of pipe or a pipe and a fitting are connected together. Various joint types not defined in this standard shall be defined by ASTM F412.
3.9 **mechanical joint**: a connection between two pieces of pipe or a pipe and a fitting using a physical force to establish a seal or alignment.

3.10 **plastic pipe**: A hollow cylinder of plastic, in which the wall thicknesses are usually small when compared to the diameter, and in which the inside and outside walls are essentially concentric.

3.11 **plastic**: A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state, and, at some stage in its manufacture or processing into finished articles, can be shaped by flow.

3.12 **pressure rating**: The estimated maximum water pressure at a specified temperature that a pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.13 **quality assurance**: A formal system for verifying that products conform to specific standards. Quality assurance is intended as an audit of quality control testing.

3.14 **quality control**: The methods used to ensure that a production process yields products in conformance with the appropriate specifications established by the quality assurance program.

3.15 **rework material**: A material from a manufacturer’s own production that has been reground or pelletized for reuse by that same manufacturer.

3.16 **steady-state**: An operational condition of the manufacturing process that does not change with time.

3.17 **thermoplastic**: *noun* – A plastic that can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and in the softened state, can be shaped by flow through molding or extrusion. *adj.* – Capable of being repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and able in the softened state to be shaped by flow into articles by molding or extrusion.

3.18 **virgin material**: A material in the form of pellets, granules, powder, floc, or liquid that has not been subjected to use or processing other than that required for its initial manufacture.

### 4 Material Requirements

#### 4.1 Plastic Materials

Plastic piping system components and related materials shall be produced from virgin plastics or clean rework materials.

#### 4.2 Rework Materials

The use of clean, rework material of the same formulation and physical properties from the same production facility is acceptable provided the finished products meet the requirements of this standard. Plastic piping system components and related materials shall be manufactured to prevent contamination.

Fittings requiring exposed metallic components shall not be suitable for burial.
Material used for polyethylene pipe and fittings shall be 3608, 3710, 4608, or 4710 high-density polyethylene having a minimum cell classification of PE 345464C, PE 345464D or PE345464E as specified in ASTM D-3350.

4.3 Long-term strength of plastic pipe

Materials for use in plastic pipe shall comply with long term strength compliance in 4.4. Listing in PPI Technical Report Number 4 (TR-4) is acceptable evidence of hydrostatic design stress compliance.

4.4 Hydrostatic design

The maximum hydrostatic design basis of polyethylene material shall be determined in accordance with PPI Technical Report Number 3 (TR-3) for the temperature and hydrostatic design stresses in Table 1.

<table>
<thead>
<tr>
<th>Plastic Material</th>
<th>HDS at 73°F</th>
<th>HDS at 140°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE3608</td>
<td>800</td>
<td>400</td>
</tr>
<tr>
<td>PE3710</td>
<td>1000</td>
<td>630</td>
</tr>
<tr>
<td>PE4608</td>
<td>800</td>
<td>400</td>
</tr>
<tr>
<td>PE4710</td>
<td>1000</td>
<td>630</td>
</tr>
</tbody>
</table>

5 General Requirements

5.1 Polyethylene Pipe

Polyethylene pipe shall comply with ASTM F714, ASTM D2447, ASTM D3035, CSA B137.1, or AWWA C901. Pipe with a diameter of 2 inches (6.033cm) (nominal) and smaller shall have a maximum dimension ratio (minimum wall thickness) of 11. Pipe with a diameter of 3 in (7.62 cm) (nominal) and larger shall have a maximum dimension ratio (minimum wall thickness) of 17.

5.2 Polyethylene Fittings

Butt heat fusion polyethylene fittings shall comply with ASTM D3261.

Socket-type polyethylene fittings shall comply with ASTM D2683.

Electrofusion type polyethylene fittings shall comply with ASTM F1055.

U-bends containing assembled joints shall comply with the sustained pressure at elevated temperature requirements of 7.2.3 of ASTM D3261 at a temperature of 176F for 170 hours as identified in Option 3 of Table 8 of ASTM D3261. Each test specimen shall contain assembled joints consistent with how the product is sold.

