

GEOTHERMAL HEATING AND COOLING INTRODUCTION

Geothermal Heating and Cooling Systems provide space conditioning -- heating, cooling, and humidity control. They may also provide water heating -- either to supplement or replace conventional water heaters. Geothermal Heating and Cooling Systems work by moving heat, rather than by converting chemical energy to heat like in a furnace. Every Geothermal Heating and Cooling Systems has three major subsystems or parts: a geothermal heat pump to move heat between the building and the fluid in the earth connection, an earth connection for transferring heat between its fluid and the earth, and a distribution subsystem for delivering heating or cooling to the building. Each system may also have a desuperheater to supplement the building's water heater, or a full-demand water heater to meet all of the building's hot water needs.

Geothermal Heat Pump

The geothermal heat pump is packaged in a single cabinet, and includes the compressor, loop-to-refrigerant heat exchanger, and controls. Systems that distribute heat using ducted air also contain the air handler, duct fan, filter, refrigerant-to-air heat exchanger, and condensate removal system for air conditioning. For home installations, the geothermal heat pump cabinet is usually located in a basement, attic, or closet. In commercial installations, it may be hung above a suspended ceiling or installed as a self-contained console.

Distribution Subsystem

Most residential geothermal systems use conventional ductwork to distribute hot or cold air and to provide humidity control. (A few systems use water-to-water heat pumps with one or more fan-coil units, baseboard radiators, or under-floor circulating pipes.) Properly sized, constructed, and sealed ducts are essential to maintain system efficiency. Ducts must be well insulated and, whenever possible, located inside of the building's thermal envelope (conditioned space).

Geothermal heating and cooling systems for large commercial buildings, such as schools and offices, often use a different arrangement. Multiple heat pumps (perhaps one for each classroom or office) are attached to the same earth connection by a loop inside the building. This way, each area of the building can be individually controlled. The heat pumps on the sunny side of the building may provide cooling while those on the shady side are providing heat. This arrangement is very economical, as heat is merely being transferred from one area of the building to another, with the earth connection serving as the heat source or heat sink only for the difference between the building's heating and cooling needs.

Water Heating

Many residential-sized systems installed today are equipped with desuperheaters to provide domestic hot water when the system is providing heat or air conditioning. The desuperheater is a small auxiliary heat exchanger at the compressor outlet. It transfers excess heat from the compressed gas to a water line that circulates water to the house's hot water tank. In summer, when the air conditioning runs frequently, a desuperheater may provide all the hot water needed by a household. It can provide four to eight gallons of hot water per ton of cooling capacity each hour it operates. A desuperheater provides less hot water during the winter, and none during the spring and fall when the system is not operating.

Because the heat pump is so much more efficient than other means of water heating, manufacturers are beginning to offer "triple function," "full condensing," or "full demand" systems that use a separate heat exchanger to meet all of a household hot water needs. These units cost-effectively provide hot water as quickly as any competing system.

The water heating system that is installed in the Finger Lakes Institute is an on demand system. This system provides hot water as soon as there is a demand for it. Using this type of system eliminates the need to heat stored water like a conventional hot water tank requires.

Types of Systems

Geothermal systems use the earth as a heat source and heat sink. A series of pipes, commonly called a "loop," carry a fluid used to connect the geothermal system's heat pump to the earth.

Closed and Open Loops

There are two basic types of loops: closed and open. Open loop systems are the simplest. Used successfully for decades, ground water is drawn from an aquifer through one well, passes through the heat pump's heat exchanger, and is discharged to the same aquifer through a second well at a distance from the first. Generally, two to three gallons per minute per ton of capacity are necessary for effective heat exchange. Since the temperature of ground water is nearly constant throughout the year, open loops are a popular option in areas where they are permitted. Open loop systems do have some associated challenges:

Some local ground water chemical conditions can lead to fouling the heat pump's heat exchanger. Such situations may require precautions to keep carbon dioxide and other gases in solution in the water. Other options include



the use of cupronickel heat exchangers and heat exchangers that can be cleaned without introducing chemicals into the groundwater.

Increasing environmental concerns mean that local officials must be consulted to assure compliance with regulations concerning water use and acceptable water discharge methods. For example, discharge to a sanitary sewer system is rarely acceptable.

