NSF International Standard
for Plastics –

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 is intended for ground loop heat exchangers with a maximum temperature and pressure of 140 °F (60 °C) at 100 psi. Water-based ground-source heat pump systems commonly include the use of anti-freeze, heat transfer fluids or other chemical additives. 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. The most recent published edition of the document shall be used for undated references.

ASTM D2290-12, Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method

ASTM F1588-96(20112015), Standard Test Method for Constant Tensile Load Joint Test (CTLJT)

ASTM D2683-10e1, Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing

ASTM D2737-12a, Standard Specification for Polyethylene (PE) Plastic Tubing

ASTM D2837-1113e1, Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products

ASTM D3035-12e1, Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

1 American Society for Testing Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 <www.astm.org>.
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 term 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 D2837 for a plastic compound, obtained by categorizing the long-term hydrostatic strength determined in accordance with ASTM D2837.

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 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.

3.10 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.

3.11 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.

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

3.13 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.

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

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

3.16 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. adjective – 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.

3.17 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 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 PE 345464E as specified in ASTM D3350. All polyethylene fitting and component materials used in the system shall meet or exceed the material designation of the pipe used in the piping system.

4.3 Long-term strength of plastic pipe and fittings

Materials for use in plastic pipe and fittings 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.

Rationale: Fitting standards ASTM D3261, ASTM D2683, ASTM F1055 all require long term strength ratings on materials. We are simply highlighting this in the body of this standard as well. Fittings materials have been evaluated to this requirement already.

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 (23 °C)</th>
<th>HDS at 140 °F (60 °C)</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 D2737, ASTM D3035, CSA B137.1, or AWWA C901. Pipe with a diameter of 2 in (6.033 cm) (nominal) and smaller shall have a maximum dimension ratio (minimum wall thickness) of 11. Pipe with a diameter of larger than 2 in (7.62 cm) (nominal) shall have a maximum dimension ratio (minimum wall thickness) of 17.
5.2 Polyethylene fittings

5.2.1 Butt heat fusion polyethylene fittings, including U-bend fittings, shall comply with ASTM D3261.

5.2.2 Socket-type polyethylene fittings, including U-bend fittings, shall comply with ASTM D2683.

5.2.3 Electrofusion type polyethylene fittings, including U-bend fittings, shall comply with ASTM F1055.

Rationale: U-bends are U-shaped fittings used in geothermal systems to change direction of flow at the bottom of a geothermal well. Some readers may not realize that U-bends are in fact fittings and need to comply with fitting requirements. This change is making it clear that U-bends are subject to fitting requirements.

5.3 Factory assembled joints

U-bends containing factory assembled joints, such as U-bend fittings factory fused to pipe shall comply with the sustained pressure at elevated temperature requirements of 7.2.3 of ASTM D3261. Each test specimen shall contain assembled joints consistent with how the product is sold.

Rationale: U-bend fittings are most commonly fused to geothermal pipe by the pipe producer and shipped in coils with the U-bend attached. This section was meant to ensure the factory assembled joint is tested. The previous heading of U-bends was a little unclear that the requirement was about the joint and not only the U-bend itself. The term factory assembled joints was introduced to clarify that this test applies to joints and not only the U-bend fitting.

5.3.5 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.

5.3.5.4.1 Determine the resistance to the chemicals in Table 2 in accordance with ASTM D543.

5.3.5.4.2 Ring specimens shall be cut from a minimum 1 in (2.54 cm) diameter pipe where available. The specimens shall be ½ in (1.27 cm) wide with a ¼ in (0.64 cm) wide reduced section. For materials that are not readily available as minimum 1 in diameter pipe, the test specimen shall be a tensile bar type IV per test method ASTM D638 with a thickness of 0.075 ± 0.008 in (1.9 ± 0.2 mm). Specimen shall be either die-cut or machined.

5.3.5.4.3 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 h. On removal from the chemicals, wipe the specimens with a clean dry cloth. Condition in air for 2 to 2 ½ h and reweigh. Calculate the change in weight to the nearest 0.01% on the basis of initial weight.

5.3.5.4.4 Test the specimens for tensile strength in accordance with ASTM D2290, Procedure B using 0.5 in/min testing speed within ½ h after weighting for ring tensile specimens and per ASTM D638 using 2 in/min testing speed within ½ h after weighting for tensile bar specimens. Examine the weight and apparent tensile strength of each specimen.

