GEOTHERMAL HEATING & COOLING SYSTEMS

Let's begin this CEU by being clear on the names we will use throughout this presentation.

This presentation will be an introduction to the method of installation and operation of heating and cooling systems that use the earth as a "heat source" and a "heat sink." In the past these types of "ground source" or "ground based" systems have been called *geothermal* systems, and they still often are known by that name.

But some confusion can arise because *geothermal* is also the term used to describe the technology that harnesses heated water or steam that comes from the depths of the earth and is used to generate electricity or provide a direct heat source. Sometimes the following explanation is used to distinguish between these separate types of "geothermal energy."

There are two types of geothermal energy:

1.High grade

High-grade geothermal energy is the heat of the earth's pressure that turns water into stream. Old Faithful at Yellowstone National Park is an excellent example.

2.Low Grade

Low-grade geothermal energy is the heat within the earth's crust. This heat is actually stored solar energy.

We will use the terms '*low grade geothermal' or 'geothermal'* throughout this presentation because it is the most commonly used term. These systems are also called GHP's (geothermal heat pumps), or GSHP's (ground sourced heat pumps), Earth-Coupled Heat Pumps, Earth-Coupled Water Source Heat Pumps, Earth Exchange Systems (EES), Geo-Exchange systems and underground thermal energy storage systems (UTES). Which ever of these names is used, this technology is the same.

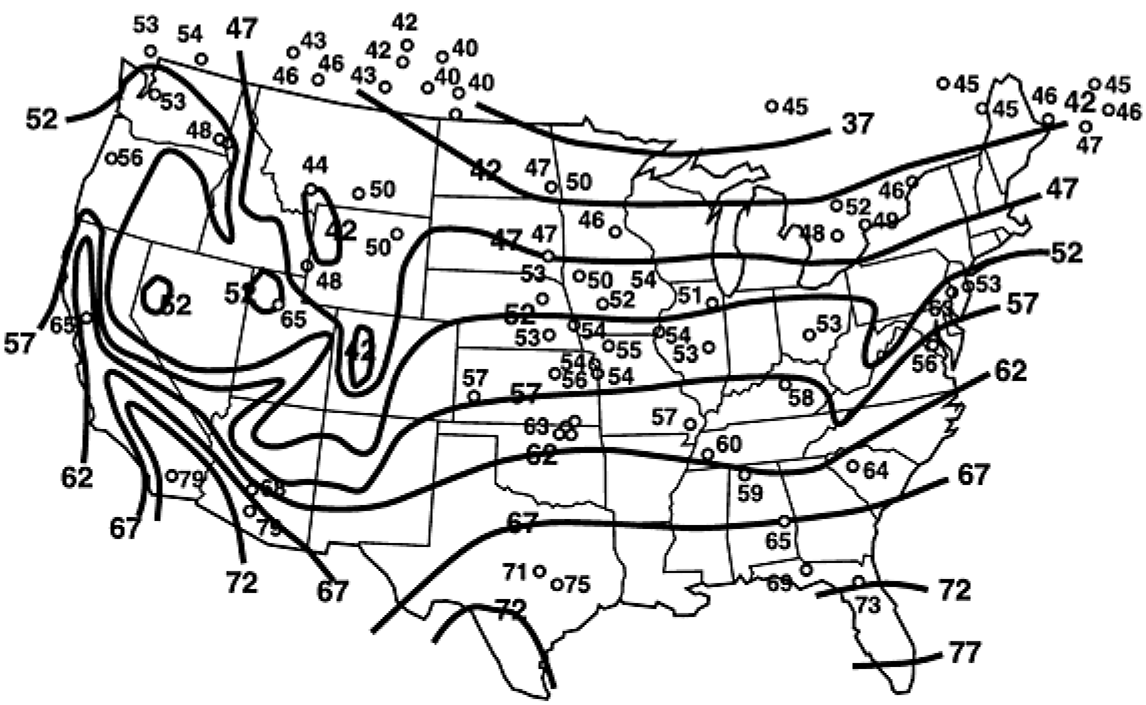
To create a separate identity for the technology of using "ground sourced" heat exchangers to provide residential and commercial properties with heating and cooling, the commercial name *geoexchange* has been coined.

Like everything else, low-grade geothermal heat pumps have a history.

HISTORY OF LOW GRADE GEOTHERMAL HEAT PUMPS

Humankind didn't always know that the earth stored solar energy. Nor did we know that this stored solar energy is in the form of heat (measured as temperature) and that the stored solar energy (temperature) remains very nearly constant for each point on the earth.

That is to say, cold climate areas have less stored solar heat so their below ground temperatures remain constant, but at a lower reading (temperature) than the below ground temperatures of warmer climate areas of the earth. Although the temperatures vary according to latitude, at six feet underground, temperatures range from approximately 45 degrees to 75 degrees Fahrenheit in the United States.

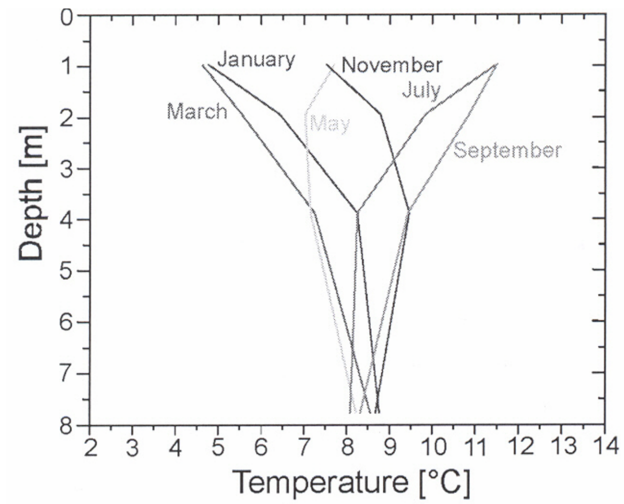


Mean annual earth temperature observations at individual stations, superimposed on well-water temperature contours.

A steady temperature in the underground was scientifically proven in deep vaults under the *Observatory* in Paris. The famous French chemist and physicist Lavoisier installed a mercury thermometer there at the end of the 17th century, at a depth of 85 feet below street level. *Buffon* reported in 1778 in his "Natural History- General and Specific," that *"the temperature readings from this thermometer are constant throughout the year*."

During his studies in Paris, Alexander von Humboldt noted in 1799: *"The average temperature supplied by the measurements taken since 1680 in this basement have varied less than one degree."*

In 1838, very exact measurements of temperature in the ground were started at the Royal Edinburgh Observatory. The findings showed temperature variation at a 25-foot depth to be about 1/20 of the surface variation, and at a 50-foot depth the temperature variation is only 1/400 of the surface variation.



(Note: the deeper below the surface, the less the temperature varies throughout the year!)

The first ground-source heat pump installation was in Indianapolis, in 1945 at the home of Robert C. Webber, an employee of the Indianapolis Power and Light Co. A 2.2 kW compressor hooked to a direct expansion ground coil system in trenches supplied heat to a warm air heating system.

The plant was monitored beginning Oct. 1, 1945. *This date can be considered as the first day of ground source heat pump operation documented in literature*. The monitoring report concludes with the words:

"It is hoped, however, that this report of an actual installation under average operating conditions will help give to other utilities an idea of the practicability of electric power use in house heating with the earth heat pump."

In the following years, several proposals were made how to best exploit the earth as heat source and heat sink for heat pumps. Research since 1947 shows that virtually all methods in use until today, including ground water wells, horizontal coils with direct expansion as well as with brine circuit,

vertical borehole heat exchangers in coaxial, U-pipe and spiral form were tried in the early days of this technology.

The first Canadian low grade geothermal installation was installed in 1949 in a house owned by the University of Toronto. Europe began using the technology around 1970. Presently several installations of low grade geothermal technologies exist in: Japan, China, USA, Canada, Germany, Belgium, The Netherlands, Sweden, Switzerland, Finland, and France.

WHAT IS LOW-GRADE GEOTHERMAL TECHNOLOGY?

The earth offers a steady and incredibly large heat source, heat sink and heat storage medium for thermal energy uses, such as for geothermal heat pumps.

Heat naturally flows "downhill", from higher to lower temperatures. A heat pump is a machine which causes the heat to flow in a direction opposite of its natural tendency or "uphill" in terms of temperature. Because work must be done (energy consumed) to accomplish this, the name heat "pump" is used to describe the device.

Heat pumps come in different types. This CEU discusses geothermal heat pumps, which means heat pumps that use as their energy source the earth's stored solar energy. Air sourced heat pumps or "air conditioners" don't use the earth, rather they use "the atmosphere" or air as their heat source. These air-sourced 'air conditioners,' too, are "heat pumps," but they are NOT "geothermal" or ground sourced "heat pumps. We will limit our discussion to ground sourced or geothermal heat pumps.

Geothermal technology relies on the fact that the Earth (beneath the surface) remains at a relatively constant temperature throughout the year, warmer than the air above it during the winter and cooler in the summer, very much like a cave. The geothermal heat pump takes advantage of this by transferring heat stored in the Earth or in ground water into a building during the winter, and transferring it out of the building and back into the ground during the summer. ***The ground, in other words, acts as a heat source in winter and a heat sink in summer.***

Its great advantage is that it works by concentrating naturally existing heat, rather than by producing heat through combustion of fossil fuels. A geothermal heat pump doesn't create heat by burning fuel, like a furnace does. Instead, in winter it collects the Earth's natural stored heat below ground. In summer geothermal heat pumps remove heat from the space being serviced and transfers it to the earth where it is cooler.

The system includes three principal components:

1. **Geothermal earth connection subsystem**
2. **Geothermal heat pump subsystem**
3. **Geothermal heat distribution subsystem.**

1. <u>Geothermal Earth Connection Subsystem</u>

Using the Earth as a heat source/sink a connection is made between the object (building/home/mall/etc) which is to be heated/cooled and the earth. This earth connection begins as piping exiting from the object being heated/cooled and ultimately returns as piping into the object being heated/cooled.

However it is the path taken by the earth connection between its beginning and its final return that is most important and sophisticated. This middle part of the geothermal earth connection is called a 'loop.' Geothermal earth connections may be categorized as "<u>open loop</u>" or "<u>closed loop</u>" systems. Many factors affect the design of this loop section of the earth connection of a geothermal system. Open and closed loop systems are discussed in detail below.

<u>2. Geothermal Heat Pump Subsystem</u>

In reality, a heat pump is nothing more than a refrigerator that can be reversed! Think of the area to be heated/cooled by the geothermal system as the inside of your home refrigerator.

Any refrigeration device (window air conditioner, refrigerator, freezer, etc.) moves heat from a space where it isn't wanted and discharges that heat somewhere else. The only difference between a geothermal heat pump and your home refrigerator is that heat pumps *<u>are</u>* reversible and can provide *<u>either</u>* heating or cooling to almost any space or location you choose. For example in addition to cooling/heating spaces such as homes/office buildings/malls/etc, geothermal systems are also used to heat swimming pools and to deice sidewalks and driveways.

In warm weather the geothermal unit acts like your home refrigerator. It removes unwanted heat from the space being cooled (building/home/mall/etc) and deposits that unwanted heat somewhere else, in this case to the earth. In cool weather the geothermal heat pump acts as a reverse refrigerator because it withdraws heat from the earth and

transfers that earth heat into the space being heated (building/home/mall/etc).

We discuss the operation of a heat pump fully, below.

3. Geothermal Heat Distribution Subsystem

Conventional ductwork is generally used to distribute heated or cooled air from the geothermal heat pump throughout the object being cooled/heated. However other approaches to heat distribution have also been successfully employed. These include a wide variety of distribution systems including: radiant floor, cast iron radiators, baseboard, and fan coils.

We will discuss each of the 3 subsystems in more detail below. Subsystem # 1 is discussed last and is treated in the greatest detail as it is in this subsystem that drillers are involved in most:

GEOTHERMAL SUBSYSTEMS # 2 & 3

THE HEAT PUMP & HEAT DISTRIBUTION SUBSYSTEMS

THE INSIDE PORTIONS OF A GEOTHERMAL SYSTEM

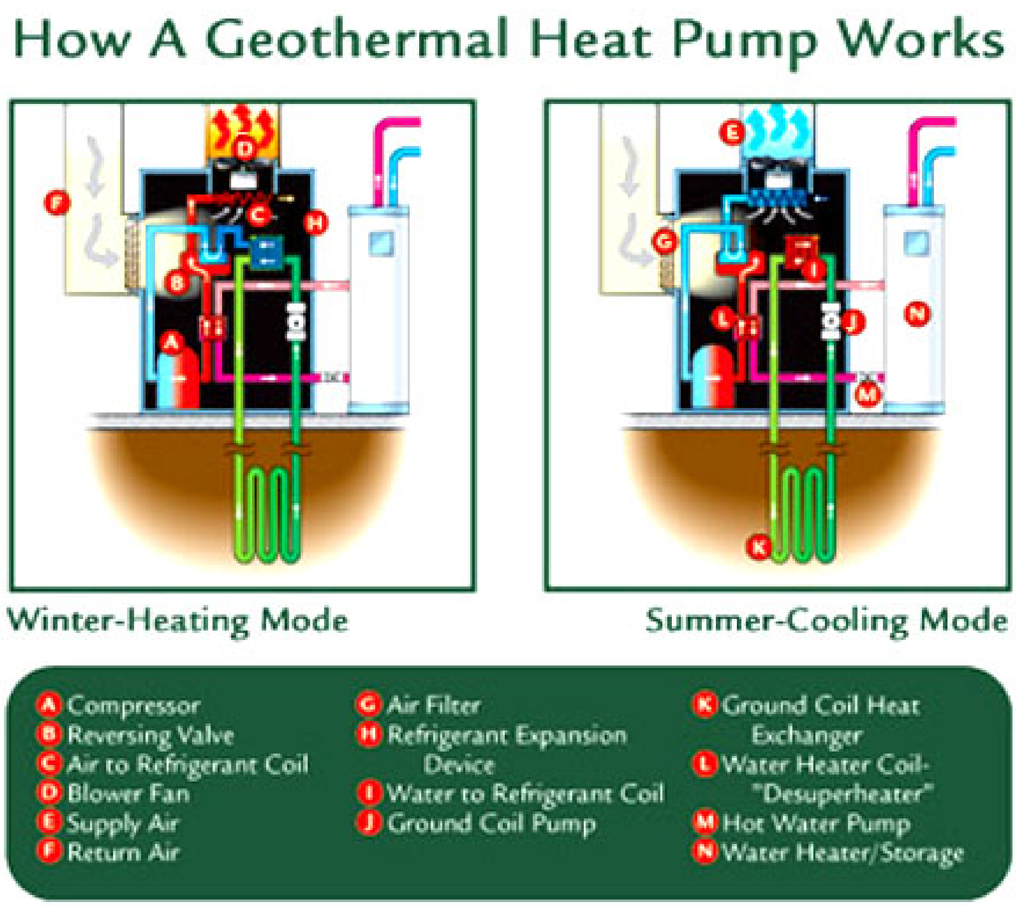
The geothermal heat pump may be packaged in a single cabinet, which includes the compressor, loop-to-refrigerant heat exchanger, and controls.

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. Console heat pumps are free standing units that do not require a distributing system. They are used in

applications such as: hotel rooms, classrooms, churches, warehouses and industrial work areas.

The diagram below illustrates a refrigerant-to-air heat exchanger for a forced-air/ductwork distribution system.



Heat pumps use a <u>vapor compression cycle</u> to transport heat from one location to another.

<u>In heating mode</u>, the cycle starts as the cold liquid refrigerant within the heat pump passes through a heat exchanger (evaporator) and absorbs heat from the fluid circulated through the earth connection [See I in diagram above].

The refrigerant evaporates into a gas as heat is absorbed from the earth connection heat exchanger (evaporator). The gaseous refrigerant then passes through a compressor [See A in diagram above] where it is pressurized, raising its temperature to over 180 degrees F.

The hot gas then circulates through a refrigerant-to-air heat exchanger [See C in diagram above] 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 [See H in diagram above] and the process begins again.

The heating description above is for a system with a *forced air/ductwork distribution system*, the most common geothermal application.

Systems that use radiators, radiant floor heaters, or baseboard heaters or for use in swimming pool heating may have *refrigerant-to-liquid or liquid-to-liquid* heat exchangers instead of *refrigerant-to-air* heat exchangers as shown in the diagram above [See C in diagram above].

Geothermal systems may also be equipped with a device called a "desuperheater" [See L in diagram above] that can heat household water, which circulates into the regular water heater tank. In the summer, heat that is taken from the house and would be expelled into the loop is used to heat the water for free. In the winter, the desuperheater can reduce water-heating costs by about half, while a conventional water heater meets the rest of the household's needs. In the spring and fall when temperatures are mild and the heat pump may not be operating at all, the regular water heater provides hot water.

GEOTHERMAL SUBSYSTEM # 1-

THE EARTH CONNECTION SUBSYSTEM

THE OUTSIDE PORTION OF A GEOTHERMAL SYSTEM

As was stated earlier: “Geothermal earth connections may be categorized as “open loop” or “closed loop” systems. Many factors affect the design of the loop section of the earth connection of a geothermal system.

Design factors include: geologic conditions (the thermal and hydraulic characteristics of the underground), technical parameters (length and type of ground heat exchanger, type and quality of grouting), other technical factors include the heating/cooling load, the type of space to be heated/cooled, and the supply temperature from underground.

Generally speaking, the advantage of closed loop systems is the independence from aquifers and water chemistry. An advantage of open

systems is the higher heat transfer capacity of the wells compared to a borehole.

Designing the system calls for professional expertise. Design choices open to the geothermal system installer of the earth connection are:

- **<u>Open loop</u> earth connection systems where ground water is used directly and may include a single water well or multiple water wells drilled to depths up to 1500 feet deep! Types of open loop systems are shown below.**
- **<u>Closed loop</u> earth connection systems where water or a water antifreeze mixture is circulated through polyethylene tubing. Closed loop systems come in many configurations which are shown below.**
- **<u>Hybrid closed loop</u> earth connection systems which incorporate features into their design that are not normally part of the 3 subsystems of a geothermal system, but which add to the system's efficiency. Hybrid systems are shown below.**
- **<u>Direct Exchange</u> (DX) systems do not use an intermediate working fluid or heat exchanger. Instead, DX systems employ closed loops of soft copper tubing to directly transfer heat between the ground and the refrigerant -- the heat pump's refrigerant loop is buried in the ground. Direct exchange systems are shown below.**

OPEN LOOP EARTH CONNECTION SYSTEMS

Open loop systems are the simplest. Used successfully for decades, ground water is drawn from an aquifer, passes through the heat pump's heat exchanger, and is discharged.

After it leaves the building, water may be disposed of by one of three methods. Note that local codes and regulations may restrict which discharge method is allowed.

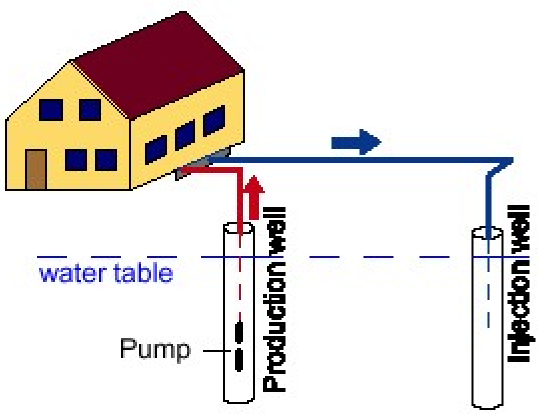
1. **Surface drainage – to a low area such as a pond, river, lake or stream, etc.**
2. **Sub surface – to a dedicated drainfield sized to the required volume of water of the heat pump (shown below)**

3. Re-injection - water is pumped back into the same aquifer.

This CEU will discuss only open loop systems that re-inject water into the source where it was drawn from, (# 3 above).

<u>Multiple Well Open Loop Earth Connection</u>

Open loop systems typically include one or more supply wells and one or more <u>diffusion</u>, <u>discharge</u>, <u>recharge</u>, <u>return</u> or <u>injection</u> wells *(each of the preceding five terms <u>diffusion, discharge, recharge, return, injection</u> means the same thing as the terms are used here*).



In an open loop geothermal well system, groundwater is withdrawn from an aquifer through the supply/production well and pumped to the heat pump where it acts as a heat source or sink in the heating or cooling process.

Once the groundwater passes through the heat pump it is returned to the aquifer through an injection well. The only difference between the supply

and return water is the temperature.

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 are used less frequently than closed loop systems, but may be employed cost-effectively if ground water is plentiful. Local environmental officials should be consulted whenever an open-loop system is being considered. In some localities, all or parts of the installation may be subject to local ordinances, codes, covenants or licensing requirements.

Poor water quality will cause serious problems in open-loop applications. Water should be tested for hardness, acidity and iron content before the heat pump is installed. Poor water quality can cause mineral deposits to build up inside the heat pump heat exchanger and periodic cleaning will be required.

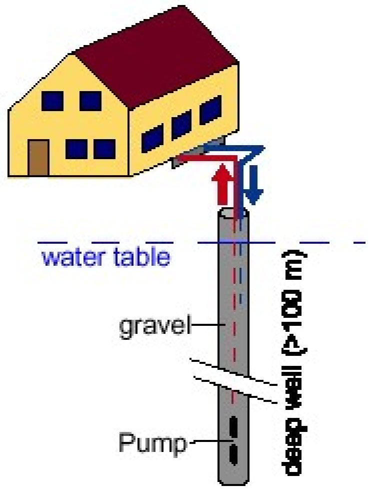
No environmental damage is created by open loop wells since the only difference between the water being removed by the supply well and the water being reinjected through the discharge well is a slight increase in temperature.

The distance between the production and injection wells is an important design consideration. It is not necessary to completely prevent flow from the injection well to the production well, but simply to make sure that any flow between the wells is sufficiently low that discharged water arrives at the production well at a temperature at nearly the same temperature as the aquifer.

Well spacing typically will be in the range of 200 to 600 feet, depending on the maximum system cooling or heating load, the typical duration of the maximum load, and the thickness and natural flow rate of the aquifer. If proper attention is not given to this important design factor undesired temperature increases in the aquifer can lead to the growth of undesireable organisms which can cause increased biofouling and incrustation.

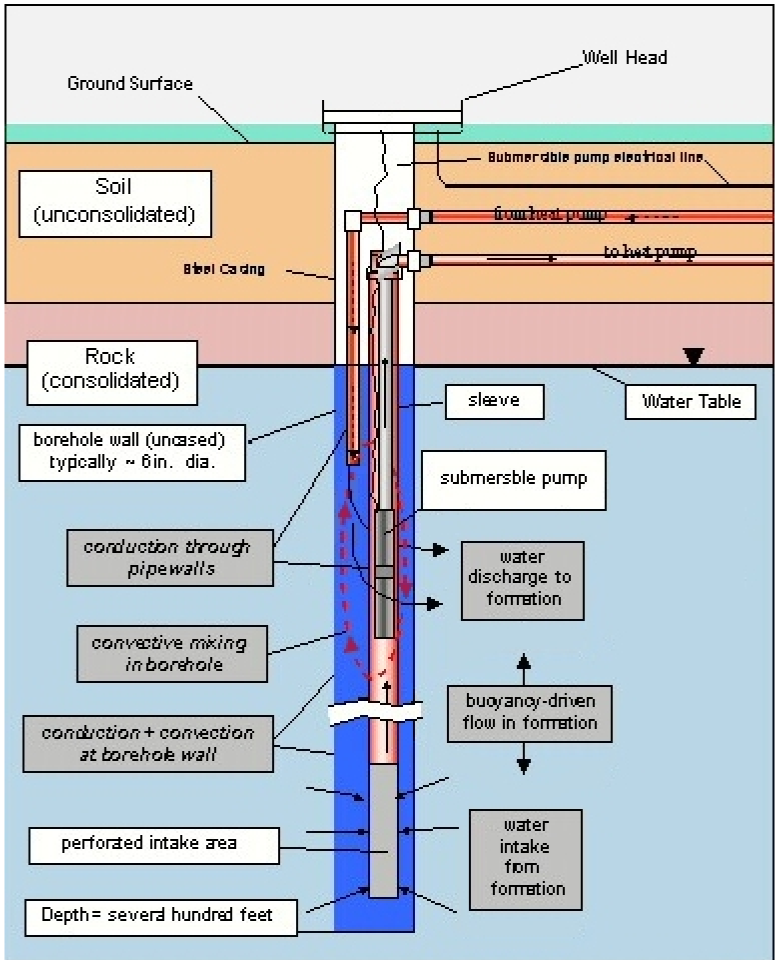
Standing Water Column Open Loop Earth Connection

Another type of open loop system is the *standing water column system*.



A standing water column system is generally a single deep well drilled into bedrock. A casing is set from grade down to bedrock and from there the well is essentially an open rock well. The standing water column method works best with non-corrosive and non-scaling water, as the water is used directly in the heat pumps.

***<u>The geothermal water in this case is circulated within the same well</u>*. Here, if the water is withdrawn from the bottom of the well. The water will be returned at the top and allowed to heat or cool as it traverses down the well to where it is being withdrawn.**



This vertical movement of water and heat exchange is called a standing column well and provides a convenient and effective heat transfer method. Based on experience by the Water and Energy Systems Corporation, 50 to 60 feet of water column is needed per ton (a nominal 12,000 Btu/hr of cooling) of building load.

Standing column wells, also called turbulent wells have become an established technology in some regions, especially the northeastern United States. Standing wells are typically six inches in diameter and may be as deep as 1500 feet.

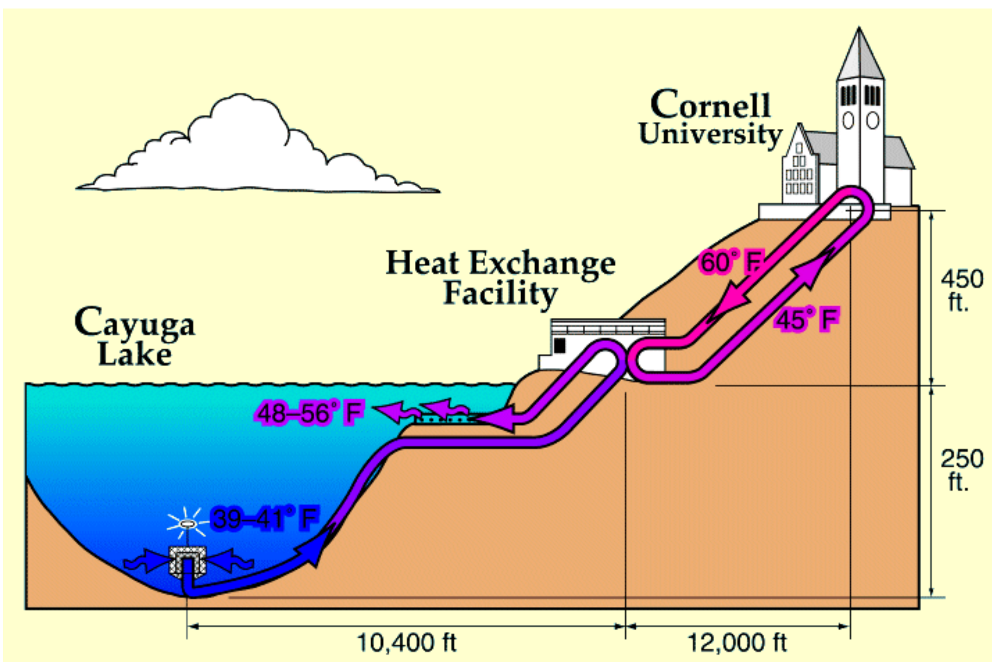
Ground water must be plentiful for a standing well system to operate effectively. If the standing well is installed where the water table is too deep, pumping would be prohibitively costly. Under normal circumstances, the water diverted for building (potable) use is replaced by constant-temperature ground water, which makes the system act like a true open-loop system.

If the well-water temperature climbs too high or drops too low, water can be "bled" from the system to allow ground water to restore the well-water temperature to the normal operating range. Permitting conditions for discharging the bleed water vary from locality to locality, but are eased by the fact that the quantities are small and the water is never treated with chemicals.

Surface Water Systems

Surface water systems use a large body of water such as an ocean bay or inland lake for a water supply, as well as discharge. Conceptually, surface water systems are similar to the Standing Water Column Systems described above.

A leading example of a surface water open-loop system is shown below. Water from Cayuga Lake is used as the source for geothermal exchange to provide cooling at Cornell University. This cooling-only application uses no heat pumps.



CLOSED LOOP EARTH CONNECTION SYSTEMS

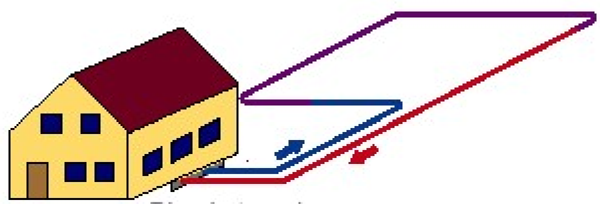
There are several types of closed loop systems. All types use a continuous loop where the heat transfer fluid is circulated. The geothermal loop that is buried underground is typically made of high-density polyethylene, a tough plastic that is extraordinarily durable but which allows heat to pass through efficiently.

When installers connect sections of pipe, they heat fuse the joints, making the connections stronger than the pipe itself. The fluid in the loop is water or an environmentally safe antifreeze solution that circulates through the pipes in a closed system.

Horizontal Closed Loop Earth Connection

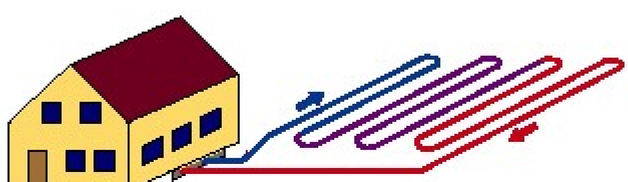
A horizontal loop is usually the most cost effective when adequate yard space is available and trenches are easy to dig. