UTILIZING PLASTIC PIPING IN SOLAR THERMAL HEATING SYSTEMS

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Foreword

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The purpose of this technical note is to provide general information on the applications for plastic pipe used in solar thermal heating systems.

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1.0 INTRODUCTION

This technical note describes the applications for plastic piping materials used in solar thermal heating systems. The limitations of plastic piping materials for solar thermal applications will be discussed and recommendations for managing those limitations are provided.

Plastic pressure pipe materials can have several advantages in all types of mechanical systems, including resistance to corrosion, flexibility, durability, ease of installation, long life, and affordability.

This document applies to the following plastic pressure pipe materials:

- CPVC: *chlorinated polyvinyl chloride*
- HDPE: *high density polyethylene*
- PEX: *crosslinked polyethylene*
- PE-RT: *polyethylene of raised temperature resistance*
- PP-R: *polypropylene random copolymer*
- PP-RCT: *polypropylene random copolymer with modified crystallinity & temperature resistance*

2.0 OVERVIEW

According to the US Department of Energy (DOE), “Active solar heating systems use solar energy to heat a fluid – either liquid or air – and then transfer the solar heat directly to the interior space or to a storage system for later use”[1]. Solar thermal systems typically circulate water-based fluids through outdoor panels exposed to the sun, and then transfer that heat for production of domestic hot water and indoor space heating.

The use of solar thermal energy on a commercial scale was uncommon in the US and Canada until the 1970s, but has since grown to become a significant technology for generating domestic hot water and hot water for heating buildings. Depending on the climate, location, and heating loads of a building, a solar thermal system can collect much of the solar energy needed for domestic hot water and indoor space heating over an annual period. Most solar thermal systems are combined with other forms of heat generation, such as ground source geothermal heat pumps, electric resistance heat, or fuel-burning appliances, to provide domestic hot water and space heating when solar thermal energy is not adequate or not available.[1]

[1] https://www.energy.gov/energysaver/active-solar-heating

Solar thermal systems reduce the consumption of traditional energy for these purposes, leading to reduced energy costs and carbon emissions. These systems also support building resiliency by allowing buildings to generate heating energy during power outages, and support decarbonization efforts in the building discipline.

Historically, most solar thermal applications are geographically concentrated in the states of California, Arizona, New Mexico, Colorado, Hawaii, and Florida, although the technology is effective in all regions of North America, especially with the latest efficiency enhancements.

Solar thermal heating systems range in size and complexity. The very simplest consist of nothing more than a loop of black pipe exposed to the sun with a circulating pump transferring a heat-transfer fluid through the pipe and to a load, such as a swimming pool or water tank.

More complex systems consist of highly engineered collectors with one or more layers of glazing plus piping, valves, pumps, an expansion tank, various safety devices, and controls. These systems frequently utilize heat transfer fluids such as non-toxic propylene glycol antifreeze mixed with water connected to heat storage tanks and heat exchangers with sophisticated control systems to manage the flow of heated fluids as needed.

Solar thermal systems are often connected to hydronic distribution systems within buildings where the final heat-transfer medium is a fluid such as water transferred using circulating pump(s). Examples include radiant heating, baseboard radiators, panel radiators, fan-assisted convectors, and ducted fan coils. The combination of solar thermal panel collection with hydronic distribution can result in high operating efficiency and low operating costs with a high level of resilience.

For the purposes of this technical note, all subsequent references to plastic pipe apply only to the piping outside of the collectors themselves and not to piping within the collectors, unless otherwise stated.

3.0 SOLAR THERMAL COLLECTOR TECHNOLOGIES

The three primary active solar thermal collection technologies are flat plate, evacuated tube, and thermodynamic panels. Systems can also be categorized as direct (open-loop) or indirect (closed-loop), as well as drainback and thermosiphon.

Solar collectors are also classified according to their water discharge temperatures: low temperature, medium temperature, and high temperature.

- Low temperature systems generally operate at a fluid temperature of 120°F (49°C) and have a maximum stagnation temperature of 180°F (82°C).
- Medium temperature collectors typically have fluid discharge temperatures of 180 - 200°F (82 - 93°C) but can generate stagnation temperatures of up to 280°F (154°C) or more for several hours.
- High temperature collectors routinely operate at temperatures of at least 210°F (99°C) and can generate stagnation temperatures of more than 400°F (204°C).
- High-temperature collectors typically operate above the capabilities of the plastic piping materials listed in this document.

Several types of plastic pressure pipe materials, such as those listed in Section 1.0 Introduction, may be used directly with low temperature collectors, because those piping materials are pressure-rated at temperatures higher than those expected in low temperature systems. In addition, certain types of plastic piping may be used inside unglazed collectors where operating temperatures rarely exceed 110°F (43°C). To protect against ultraviolet (UV) exposure damage and to increase efficiency, plastic piping for use in collector panels should contain a minimum of 2% carbon black of proper particle size and with good dispersion. Check with the pipe manufacturer to be sure the pipe is suitable for long-term exposure to sunlight in this type of application.

Medium temperature collectors constitute the largest segment of the market. These glazed collectors are often used in domestic hot water and space heating systems.

Medium temperature systems are either “passive” or “active”. Passive solar systems use no pumps, controls, or mechanical equipment to transport heated water. The integral collector storage (ICS) is a passive design which uses a tank or tube assembly absorber in an insulated metal case which is covered with a glazing material, usually glass. The absorber is painted flat black or coated with a “selective” material to increase solar energy absorption. Another type of passive solar heater is called “thermosiphon.” In this design, a storage tank is mounted above the solar collector on the roof surface and fluid is circulated due to changes in temperature, density, and buoyancy.

