INSULATION RECOMMENDATIONS FOR PLASTIC PRESSURE PIPING MATERIALS IN RESIDENTIAL APPLICATIONS

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Plastics Pipe Institute
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Foreword

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute (PPI). These members have shown their commitment to developing and improving quality products by assisting standards development organizations in the development of standards, and by developing design aids and reports to help engineers, code officials, specifying groups, contractors, and users.

The purpose of this technical note is to provide information regarding the need to insulate plastic pressure pipe materials used for applications such as hot- and cold-water plumbing, fire protection and hydronic heating or cooling systems within residential buildings.

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1.0 INTRODUCTION

Plastic pressure pipe materials are commonly used in applications such as hot- and cold-water plumbing, fire protection, and hydronic heating and cooling including radiant distribution systems.

This Technical Note provides guidance about insulating the following types of plastic pressure pipe and tubing materials within residential buildings:

- CPVC: *chlorinated polyvinyl chloride*
- PEX: *crosslinked polyethylene*
- PEX/AL/PEX: *crosslinked polyethylene/aluminum/crosslinked polyethylene*
- PE-RT: *polyethylene of raised temperature resistance*
- PP-R: *random copolymerized polypropylene*
- PP-RCT: *polypropylene random copolymer with modified crystallinity & temperature resistance*

This document focuses on insulating plastic pressure piping materials from the perspective of freeze protection, and not energy conservation.

Requirements and guidance for insulating all types of piping materials for energy conservation are provided in plumbing, mechanical, and energy codes, as well as industry standards such as ASHRAE 90.1 *Energy Standard for Buildings Except Low-rise Residential Buildings*, and handbooks such as those published by the American Society of Plumbing Engineers (ASPE).

This document does not apply to solar thermal collection system piping, thermal energy storage system piping, and ground source geothermal system piping. See appropriate building and mechanical codes for insulation requirements for those specific applications.

Topics discussed in this Technical Note include:

- Section 2.0: Applications
- Section 3.0: Model code requirements for piping insulation & protection
- Section 4.0: PPI recommendations to prevent freezing
- Section 5.0: Thawing frozen plastic pipes
- Section 6.0: Summary

This Technical Note is not an installation guide. Installers, builders, inspectors, engineers, and designers should refer to local regulations to determine the most appropriate requirements for protecting all types of plastic pipe and tubing against freezing.

2.0 APPLICATIONS

For the purposes of this document, the focus is on plastic pipes and tubing ("pipes") used in residential plumbing, fire protection, and several types of hydronic applications, including the distribution of heated or chilled fluids.

These are the applications covered by this Technical Note:

- Water service lines which may be susceptible to freezing
- Hot- and cold-water plumbing in exterior or cold walls, floors, or ceilings
- Fire protection piping in exterior or cold walls or ceilings
- Hot-water hydronic heating systems
- Chilled water hydronic cooling systems

Although plastic piping materials are inherently better insulators of heat energy, and therefore worse conductors of heat, as compared with traditional metal pipe materials such as steel and copper, there are several situations where plastic pipe materials should be insulated for protection against freezing of fluids within the pipes.

Proper insulation will also reduce heat transfer through the wall of piping materials, improving system efficiency and performance in a wide range of applications.

3.0 MODEL CODE REQUIREMENTS FOR PIPING INSULATION & PROTECTION

North American plumbing and mechanical codes address the need for piping insulation and freeze protection in a variety of ways. These codes treat all piping materials the same, with some exceptions.

NOTE 1: This report is *not* intended to circumvent existing code requirements.

The most relevant excerpts from US and Canadian model codes follow:

3.1. 2021 IAPMO Uniform Plumbing Code (UPC)

312.6 Freezing Protection. "No water, soil, or waste pipe shall be installed or permitted outside of a building, in attics or crawl spaces, or in an exterior wall unless, where necessary, adequate provision is made to protect such pipe from freezing."

3.2. 2021 IAPMO Uniform Mechanical Code (UMC)

1210.1 Piping, Tubing, and Fittings. “Hydronic pipe and tubing shall comply with the applicable standards referenced in Table 1210.1 and shall be approved for use based on the intended purpose. Materials shall be rated for the operating temperature and pressure of the system and shall be compatible with the type of heat transfer fluid. Pipe fittings and valves shall be approved for the specific installation with the piping, materials to be installed and shall comply with the applicable Standards referenced in Table 1210.1. **Where required, exterior piping shall be protected against freezing,** UV radiation, corrosion and degradation. Embedded pipe or tubing shall comply with Section 1221.2.”