5.3 Chemical Resistance

Plastic pipe and plastic fitting materials in direct contact with heat transfer fluids shall not exhibit a change in weight greater than 0.5% or a change in apparent tensile strength greater than 12% when tested according to 5.3.1 through 5.3.4

5.3.1 Determine the resistance to the chemicals in Table 2 in accordance with ASTM D543
5.3.2 Ring specimens shall be cut from a minimum 1” diameter pipe where available. The specimens shall be ½ inches wide with a ¼ inch wide reduced section. For materials that are not readily available as minimum 1 inch diameter pipe, the test specimen shall be a plaque of material ¼ x 2 x 4 inch with a 1 inch wide reduced section or as specified in ASTM D2290.

5.3.3 Test five specimens with each chemical listed in Table 2. Weigh the specimens to the nearest 0.005 g and completely immerse in the chemicals for 72 hours. On removal from the chemicals, wipe the specimens with a clean dry cloth. Condition in air for 2 to 2 ¼ hours and reweigh. Calculate the change in weight to the nearest 0.01% on the basis of initial weight.

5.3.4 Test the specimens for tensile strength in accordance with ASTM D2290, Procedure B using 0.5 inch/minute testing speed within ½ hour after weighting. Examine the weight and apparent tensile strength of each specimen.

Table 2

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>100%</td>
</tr>
<tr>
<td>Methanol</td>
<td>100%</td>
</tr>
<tr>
<td>Propylene glycol</td>
<td>100%</td>
</tr>
</tbody>
</table>

Note – This test is designed to establish basic chemical resistance requirements of plastic piping materials to the major chemicals used in heat transfer fluids. Plastic materials are tested with the chemicals in pure form. Heat transfer fluids contain chemical additives packages such as corrosion inhibitors that are not considered qualified by this test. Heat transfer fluid manufacturers should be consulted regarding the chemical compatibility of each fluid formulation and the piping material.

5.4 Mechanical Joints

All mechanical joints designed for use in buried applications shall meet the requirements of 5.4.1 through 5.5.1.

5.4.1 Thermocycling

Pipe and fittings assembled using the manufacturer’s instructions shall not leak following thermocycling when tested in accordance with 5.4.1.1 through 5.4.1.7.

5.4.1.1 Summary

This test method describes a pass-fail test for thermal cycling the pipe, fittings and the joining technique employed for use in the buried portion of the closed-loop ground-heat exchanger of a ground-source heat pump system over a critical temperature range for a number of selected cycles while subjected to a nominal internal pressure. This test provides a measure of resistance to failure due to the combined effects of differential thermal expansion and creep on the pipe and fitting intended for continuous use up to 120°F (49°C).

5.4.1.2 Conditioning

The test specimens should be conditioned at 70 to 77°F (23 ± 2°C) and 50 ± 5% relative humidity for not less than 24 h prior to test.

5.4.1.3 Test Conditions

Conduct the test in the standard test laboratory atmosphere of 70 to 77°F (23 ± 2°C) and 50 ± 5% relative humidity.

5.4.1.4 Apparatus
A nitrogen or air source capable of maintaining a nominal internal pressure of 100 ± 10 psig (0.69 ± 0.069 Mpa) on the specimens is required. The immersion system shall consist of two water reservoirs controlled at 38 ± 4°F (3 ± 2°C) and 120 ± 4°F (49 ± 2°C). The specimen shall be cycled from one reservoir to the other or hot and cold water shall be alternately cycled over the test specimens automatically and returned to the proper reservoirs.

5.4.1.5 Assembly

Assemble the pipe and fittings using the manufacturer’s recommended procedures. When assembled and cured as specified by the manufacturer’s recommendation, the sample specimen shall withstand for 2 hours, without leakage, separation or rupture, the internal hydrostatic pressure equivalent to the rated pressure of the lowest rated component (pipe or fitting).

5.4.1.6 Specimen Preparation

Select at least six joints from randomly selected specimens. Assemble the joints with at least 5-pipe diameters between joints and attach to a common manifold. Close the specimen assembly with any suitable end closures that allow “free-end” mounting and will not leak under the thermocycling conditions, and connect the specimen to a pressure source.