4.0 USE OF PLASTIC PIPING IN SOLAR THERMAL SYSTEMS

Plastic piping materials can play a major role in solar thermal applications. The combination of flexibility, relatively high temperature properties, and resistance to freeze damage and corrosion are major advantages for this end-use. Piping materials must be selected on several criteria:

- Code approval
- Pressure and temperature capability (see **Table 1**)
- Approval of the solar thermal panel collector manufacturer
- Approval of the plastic piping manufacturer

Several types of plastic pressure pipe materials, such as those listed in Section 1.0 Introduction, may be used directly with **low temperature** collectors, because those piping materials are pressure-rated at temperatures higher than those expected in low temperature systems. In addition, certain types of plastic piping may be used inside unglazed collectors where operating temperatures rarely exceed 110°F (43°C) with a maximum stagnation temperature of 180°F (82°C).

To protect against UV exposure damage and to increase efficiency, plastic piping for use in collector panels should contain a minimum of 2% carbon black of proper particle size and with good dispersion. Check with the pipe manufacturer to be sure the pipe is suitable for long-term exposure to sunlight in this type of application.

Because of the large volume of water in the collector(s), passive solar systems are usually not subject to high stagnation temperatures. Thus, plastic piping may be used in passive solar systems, including as hook-ups directly to the collector system, as long as the fluid temperature will not exceed the temperature rating of the pipe and fitting materials as shown in **Table 1**.

Table 1: Maximum Temperature Allowed for Plastic Piping Materials

Material	Maximum Temperature
CPVC	200°F (93°C)
HDPE	140°F (60°C)
PEX*	180°F (82°C) / 200°F (93°C)
PE-RT	180°F (82°C)
PP-R	176°F (80°C)
PP-RCT	203°F (95°C)

**Some PEX materials are rated for operation at 180°F maximum, while others are rated for operation up to 200°F. Check with manufacturer for maximum allowed temperature.*

The pressure rating of each selected pipe material must also be suitable for the application. Most plastic pipes are available in a range of wall thicknesses, described using the terms “standard dimension ratio” (SDR) or “schedule”, and the wall thickness directly affects the pressure rating of the pipe. Also, the pressure rating for plastic pipes decreases with an increase in operating temperature. Please check with the relevant pipe specification or the pipe manufacturer for the pressure rating of the selected pipes at the expected operating temperature.

Because there are several heat transfer fluid types available, the selected fluid must be approved as being suitable by the plastic pipe manufacturer. Hydrocarbon oil or silicone oils used in high temperature solar systems are generally not recommended for use with plastic pipes. See PPI TR-19 *Chemical Resistance of Plastic Piping Materials* to check chemical compatibility of various fluids with plastic pipe and fitting materials and contact the pipe manufacturer.

Active type solar thermal systems utilize a circulator pump to move heat transfer fluid through the collector and the transfer piping to the intended application(s). Open systems may utilize swimming pool or potable water as the heat transfer fluid, while closed systems typically use a non-toxic solution of propylene glycol and water to prevent freezing. Heat may be transferred from the heat transfer fluid to potable water by means of a heat exchanger in the solar storage tank or plate heat exchanger. All piping must comply with local plumbing or mechanical codes and be approved by the piping manufacturer for the application.

Active type, medium temperature collectors may be unsuitable for the use of plastic piping, because stagnation temperatures can exceed 280°F (138°C) in certain situations. Under no circumstances should any plastic piping be used inside the collector or in the system where it will be exposed to such high temperatures, unless that particular plastic pipe has been qualified for that temperature of service by its manufacturer.

The plastic pressure piping materials listed in Section 1.0 of this technical note should not be used in systems with high temperature collectors, including evacuated tube or concentrating types, because of the extreme temperatures those collectors can reach, which would damage the piping materials.

In some jurisdictions, the use of solar technologies is either codified or embedded in the rebate structures to support these sorts of applications via incentives from the utility or purveyor. These include (but not limited to):

- ASTM E1056-13 (2021) *Standard Practice for Installation and Service of Solar Domestic Water Heating Systems for One- and Two-Family Dwellings*
- CAN/CSA-F379 SERIES-09 (R2018) *Packaged solar domestic hot water systems (liquid-to-liquid heat transfer)*
- CAN/CSA-F383-08 (R2018) *Installation of packaged solar domestic hot water systems*
- IAPMO *Uniform Solar, Hydronics and Geothermal Code (USHGC)*

5.0 CONCLUSION

Solar thermal systems play an important role in producing thermal energy for the heating of buildings and production of domestic hot water. The appropriate application of these systems can reduce the consumption of energy for these purposes, leading to reduced energy costs and lower carbon emissions. These systems also support building resiliency by allowing buildings to generate heating energy during power outages, for example.

Solar thermal systems are often connected to hydronic distribution systems within buildings, where the final heat-transfer medium is a fluid such as water transferred using circulating pump(s). Examples include radiant heating, baseboard radiators, panel radiators, fan-assisted convectors, and ducted fan coils. The combination of solar thermal panel collection with hydronic distribution can result in high operating efficiency and low operating costs with a high level of resilience.

Plastic pressure pipe materials CPVC, HDPE, PEX, PE-RT, PP-R, and PP-RCT can be suitable for low-temperature and medium-temperature solar thermal systems when carefully selected and applied. Installation should be performed by knowledgeable, licensed contractors under the guidance of the relevant authority having jurisdiction in accordance with local regulations.

See links below for additional resources on this topic.

- https://www.eia.gov/energyexplained/index.php?page=solar_thermal_collectors
- https://www.renewableenergyhub.us/solar-thermal-information/the-different-types-of-solar-thermal-panel-collectors.html
- https://www.energy.gov/energysaver/home-heating-systems/active-solar-heating