1215.3 Freeze Protection. “Hydronic systems and components shall be designed, installed and protected from freezing.”

3.3. 2021 IAPMO Uniform Solar, Hydronics and Geothermal Code (USHGC)

401.8 Freeze Protection. “Hydronic systems and components shall be designed, installed, and protected from freezing.”

408.1 Pipe, Tube, Tubing, and Fittings. “Hydronic pipe and tubing shall comply with the applicable standards referenced in Table 408.1 and shall be approved for use based on the intended purpose. Materials shall be rated for the operating temperature and pressure of the system and shall be compatible with the type of heat transfer fluid. Pipe fittings and valves shall be approved for the installation with the piping, materials to be installed and shall comply with the applicable standards referenced in Table 408.1. **Where required, exterior piping shall be protected against freezing**, UV radiation, corrosion and degradation. Embedded pipe or tubing shall comply with Section 417.2.”

3.4. 2021 ICC International Plumbing Code (IPC)

305.4 Freezing. “Water, soil and waste pipes shall not be installed outside of a building, in attics or crawl spaces, concealed in outside walls, **or in any other place subjected to freezing temperatures** unless adequate provision is made to protect such pipes from freezing by insulation or heat or both. Exterior water supply system piping shall be installed not less than 6 inches (152 mm) below the frost line and not less than 12 inches (305 mm) below grade.”

1301.8 Freeze protection. "Where sustained freezing temperatures occur, provisions shall be made to keep storage tanks and the related piping from freezing."

3.5. 2021 National Standard Plumbing Code (NSPC)

2.16 FREEZING OR OVERHEATING a. "The plumbing system shall be protected from freezing or overheating. The following conditions shall be met"

1. "Exterior water piping shall be installed below recorded frost lines. Minimum earth cover above the top of the pipe shall be ___ inches."

5. "In areas with seasonal freezing outdoor temperatures, all drain piping and water piping installed in exterior walls, attics, and other areas exposed to outdoor temperatures shall be protected from freezing. In heated spaces, the piping shall be installed on the heated side of the building insulation."

3.6. 2015 National Plumbing Code of Canada (NPC)

Clause 2.3.5.4 Protection Against Freezing: "Where piping may be exposed to freezing conditions, it shall be protected from the effects of freezing."

3.7. CSA B214/2021 Installation Code for Hydronic Heating Systems

Clause 13.1 Freeze Protection [*Hydronic space heating*]
"Heat-distribution units or other system components that can be subjected to freezing shall be protected with an appropriate hydronic fluid or a suitable isolation control strategy to prevent freezing."

Clause 17.2 Freeze Protection [*Hydronic snow and ice melting*]
"Snow and ice melt systems shall be protected from freezing with a hydronic fluid, which shall be an appropriate mixture of propylene or ethylene glycol and water. Automotive antifreeze shall not be used."

3.8. ANSI/CSA/IGSHPA C448/2016 Design and Installation of Ground Source Heat Pump Systems

Clause 5.7.1.1.7 [C448.0 Generic applications for all systems]
"The heat-transfer fluid shall ensure freeze protection to at least 5°C (9°F) below the minimum loop design temperature."

3.9. Other Documents

At the time of publication of this Technical Note, the latest versions of the following codes and industry publications were reviewed and found to not contain information related to freeze protection of piping systems for the specified applications:

- 2015 National Building Code of Canada
- 2017 National Energy Code of Canada
- 2021 ICC International Mechanical Code (IMC)
- 2021 ICC International Residential Code (IRC)
- 2021 ICC International Energy Conservation Code (IECC)
- ASPE Domestic Water Heating Design Manual, Second Edition

4.0 PPI RECOMMENDATIONS TO PREVENT FREEZING

Plastic pipe material does not *prevent* water from freezing in the pipe, but its lower thermal conductivity than metal pipes (i.e., higher insulating value) can *delay* freezing of water or other fluids within the pipes. In other words, it may take longer for fluid within plastic pipe or tubing to freeze, as compared with copper or steel pipes. This can prevent freezing events that could happen if metal pipes were used.

Materials such as PEX and PE-RT tubing may be less susceptible to the effects of cold temperatures, retaining flexibility even to temperatures below -40°F (-40°C). This flexibility means that if water-filled PEX or PE-RT tubing freezes, the elasticity of the material typically allows it to expand without cracking or splitting, and then to return to its original diameter upon thawing.

CPVC, PP-R, and PP-RCT pipes and fittings also have some ability to withstand the freezing of fluids without breaking.

The ability of plastic pipes and fittings to withstand the freezing of fluids within them applies when they have room to expand evenly along their length, as is typical when installed within floors, walls or ceilings, or lightly compacted earth. This material characteristic is beneficial for applications such as plumbing, water service, fire protection, hydronics, and geothermal ground loops. Fluid-filled pipes that freeze inside a concrete slab or highly compacted soil may not be able to expand evenly and may suffer localized damage, such as splitting. This must be prevented to avoid leaks and potential property damage.