5.4.1.7 Procedure

Pressurize the specimen assembly with nitrogen or air to 100 ± 10 psig (0.69 ± 0.069 Mpa). Immerse the specimen assembly in 120 ± 4°F (49 ± 2°C) water to determine if there are any initial leaks. All leaks shall be eliminated before the thermocycling test is started. Thermally cycle the specimen assembly either manually or automatically and under constant internal pressure of 100 ± 10 psig (0.69 ± 0.069 Mpa), alternately between 38 ± 4°F (3 ± 2°C) and 120 ± 4°F (49 ± 2°C) by means of immersion in water. Specimens 2 inches and less in nominal diameter shall complete 5000, 15 minute thermal cycles at each temperature and Specimens greater than 2 inches in nominal diameter shall complete 2500. The thermal cycles shall be at least 30 minutes or sufficient time required to achieve homogenous sample temperature. Upon completion of thermal cycles, immerse the specimen assembly again in the 120 ± 4°F (49 ± 2°C) water and check for any sign of gas leakage. Any evidence of leakage at the fitting or separation of the fitting from the pipe constitutes failure.

5.4.1.8 Pressure Test

Each specimen assembly shall again withstand for 2 hours, without leakage, separation or rupture, the internal hydrostatic pressure equivalent to the rated pressure of the lowest-rated component (pipe or fitting). Failure of any one of the six joints tested shall constitute failure of this test.

5.5 Constant Tensile Load Joint Test

Joints shall not fail by leakage or pullout when tested per 5.5.1

5.5.1 One specimen of largest nominal size shall be tested in accordance with ASTM F1588 for 1000 hours at an internal pressure of 100psi with the joint loaded to an axial tensile stress of 1320psi.

5.6 Joining

Joints between PE pipe and fittings shall be socket-fusion, butt-fusion, electrofusion, or saddle fusion in accordance with ASTM F 2620. Mechanical joints such as threads, flanges,
compression fittings, or stab type mechanical fittings shall be in accordance with manufacturer’s instructions.

6 Marking Requirements

6.1 Pipe Marking

Marking shall be applied so that it can only be physically removed by removing part of the pipe wall. Pipe shall be marked in a contrasting color with the following information:

- Nominal Size
- Material Designation
- Third-party certification Mark (if applicable)
- End use of “Geo” or “Geothermal”
- This standard designation, i.e. NSF/ANSI-358-1
- Pressure rating at rated temperature

6.2 Fitting Marking

Fittings shall be marked with the following information:

- Nominal Size
- Third-party certification mark (if applicable)
- Standard designation as referenced in 5.1 or 5.2

6.3 Manufacturers Instructions

6.3.1 Protection from UV Exposure

Manufacturers instructions shall contain instructions for the appropriate protection from UV exposure during shipping, handling, storage and installation.

6.3.2 Suitability for burial

Manufacturers instructions for fittings shall indicate whether or not the fittings are suitable for burial.

7 Quality Assurance

7.1 General

A quality control program shall be operated and maintained to ensure that products conform to the applicable requirements of this Standard on a continuous basis. The manufacturer shall provide and maintain quality control testing facilities at each production facility.

7.1.1 Quality control testing shall be conducted at ambient temperature and humidity or standard laboratory conditions of 23 ± 2°C (73 ± 3.6°F) and 45 to 55% relative humidity.

7.1.2 The tests and testing frequencies shall conform to the minimum requirements listed in 7.8. Where quality control requirements are specified in the product standards, the tests and test frequencies specified in the product standards shall be conducted in addition to the requirements
listed in 7.8. If the test frequencies specified in the product standard conflict with the frequencies
tained in 7.8 then the more frequent requirement shall be followed. Variations from these
minimum requirements shall be permitted if an alternate program is established in writing and
determined to be equivalent.

7.1.3 Annual testing performed by a third-party certifier shall satisfy the requirement of annual
quality control testing.

7.2 Start-up and qualification of molds

7.2.1 Start-up

In each case, with the exception of annual and semi-annual tests, the frequency of testing
indicated in 7.8 shall be interpreted as follows: the indicated tests shall be performed at the start-
up of any production operation, on each extruder or injection molder, and continued until a
steady-state operation that meets the test requirement is obtained. The test shall be repeated at
the required frequency until there is a change in the steady-state operation. When there is a
change in operation, testing shall be conducted continuously until a new steady-state operation is
achieved. After a steady-state operation is attained, the applicable testing frequencies shown in
7.8 shall resume.