A closed loop system is being used for the Finger Lakes Institute. Closed loop systems are becoming the most common. When properly installed, they are economical, efficient, and reliable. Water (or a water and antifreeze solution) is circulated through a continuous buried pipe keeping. The closed loop system is environmentally friendly because water in the loop prevents contamination to the external environment.

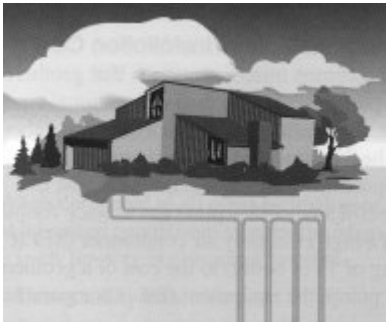
The length of loop piping varies depending on ground temperature, thermal conductivity of the ground, soil moisture, and system design. (Some heat pumps work well with larger inlet temperature variations, which allows marginally smaller loops).

Horizontal Loops



Horizontal closed loop installations are generally most cost-effective for small installations, particularly for new construction where sufficient land area is available. These installations involve burying pipe in trenches dug with back-hoes or chain trenchers. Up to six pipes, usually in parallel connections, are buried in each trench, with minimum separations of a foot between pipes and ten to fifteen feet between trenches.

Vertical Loops



Vertical closed loops are preferred in many situations. For example, most large commercial buildings and schools use vertical loops because the land area required for horizontal loops would be prohibitive. Vertical loops are also used where the soil is too shallow for trenching. Vertical loops also minimize the disturbance to existing landscaping.

For vertical closed loop systems, a U-tube (more rarely, two U-tubes) is installed in a well drilled 100 to 400 feet deep. Because conditions in the ground may vary greatly, loop lengths can range from 130 to 300 feet per ton of heat exchange. Multiple drill holes are required for most installations, where the pipes are generally joined in parallel or series-parallel configurations.

A vertical loop well field, being used for the Finger Lakes Institute, consists of 20 wells, drilled to a depth of 100'. There are 5 (clusters) of 4 wells spaced approximately 12 feet on center. The depth and number of wells was determined by the estimated heat and cooling load required maintain a comfortable environment for the occupants.

Slinky Loops

Increasingly, "Slinky" coils -- overlapping coils of polyethylene pipe -- are used to increase the heat exchange per foot of trench, but require more pipe per ton of capacity. Two-pipe systems may require 200 to 300 feet of trench per ton of nominal heat exchange capacity. The trench length decreases as the number of pipes in the trench increases -- or as Slinky coil overlap increases. (Illustration below shows a slinky coil in a pond)

Pond Loops

Pond closed loops are a special kind of closed loop system. Where there is a pond or stream that is deep enough and with enough flow, closed loop coils can be placed on the pond bottom. Fluid is pumped just as for a conventional closed loop ground system where conditions are suitable, the economics are very attractive, and no aquatic system impacts have been shown



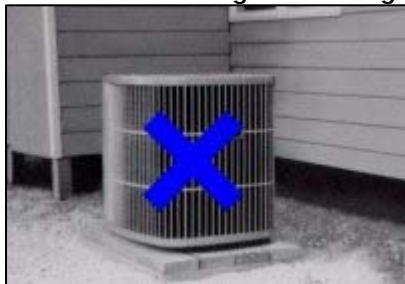
Conclusion

Geothermal heating and cooling systems can be connected to the earth in a variety of ways -- all thoroughly field proven. However, high performance requires the use of experienced professionals who understand local conditions. Ground Loop today to discuss the best system for you.

DETAILS AND DIAGRAMS INTRODUCTION

Refrigerators and air conditioners both contain heat pumps. In a refrigerator, heat is moved from the food storage sections and discharged to the kitchen air. Air conditioners work the same way -- they move heat from the inside of a building and discharge it to the outside air. Conventional or air source heat pumps differ from those in a refrigerator or air conditioner because they are reversible -- they can concentrate heat from the outside air and move it inside to provide warmth, as well as move heat out of the building to provide cooling. To do this, air-source heat pumps (and central air conditioners) need a large outside unit to exchange heat with the outdoor air.

Geothermal Heating and Cooling Systems



In a geothermal heating and cooling system, the heat pump is connected to the building by a distribution system -- most commonly air ducts.

And the heat pump is connected to the earth through a series of pipes called a "loop" which was previously described above. The system exchanges heat with the earth, meaning that no noisy or unsightly outdoor unit is needed.

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STATUS: SUMMER OPERATION

Bottom of Form

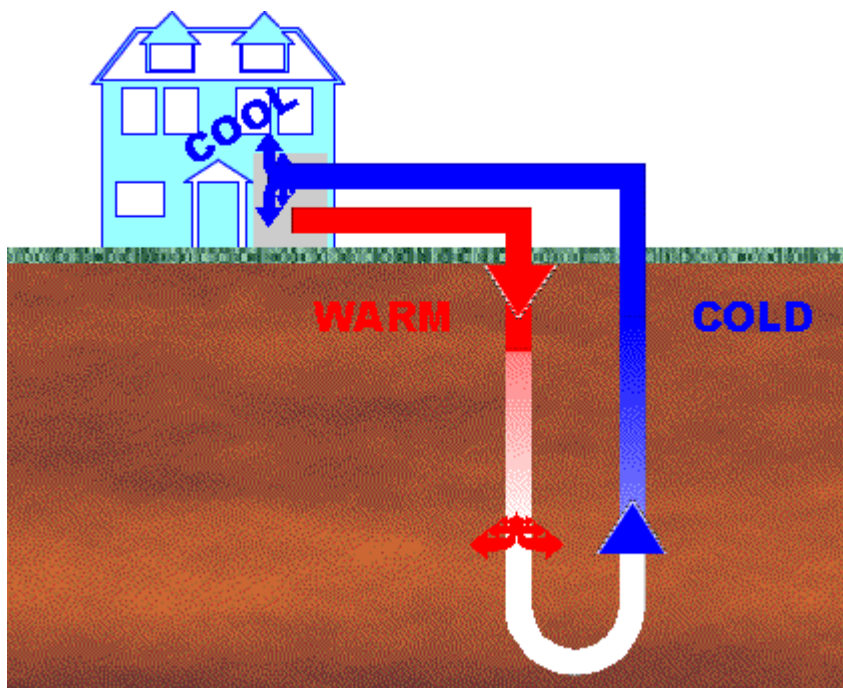
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outside air temp:



ground temp:



Top of Form

WINTER OPERATION

STATUS:

Bottom of Form

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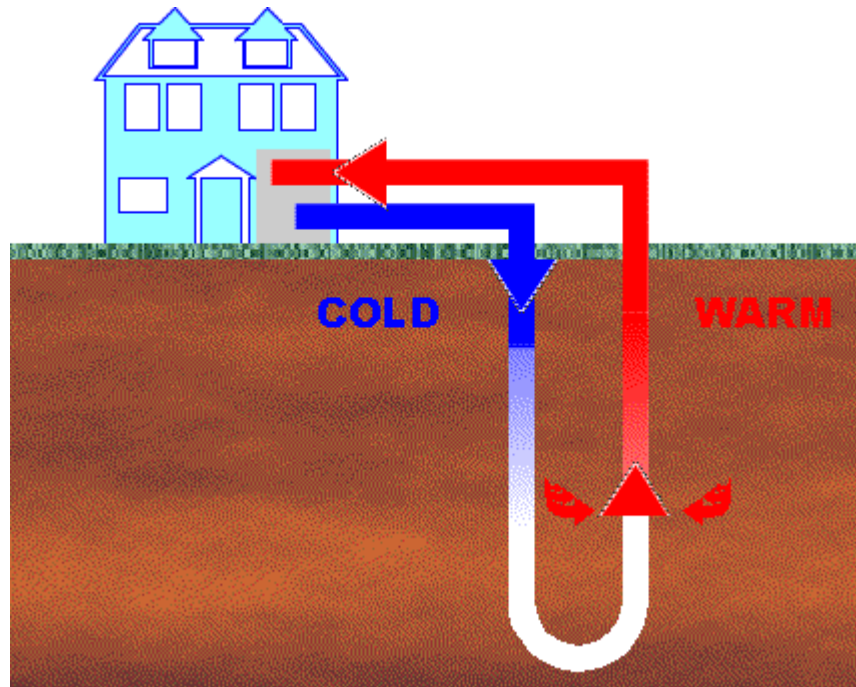
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20

ground temp:

55



Vapor Compression Cycle

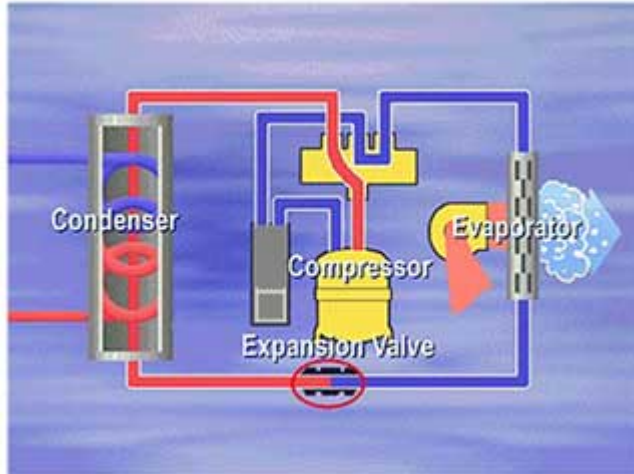
All heat pumps use a vapor compression cycle to transport heat from one location to another. In heating mode, the cycle starts as the cold liquid refrigerant within the heat pump passes through a heat exchanger (evaporator) and absorbs heat from the low-temperature source (fluid circulated through the earth connection). The refrigerant evaporates into a gas as heat is absorbed. The gaseous refrigerant then passes through a compressor where it is pressurized, raising its temperature to over 180 degrees F. The hot gas then circulates through a refrigerant-to-air heat exchanger where the heat is removed and sent through the air ducts. When the refrigerant loses the heat, it changes back to a liquid. The liquid refrigerant cools as it passes through an expansion valve, and the process begins again.

Although heat pumps are complex internally, they are marvels of compact design for reliability. Some include features such as additional heat exchangers for water heating, and microprocessor-based automatic controls and protection devices.

How It Works

Anatomy of a Geothermal Heat Pump

Instead of producing heat like a conventional furnace, a geothermal system moves heat from one place to another. The example below illustrates the summer cooling process:



The cool, liquid refrigerant enters the indoor coil during cooling. As it enters the coil, the temperature of the refrigerant is between 40 and 50 degrees.

As warm, moist room air passes over the cool coil, the refrigerant inside absorbs the heat.

The new cooler, drier air is circulated back into the room with a blower fan.

The refrigerant moves into the compressor, which is a pump that raises the pressure so it will move through the system. The increased pressure from the compressor causes the refrigerant to heat to roughly 120 to 140 degrees.

The hot vapor now moves into the condenser (the underground loops), where the refrigerant gives up its heat to the cooler ground and condenses back into a liquid.

As the refrigerant leaves the compressor, it's still under high pressure. It reaches the expansion valve, where the pressure is reduced.

The cycle is complete as the cool, liquid refrigerant re-enters the evaporator to pick up room heat.

During the winter, the reversing valve switches the indoor coil to function as the condenser, and the underground piping to act as the evaporator.

In short, the indoor coil and underground piping cause the refrigerant to change state, absorbing and releasing heat through boiling and condensing. The compressor and expansion valve move the refrigerant through the system by changing the pressure.

The heat pump system for the Finger Lakes Institute consists of 6 units located throughout the building. Each heat pump has been sized to meet the heating and cooling needs for the building space. Each heat pump will have a rate of heat absorption and a rate of heat rejection. The rates are listed as follows:

3rd floor heat pump model 025

- rate of absorption 15,668 btu's (heating mode)
- rate of rejection 29,700 btu's (cooling mode)

2nd floor heat pump rear model 030

- rate of absorption 20,972 btu's (heating mode)
- rate of rejection 36,178 btu's (cooling mode)

2nd floor heat pump front model 036

- rate of absorption 25,105 btu's (heating mode)
- rate of rejection 43,835 btu's (cooling mode)

1st floor heat pump rear model 036

- rate of absorption 25,105 btu's (heating mode)
- rate of rejection 43,835 btu's (cooling mode)

1st floor heat pump front model 019

- rate of absorption 12,866 btu's (heating mode)
- rate of rejection 25,380 btu's (cooling mode)

Basement heat pump model 030

- rate of absorption 20,972 btu's (heating mode)
- rate of rejection 36,178 btu's (cooling mode)

GEOHERMAL ADVANTAGES

Efficiency

Geothermal heat pumps are much more efficient than air source heat pumps because earth temperatures are much more uniform through the year than air temperatures. Not only are earth temperatures more constant, but also the range of temperatures in ground water is rather small in the United States, varying from upper 40s to upper 70s nationwide.

Geothermal Heating and Cooling Makes Sense

Geothermal systems are efficient, environmentally-sensitive, comfortable, and economical. Operating savings often provide paybacks of considerably less than five years -- sometimes less than two years. In addition, electric utilities are so convinced of the value of this technology for their customers that they offer design assistance, referrals, or financial incentives to defray the first cost increment of geothermal systems.

The key is that geothermal heat pumps use electricity to move heat, not to generate it by the burning fuel or using electric resistance elements. Indeed, the U.S. EPA has found that no other technology with more favorable operating efficiencies and economics than emerging geothermal heat and cooling systems.

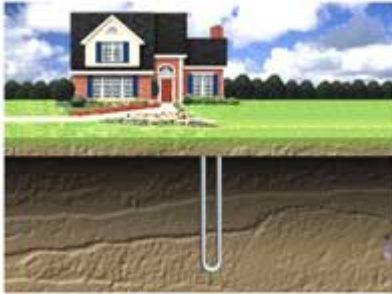
An Important Renewable Energy Technology

The U.S. Environmental Protection Agency has concluded that well-designed and properly installed high efficiency geothermal heat pump systems produce less environmental harm than any other alternative space conditioning technology currently available. On a full fuel cycle basis, emerging geothermal systems are the most efficient technology available, with the lowest CO₂ emissions for minimum greenhouse warming impact. Overall, the EPA found emerging geothermal heating and cooling systems to have the lowest environmental cost of all technologies analyzed -- including air-source heat pumps and natural gas furnaces.

Geothermal Heat Pump Systems Work!

No existing space conditioning technology offers greater comfort, economy, or environmental benefits than the geothermal heat and cooling systems now available for residential and commercial installations. Over 250,000 installations are in place in the United States today, and the number is rapidly increasing. More than 95 percent of all geothermal heat and cooling customers are completely satisfied with their systems

Closed Loop Systems Vertical Loops



If the soil conditions are not conducive to trenching, a vertical loop may be the choice. Vertical systems are used where land is too rocky for an economic horizontal system, and for commercial or educational facilities.

Spacing vertical boreholes can be in any variety of ways - lines, squares, rectangles, grids - depending on available land areas and system borehole requirements.

The ground heat exchanger may be either series or parallel piping.

Major components

- Supply and return headers of larger pipe to minimize the pressure loss down the length of the pipe run
- Loops extending from the supply header down the borehole and back, connected to the return header.
- Reverse return or compact headers to allow each loop to have

approximately the same flow

- U-bends, a 180-degree fitting used at the bottom of the borehole

Examples:

- Single U-bend with 0.75- or 1-inch pipe loops, 1.25- to 2-inch headers, parallel water flow, 150 to 280 feet per ton bore lengths, and 300 to 500 feet per ton pipe lengths.
- Single U-bend with 1-, 1.25-, 1.5 or 2-inch pipe, series water flow, 125 to 225 feet per ton borehole lengths, and 250 to 450 feet per ton pipe lengths.

How It Works - Concepts Ground Temperature



At a depth of below four feet, the ground temperature stays a constant 50 to 55 degrees year-round.

During the winter, a geothermal system absorbs this extra heat from the earth and transfers it into your home. During the summer, the system takes heat from indoors and moves it back underground.

Annual air temperature, moisture content, soil type and vegetative cover (i.e., trees and plants) all have an effect on underground soil temperature. As you might expect, the earth's temperature changes in response to weather changes, but there is less change at greater depths.