However, even when pipes have space to expand evenly along their full length, as is typical when installed within floors, walls or ceilings, the freezing of fluid within the pipes still has the potential to generate internal pressures beyond the capability of plastic or metal pipes through the formation of ice blockages or “dams”.

PPI TR-52 includes an excerpt from the 2006 research paper *Northward Market Extension for Passive Solar Water Heaters by Using Pipe Freeze Protection with Freeze-Tolerant Piping* by J. Burch, NREL and M. Heater, M. Brandemuhl, and M. Krarti, University of Colorado which states, "As pipes freeze, an annulus of ice attaches on the pipe inner surface and freezes inward toward the pipe axis. However, there is not pressure buildup until two separated 'ice blockages' occur because until that occurs water is pushed back into the mains or forward in the downstream house piping system (which has significant expansion capability).

"Subsequent to blockages, further freezing causes pressure to build up. Pathological cases of non-uniform freezing with a 'piston action' can be created by tapering insulation to force the freeze between the blockages to occur non-uniformly from the blockages in, forcing water inward and creating potentially very high pressures and/or strains."

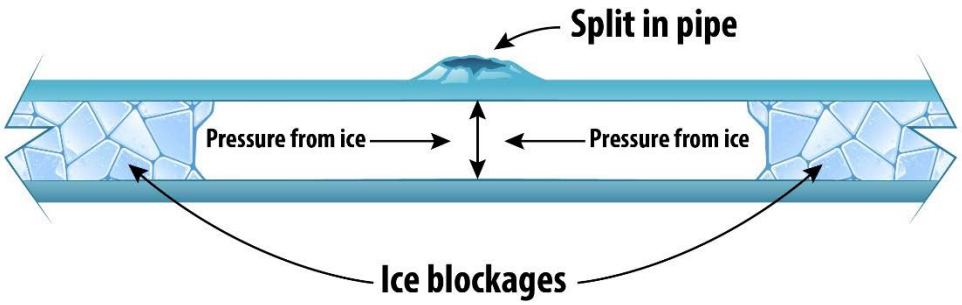

Figure 1: Illustration of ice blockages

Pressure inside the pipe increases as the fluid between the ice blockages continues to freeze, creating a piston effect on the water; this may exceed the elastic limits of the plastic pipe and cause a split.

Therefore, despite the ability of plastic pipe materials to withstand freezing in certain situations, the freezing of water or other fluids within all pipes should be prevented to protect plastic pipes and fittings against potential damage.

It is also important to recognize that a piping system with frozen fluid cannot perform as expected. For example, a frozen plumbing system will not deliver water; a frozen fire protection system will not activate to extinguish a blaze; a frozen heating system will not deliver heat to occupied areas, creating a health risk for occupants and the potential for other pipes to freeze, and a frozen snow melting system will not deliver heat to the intended outdoor areas, leaving them uncleared and potentially unsafe.

CAUTION: No plastic pipe system should be intentionally subjected to freezing.

Sections 4.1 to 4.5 provide recommendations for protecting specific piping systems against freezing. The amount of insulation and/or antifreeze required to achieve this protection varies for every climate zone and location around the world. Local building codes and regulations should apply, and calculations can be performed by design professionals to determine the amount of required insulation.

CAUTION: Users should ensure that selected insulation materials are compatible with the plastic pipe and fitting materials to avoid chemical incompatibility issues.

4.1. Water Service

In water service applications, care should be taken to ensure that pipe or tubing is buried below the frost line to prevent freezing and to avoid interrupting the water supply. If this is not possible, then suitable insulation should be installed around buried pipelines to prevent freezing.

Pre-insulated piping materials are available that include the waterproof casing, insulating materials, and the carrier pipe within a pre-manufactured assembly.

4.2. Plumbing and Fire Protection

In plumbing distribution installations, pipe and tubing should be installed within heated spaces such as interior walls, floors, or ceilings. If installed within exterior walls, floors, or ceilings, the tubing should be insulated sufficiently to prevent freezing of the water within.

Antifreeze solutions are often used within stand-alone fire sprinkler systems, which are independent from water distribution systems, to ensure freeze-protection and operation at cold temperatures in case of a fire.

Multi-purpose sprinkler systems, which are combined with a building's cold-water plumbing system, cannot use antifreeze, and must rely on insulation around the pipe to prevent freezing.

4.3. Hydronic Heating and Cooling

In hydronic heating and cooling installations, including radiant heating and cooling systems, plastic pipe should be installed within heated spaces such as interior walls, floors, or ceilings. If installed above an unheated crawl space, there should be adequate insulation below the tubing to prevent freezing of the water within, even when the heating system is deactivated.

In some situations, an antifreeze solution, usually glycol and water, can prevent freezing of the fluid within hydronic heating/cooling pipes, even when the heating system is deactivated. Adequate antifreeze is critically important for outdoor systems such as snow and ice melting or turf conditioning.