7.3 Qualification of molds

The test frequency indicated for fittings shall be used only after the mold has been qualified. In
order for a new or retooled mold to be considered “qualified,” all products from all cavities in the
mold shall attain compliance with all of the appropriate dimensions and tests. This does not
include annual or semiannual tests. After qualification, the indicated test frequencies shall apply
to one cavity per mold, rotating cavities within the mold, including start-ups. If any physical
change is made to the mold itself, all cavities within the mold must be re-qualified.

7.4 The calibration of all equipment used to check critical dimensions shall be verified weekly.
Verification shall consist of checking the zero point, if applicable, and the critical dimension or a
point near the upper limit of the instrument. Where applicable, references used for verification
shall be traceable to the National Institute of Standards and Technology (NIST).

7.5 Other equipment, including equipment used for measuring ingredients in in-plant blending
operations, shall be verified at a minimum of once annually. Records of equipment verification
shall include the following:

– date that the verification was performed;
– identity of the equipment verified (description and serial number);
– verification data;
– description of any corrective actions taken, if applicable; and
– identity of the person who performed the verification.

7.6 Quality assurance records

The manufacturer shall maintain records of quality assurance testing at each production location
for at least three years.

7.7 Production code identification

In instances where code identification of products is required, the manufacturer shall maintain
records necessary to confirm identification of all products.
7.8 Number of test specimens

Unless otherwise specified by an applicable standard as referenced in 2 of this Standard, the minimum number of test specimens for a sample of one size, style, configuration, and material shall be as indicated in Table 3 and 4.

Product-specific quality assurance requirements for polyethylene pipe and fittings are contained within Table 3 and 4.

<table>
<thead>
<tr>
<th>Test</th>
<th>PE Pipe</th>
<th>Minimum number of specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burst pressure&lt;sup&gt;1&lt;/sup&gt;</td>
<td>24 hours</td>
<td>5</td>
</tr>
<tr>
<td>Dimensions, (Inner diameter or outer diameter)</td>
<td>2 hours</td>
<td>3</td>
</tr>
<tr>
<td>Dimensions, minimum and maximum wall thickness</td>
<td>2 hours</td>
<td>3</td>
</tr>
<tr>
<td>Elevated temperature sustained pressure 80C (176 F)</td>
<td>annually</td>
<td>6</td>
</tr>
<tr>
<td>Environmental stress crack corrosion</td>
<td>annually</td>
<td>6</td>
</tr>
</tbody>
</table>

<sup>1</sup> If one material is continuously used in several machines or sizes, then when a steady-state operation is obtained on each machine, sample selection shall be from a different extruder each day and rotated in sequence among all machines or sizes.

<table>
<thead>
<tr>
<th>Test</th>
<th>PE Electro-fusion fittings</th>
<th>PE butt fusion fittings</th>
<th>PE socket type fittings</th>
<th>Minimum number of specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burst pressure&lt;sup&gt;1&lt;/sup&gt;</td>
<td>weekly</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>24 hours</td>
<td>24 hours</td>
<td>24 hours</td>
<td>3</td>
</tr>
<tr>
<td>Outside diameter</td>
<td></td>
<td></td>
<td>24 hours</td>
<td>3</td>
</tr>
<tr>
<td>Socket bottom&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td>24 hours</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Socket depth&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td>24 hours</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Socket entrance</td>
<td></td>
<td></td>
<td>24 hours</td>
<td>3</td>
</tr>
<tr>
<td>Impact</td>
<td>weekly</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Joint crush</td>
<td>weekly</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Short term rupture strength</td>
<td>weekly</td>
<td>weekly</td>
<td>weekly</td>
<td>5</td>
</tr>
<tr>
<td>Sustained pressure</td>
<td>annually</td>
<td>annually</td>
<td>annually</td>
<td>6</td>
</tr>
<tr>
<td>Tensile</td>
<td>weekly</td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

<sup>1</sup> Plug gauges are permitted, provided that the mold has been qualified by complete dimensioning and performance of appropriate testing on all products from all mold cavities to verify compliance with the referenced standard.

<sup>2</sup> Socket depth and thread length are only required to be verified at the time a new tool is “qualified” or when new or repaired cores are made.