Chapter 13

HVAC Applications for PE Pipe

Introduction

The performance and use characteristics of polyethylene pipe make it an ideal choice for use in certain HVAC – Heating, Ventilation, and Air Conditioning – applications. Typically, HVAC is thought of as flexible vent pipes, steam pipes, etc. However, since the 1980's polyethylene pipe's flexibility, strength, and ease of use has had a major impact on HVAC applications such as geothermal heat pumps and radiant heating systems.

This chapter presents information and general design criteria for the use of polyethylene pipe in applications such as:

Ground Source Heat Pumps – basic use and standards, configuration, joining methods and installation considerations.

Solar Applications – use of PE pipe for solar water heating applications.

Vacuum Systems – use and design limitations.

Ground Source Heat Pump Systems

Due to polyethylene pipe's versatility, flexibility, durability, leakproof fusion joints, and ease of use, it has become a key component in the success of Ground Source Heat Pumps systems.

There are two basic types of heat pumps – air source and ground source. An air source system utilizes temperature variations in the air to gain operating efficiency. A ground source, or Geothermal Heat Pump (GHP) system uses an electric pump to circulate fluid from the heat pump cycle through a series of polyethylene pipes buried in the ground to take advantage of the relatively constant ground temperatures. These pipes are known as Ground Heat Exchangers. In simple terms, in the summer the heat pump's refrigerant cycle transfers heat from the building into the circulating fluid. The fluid is then circulated through the ground heat exchanger where the ground acts as a heat sink, cooling the fluid before it returns to the building. In the winter, the system works in reverse. The heat pump uses the earth to warm the circulating fluid, which is then transferred back to the inside heat

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exchanger. In addition to heating and cooling the air, a desuperheater can be added to this cycle that can provide most, if not all, hot water for use in the building as well.

The properties that control this process are based on the ability of the PE pipe to transfer heat either out of, or into, the system. The heat transfer by conduction mechanism that governs this system is the same as any heat exchanger. It is assumed that the ground is at a steady state condition. This type of heat transfer mechanism is governed by the basic equation:

$$q = (k\,A/x)\,(T_1 - T_2)$$

WHERE

q = **Heat loss, BTU/hr**

k = **Thermal conductivity, BTU/in/ft ^{2}/hr/°F**

A = **Heat transfer area, ft ^{2}**

x = **Wall thickness, inches**

T_1 = **Outside temperature, °F**

T_2 = **Inside pipe temperature, °F**

Note: The above equation only addresses the question of heat transfer through the PE pipe. Depending on the application (ground source heat exchange systems, snow melting, radiant heating, etc.) there are other factors that may have a significant influence on the accuracy of the heat transfer calculation including the thermal conductivity of the surrounding embedment material, the inside and outside film coefficients of the pipe and perhaps others. Therefore it is recommended that such calculations should be referred to engineers who are expert in this field.

Polyethylene itself is typically considered an insulator and holds heat rather well. However, in this application, the benefits of the polyethylene pipe far outweigh this performance characteristic. There are many other variables that need consideration when designing a GHP system. Most manufacturers have software available to aid in the determination of the size of the unit and the footage of pipe needed for the geothermal heat exchanger.

Geothermal heat pumps are very economical to operate and can save a substantial amount of money in operating costs over the life of the system. It has been reported[1] that a traditional furnace uses one unit of energy but returns less than one unit back as heat. A ground source heat pump uses one unit of energy but returns as much as three units back as heat. The polyethylene pipe acting as the heat transfer medium in the ground helps make this possible.

Types of Ground Heat Exchangers

There are two basic types of heat exchangers: open and closed loop systems. Both can be configured several different ways depending on the size of the system, surrounding land, or availability of a large open water source.