4.4. Chilled Water

In chilled water installations, the level and type of insulation is typically specified by a design professional to prevent heat transfer through the pipe wall and to prevent condensation on the pipe wall, within the insulation, and on the outside of the insulation material. Protection against freezing of the fluid within is typically provided with this inherent level of insulation. In some chilled water systems, an antifreeze solution, usually glycol and water, also prevents freezing of the fluid, such as when the cooling system is deactivated during cold weather.

The amount of insulation or antifreeze, if selected, required to achieve this protection varies for every climate zone and location around the world. Local building codes and regulations should apply, and calculations can be performed by system designers to determine the amount of required insulation or antifreeze to protect fluid from freezing.

4.5. Heat Trace Cable

As a supplement to insulation on pipes, heat trace cable, also referred to as “heating cable” or “heat tape”, may be installed onto plastic pipe, as long as the cable is thermostatically self-regulating and self-limiting (i.e., automatic temperature-controlled), is chemically-compatible with the piping material, and is recommended for use on plastic pipe. Check with the pipe or tubing manufacturer for specific approvals on the use of heat trace cable.

Heat trace cable should be secured to plastic pipe using plastic cable ties. Check with the pipe or tubing manufacturer for specific approvals regarding the use of adhesive tape.

5.0 THAWING FROZEN PLASTIC PIPES

For frozen pipe that is accessible, the following methods of safely thawing plastic pipe may be used:

- Pour warm or hot water over the affected portion of the frozen pipe.
- Apply hot air to the outside of plastic pipe using a hot air gun or hair dryer to heat frozen areas of the pipe. Ensure that the temperature of

the pipe does not exceed 180°F (82°C); ice should thaw long before this temperature is reached.

- Wrap a warm moist towel around frozen pipes to thaw ice.
- Use a temporary space heater to warm the general area around the frozen pipe.

Thawing inaccessible frozen pipes can be performed using available hot water injection equipment, which sprays hot water into an open end of a pipe through a nozzle which is designed to propel itself forward through the pipe until it reaches the ice blockage. This is usually performed at moderately warm water temperatures.

The maximum water temperature allowed for thawing is 180°F.

After thawing, plastic pipe can immediately be put back into service, unless there are signs of pipe damage.

Follow the manufacturer's published guidelines and recommendations.

NOTE 2: Do not use an open flame, excessive heat, or an electric resistance pipe thawing device (e.g., HotShot™) to thaw frozen plastic pipe, as this could damage the pipe and result in property damage and loss of water pressure. See **Figure 2**.

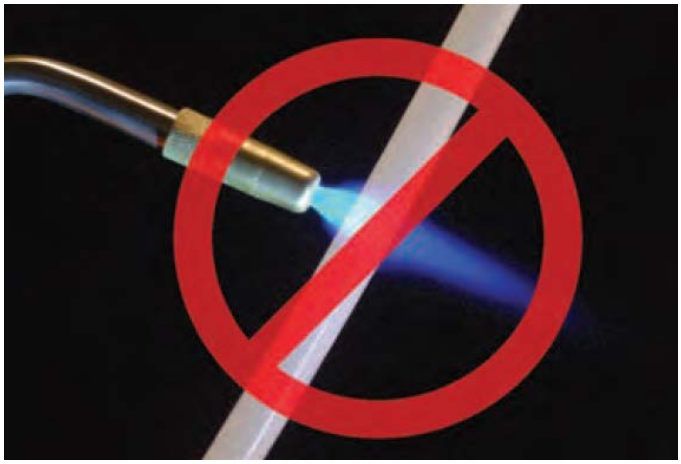

Figure 2: Do not use open flame to thaw frozen plastic pipe or tubing

CAUTION: Plastic pipe or tubing that is thawed using an open flame, excessive heat, or an electric resistance thawing device may not show any visible damage, but the integrity of the pipe or tubing may have been altered enough to cause premature failure. Any pipe that is thawed incorrectly should be replaced as soon as possible.

6.0 SUMMARY

Although plastic piping materials are inherently better insulators of heat energy, and therefore worse conductors of heat, as compared with traditional metal pipe materials such as steel and copper, there are several situations where plastic pipe materials should be insulated for protection against freezing of fluids within the pipes.

North American plumbing and mechanical codes address the need for piping insulation and freeze protection in a variety of ways. These codes treat all piping materials the same, with some exceptions. As a general practice, anywhere that metal piping requires insulation, plastic piping will too.

Section 4 of this Technical Note provides recommendations for protecting specific piping systems against freezing. The amount of insulation and/or antifreeze required to achieve this protection varies for every climate zone and location around the world. Local building codes and regulations should apply, and calculations can be performed by design professionals to determine the amount of required insulation.