<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.

6 Marking requirements

6.1 Pipe marking and factory fused assembly 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, e.g., NSF/ANSI 358-1;
— pressure rating at rated temperature; and
— applicable marking per section 5.1 and 5.2 referenced standards.

6.2 Fitting marking

Fittings shall be marked with the following information:

— nominal size;
— third-party certification mark (if applicable); and
— standard designation as referenced in 5.1 or 5.2.

Rationale: There are three main types of products addressed by this standard: 1) pipe, 2) fittings, and 3) pipe fused to U-bend fittings at the factory (factory fused assembly).

Factory fused assemblies are marked with all the marking on the pipe itself because the pipe marking much more easily modified and maintained than fitting marking. U-bend fittings used in factory fused assemblies are rarely marked. The reference to 5.2 was removed because it is specific to fittings only. The reference to section 5.1 is removed from the fitting marking because it is specific only to pipe standards.

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. Fittings requiring exposed metallic components shall not be 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 73 ± 3.6 °F (23 ± 2 °C) and 45 to 55% relative humidity.

7.1.2 The tests and testing frequencies shall conform to the minimum requirements listed in 7.6. 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 7.6. If the test frequencies specified in the product standard conflict with the frequencies contained in 7.6 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 7.6 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 7.6 shall resume.

7.2.2 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 semi-annual 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 shall be re-qualified.

7.3 Calibration

7.3.1 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)^6.

7.3.2 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.

7.4 Quality assurance records

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

7.5 Production code identification

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

7.6 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 3 – PE pipe test frequencies and minimum specimens

<table>
<thead>
<tr>
<th>Test</th>
<th>PE Pipe</th>
<th>Minimum number of specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burst pressure(^1)</td>
<td>24 h</td>
<td>5</td>
</tr>
<tr>
<td>Dimensions, (Inner diameter or outer diameter)</td>
<td>2 h</td>
<td>3</td>
</tr>
<tr>
<td>Dimensions, minimum and maximum wall thickness</td>
<td>2 h</td>
<td>3</td>
</tr>
<tr>
<td>Elevated temperature sustained pressure (176 °F) (80 °C)</td>
<td>annually</td>
<td>6</td>
</tr>
<tr>
<td>Environmental stress crack resistance</td>
<td>annually</td>
<td>6</td>
</tr>
<tr>
<td>product standards</td>
<td>ASTM F714</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>ASTM D2737</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM D3035</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CSA B137.1</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) 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 4 – PE fittings, including U-bend fittings**

test frequencies and minimum specimens

<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</td>
<td>weekly</td>
<td>—</td>
<td>—</td>
<td>54</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>24 h</td>
<td>24 h</td>
<td>24 h</td>
<td>3</td>
</tr>
<tr>
<td>Outside diameter</td>
<td>—</td>
<td>24 h</td>
<td>—</td>
<td>3</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>—</td>
<td>24 h</td>
<td>—</td>
<td>3</td>
</tr>
<tr>
<td>Socket bottom&lt;sup&gt;1&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>24 h</td>
<td>3</td>
</tr>
<tr>
<td>Socket depth&lt;sup&gt;2&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>24 h</td>
<td>3</td>
</tr>
<tr>
<td>Socket entrance</td>
<td>—</td>
<td>—</td>
<td>24 h</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>—</td>
<td>weekly</td>
<td>weekly</td>
<td>51</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>
<tr>
<td>Product standard</td>
<td>ASTM F1055</td>
<td>ASTM D3261</td>
<td>ASTM D2683</td>
<td>—</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.

**Rationale:** Standards are being added to the table to define which methods are employed for the QC. The Table 3 burst specimen number is reduced from 5 to 1 to match the requirements that recently changed in NSF-14. The Table 4 title includes U-Bend fittings to emphasize that U-Bends do have to meet fitting QC requirements. The burst pressure specimens have changed from 5 to 4 to match the requirement in the ASTM F1055 fitting standard. The short-term rupture specimens have changed from 5 to 1 to match the requirement in the ASTM D3261 and ASTM D2683 standards.