Open systems require a suitable supply of water where open discharge is possible. This type of system uses the HDPE pipe to bring fresh water to the heat pump, and

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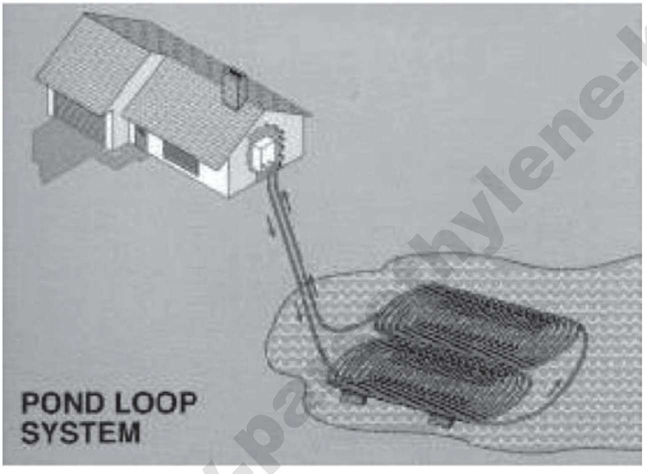
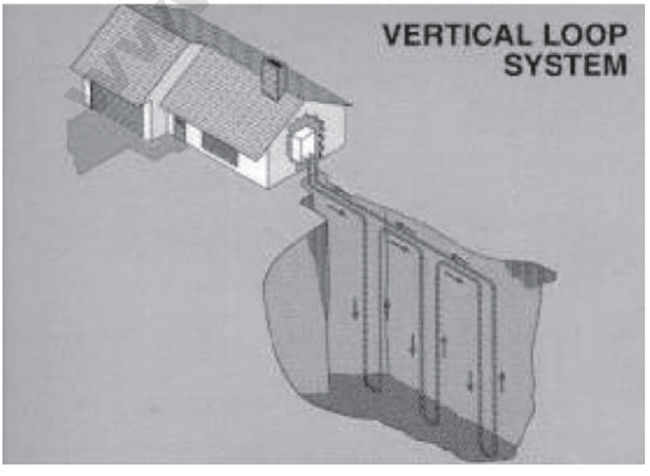
then discharges the water back into the water supply. Only fresh water is used, and there is no need for a special heat transfer or antifreeze solution. A key PE pipe design consideration for an open system is the fact that the system will have a suction and discharge loop. This means the pipe may need to be designed to handle negative vacuum pressures and positive pumping pressures.

The more common type of GHP installation is a closed loop system. A closed system is just that — a "closed loop" recirculating system where the HDPE pipe circulates an "antifreeze" solution continuously. This type of system can be installed several different ways such as: a pond loop system, a vertical loop system, or a horizontal (slinky) loop system. Each of these types of installation utilizes the basic performance benefits and versatility of HDPE pipe to get the most beneficial type installation for the surrounding conditions.





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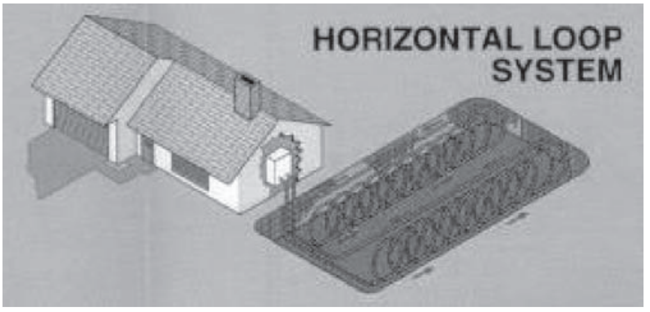

Pipe Specifications and Requirements

PE is the material of choice for the pipe in the heat exchanger for ground source heat pump system. The International Ground Source Heat Pump Association (IGSHPA) has developed some design and installation standards for the HDPE pipe that is required for a geothermal heat exchanger. For further details, refer to the latest edition of the IGSHPA publication "Closed Loop/Geothermal Heat Pump Design and Installation Standards.

The recommended specification takes into account the optimum performance based on the need to make sure the pipe and fittings can handle the pressures and stresses involved in the application, as well as the heat transfer requirements for the heat exchanger itself. Heavier wall pipe may be able to handle higher pressures and stresses, but the thicker wall lowers the heat transfer efficiency with the ground. All of these parameters must be balanced. When designing the PE pipe heat exchanger, maximum operating pressures and temperatures, as well as head and surge pressures must be taken into account.

For closed-loop geothermal heat exchangers, even though a high stress crack-resistant PE material is required, it is appropriate to make sure the antifreeze solution used in the heat exchanger does not adversely affect the stress crack performance of the pipe and fittings. The antifreeze solution manufacturer should be able to supply this information.

More information on the design of PE pipe systems for pressure, surges, flow capacities, etc. can be found in the Design of PE Piping Systems chapter of this Handbook.

Pipe Joining Methods

PE pipe can be joined by several different methods. One of the outstanding features of PE pipe is its ability to be heat-fused, producing a 100% leakproof joint that is as strong, or stronger, than the pipe itself.

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IGSHPA recommends acceptable methods for joining as 1) a heat fusion process, or 2) stab-type mechanical fittings to provide a leak-free union between the pipe ends that is stronger than the pipe itself. This type of mechanical joint is also known as a Category 1 mechanical joint according to ASTM D 2513, Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings.

In addition, it is recommended that fusion transition fittings with threads must be used to adapt to copper pipe or fittings. Fusion transition fittings with threads or barbs must be used to adapt to high strength hose. Barbed fittings are not permitted to be connected directly to the PE pipe, with the exception of stab-type fittings as described above. All mechanical connections must be accessible.

Since mechanical connections must remain accessible, fusion joints are preferred wherever possible. Butt, socket or electro-fusion is used to join individual sections of pipe. “U-bend” fusion fittings are used for creating the return line in vertical bores. In fact, it is common for polyethylene pipe made for geothermal heat exchangers to be double wrapped on a coil and the “u-bend” fitting fused on at the factory. This makes insertion into a vertical bore very quick and easy. Sidewall fusion can be used to join parallel pipe loops to a header. All fittings must be pressure rated for the expected operating and surge pressures, and joined according to the manufacturer’s recommended procedures. This is a critical feature since this joint will be at the bottom of a well and grouted into place. Repair of a leaky joint in this location would be very difficult. However, this is a rare problem due to the nature of the fusion procedure and the dependability of the joints made using this process. Extensive information on joining PE pipe can be found in the PE Joining Procedures chapter of this handbook.

Pipe Installation

As discussed previously, there are several types of installation choices for ground source heat pumps. It is important to follow the GHP manufacturer’s requirements for the type of unit being used. This will define the amount of pipe needed for the particular installation and environment. However, there are some general guidelines for polyethylene pipe that will help assure a successful installation.

Generally, it is desired to keep the diameter of the HDPE pipe as small as possible, but not so small that pumping power to circulate the antifreeze solution becomes too great, thus losing the operating efficiency of the GHP. The smaller the diameter, the higher the surface to volume ratio will be, and the better chance for turbulent flow inside the pipe. Both of these conditions promote more efficient heat transfer. Most ground heat exchangers are constructed from ¾″ to 2″ diameter pipe. The headers will be 1 ¼″ to 2″, and the individual loops will be ¾″, 1″ or 1 ¼″. The amount of pipe utilized varies depending on environmental conditions and how much heating or

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cooling capacity is needed. As an example, a typical 3-ton ground heat exchanger may use 200 feet of headers and 400 feet for each parallel loop.

If trenching for a horizontal installation or header system, avoid sharp bends around corners. Pipe manufacturers have a minimum bend radius that will assure that the pipe is not overstressed. If a sharp corner is needed, utilize an elbow fitting. Remove any sharp rocks from backfill material. Long-term contact between the polyethylene pipe and a sharp object could lead to premature failure of the pipe. Even though PE pipe has very high stress-crack resistance, it is a good idea to minimize this kind of contact. The addition of sand in the bottom of the trench and preferably all around the pipe will help minimize incidental contact with sharp objects. It is also possible to plow the pipe directly into the ground using a vibratory plow. This works well up to 3-4 feet depth in areas with loose or unstable soils, and where there is not an excessive amount of rocks that could impinge on the pipe over time.

Vertical bores for ground heat exchangers are typically much simpler than drilling a water well. Generally casing is not needed if the borehole is sufficiently stable long enough to get the pipe loop installed. It is sometimes more economical to have several shallow bores rather than one deep bore. However, the bores need to be more than 50 ft. to be assured of reaching depths where ground temperatures are cooler and constant. Vertical bores must be backfilled appropriately to be sure the pipe loops have intimate contact with the soil or grout. If there are air gaps around the pipe, the heat transfer by conduction will be negatively affected.

For both types of installations leave a significant portion (3-5% of total length) of pipe extending from the bores or trenches to compensate for any relaxation from stretching, or contraction from temperature changes. Final connections to the header can be made after the system comes to steady state, usually within 24 hours. More detailed information on the installation and burial of PE pipe can be found in the Chapter entitled Underground Installation of PE Piping.

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Pressure Testing Ground Heat Exchanger

After installation of pipe is completed, but prior to backfilling and/or grouting, it is necessary to flush, purge and pressure test the system. Flushing any dirt or foreign matter that entered the piping during construction is necessary in order to minimize excessive wear on pumps and seals. Purging of any air pockets will make sure that all loops are flowing as intended and heat transfer will be optimized. Flushing and purging can be done at the same time.

Before charging the system with antifreeze, it is necessary to pressure test the system with water (not air) to make sure all of the joints and connections were done correctly. Testing with air is not recommended due to safety considerations. Failure of any part of the system can be very dangerous due to the explosive nature of air under high pressure. It could result in serious injury to personnel in the area. Therefore, testing with air is discouraged. IGSHPA recommends that the heat exchanger be isolated and tested to 150% of the pipe design pressure, or 300% of the system operating pressure, whichever is less, when measured from the lowest point in the loop being tested. No leaks shall occur within a 30-minute test period. At this time flow rates and pressure drops can be compared to calculated design values. A minimum flow velocity of 2 ft/min. must be maintained for a minimum of 15 minutes to remove all air from the heat exchanger.

Since the PE pipe can expand slightly during this high level of pressurization, a certain amount of make-up water may be required. This is normal and does not indicate a leak in the system. If the pressure does not stabilize, then this may be an indication of a leak. Follow the pipe manufacturer's guidelines for pressure testing the system.

For additional information of Ground Source Heat Pump design and installation contact:
International Ground Source Heat Pump Association (IGSHPA) www.igshpa.okstate.edu.
American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) www.ashrae.org.

Solar Applications

The use of solar energy was virtually nonexistent 25 years ago, but has grown to become a significant industry in the United States. Most solar applications are geographically concentrated in the states with a high percentage of sunshine - California, Arizona, New Mexico, Colorado, and Florida.

Solar heating systems vary in size. The very simplest consist of nothing more than a black pipe lying in the sun connected to a swimming pool circulating pump. The more complex systems utilize collectors with 1, 2, or 3 layers of glazing plus piping and pumps. In addition, the latter systems may include heat transfer fluids, heat storage tanks, heat exchangers, and temperature and pressure controls. PE piping can play a major role in this application. Its combination of flexibility, high temperature properties, and resistance to freeze damage and corrosion are major advantages to this end-use. There are, however, precautions that should be taken to prevent misuse.

Check with the pipe manufacturer for recommendations on using PE pipe in solar applications.

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Features and Benefits

The performance benefits of polyethylene pipe in solar heating are:

Ease of Installation – Minimizing the overall cost of solar heating is important to make them viable alternatives and to expand customer acceptance. Polyethylene pipe and tubing is available in many sizes and lengths. Its versatility and flexibility allows installations to be made with the most cost-effective design.

Freeze Tolerant – Frozen lines can be a major problem. Although collectors are protected, supply lines need to be protected from freezing or they should be made of materials that are resistant to damage if water freezes. Polyethylene pipe can normally handle a full-freeze situation without cracking or splitting.

High Temperature Resistance – For continuous use, polyethylene pipe must be suitable for high temperature environments. Polyethylene materials for use at elevated temperatures are listed in PPI's TR-4. Currently, the maximum rated temperature for PE pipe designed for pressure applications is 140°F (60°C). For use at higher temperatures contact the manufacturer for recommendations.

Collector Technologies

The most significant use of solar heating has been for swimming pool and space heating. Solar collectors are classified according to their water discharge temperatures: low temperature, medium temperature, and high temperature. Low temperature systems generally operate at a temperature of 110ºF and have a maximum stagnation temperature of 180ºF. Medium temperature collectors typically have discharge temperatures of 180-200ºF, but can generate stagnation temperatures of 280ºF, or more, for several hours. High temperature collectors routinely operate at temperatures of at least 210ºF and can generate stagnation temperatures of more than 400ºF. Pipe or tubing made of PPI listed pressure rated PE materials can be used directly with low temperature collectors with no special precautions. In addition, PE piping is being used extensively inside unglazed collectors where temperatures rarely exceed 110ºF on a frequent basis.

To protect against ultraviolet 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. The carbon black has a two-fold benefit. One, the right kind of carbon black in the proper levels and adequately dispersed protects the PE from UV degradation. Two, the carbon black aids in the absorption and retention of solar radiation, making the pipe more efficient in the collection of solar energy. Check with the pipe manufacturer for recommendations on long-term UV exposure resistance.

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Plastic piping should not be used in conjunction with high temperature collectors such as the evacuated tube or concentrating types because of their extreme temperatures. In between these two extremes are the systems with medium temperature collectors that constitute the bulk of the market. These glazed collectors are used for domestic hot water and space heating systems. Depending on the type of collector and system design, some special precautions should be taken. The major types of medium temperature systems are described in the following paragraphs along with appropriate precautions. Medium temperature systems are either passive or active types.

Passive systems use no pumps or mechanical equipment to transport the heated water. The breadbox (passive) design uses a tank placed under a glazing material. The tank is painted flat black or coated with a selective absorber to increase the solar energy absorption. The collector may be the primary storage tank or the storage tank may be in the house. In the later case, when a preset temperature is reached, water flows by gravity to the storage tank in the home and fresh water from the main is added to bring the system up to volume. In the thermosyphon passive design, a storage tank is mounted above a collector and cold water flows down into the collector. As the water is heated in the collector, it rises through thermosyphon action back up to the storage tank. Because of the large volume of water in the collector, passive solar systems are not subject to high stagnation temperatures. Thus, polyethylene piping can be used throughout, including a hook-up directly to the collector system.

Active solar systems utilize a pump to move heat transfer fluids through the collector. Some utilize potable water as the heat transfer fluid (open systems) while others use solutions such as ethylene glycol, propylene glycol, silicone oils, or hydrocarbon oils (closed systems). Hydrocarbon oil or silicone oils are generally not recommended with polyethylene pipe. In closed systems, heat is transferred from the heat transfer fluid to potable water by means of a heat exchanger in the hot water storage tank. There are many types of heat transfer fluids, and it is necessary to verify that the fluid being used is compatible and will not negatively affect the long-term performance of the pipe or other system components; refer to PPI TR-33 for further assistance.

Precautions

The extreme conditions encountered during stagnation can be a problem in active medium temperature collectors. As mentioned earlier, stagnation temperatures can exceed 280ºF in most active medium temperature collectors. Under no circumstances should any PE piping be used inside the collector, or in the system where it will be exposed to such temperatures.

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Installation

In general, solar collector manufacturers do not provide piping for the system.

The installer most likely will purchase the piping from the local plumbing supply wholesaler or solar supply house. Installers are usually plumbers, but in some areas like California, solar specialists also do installations. A qualified plumbing supply house may also perform installations. The installation requires knowledge of carpentry to provide roof support or mounting, electricity to install the control system, and plumbing to install the piping system and to tie it in to the storage tank and the existing domestic water supply. Always be sure the installation meets the requirements of the local building, plumbing and mechanical codes.

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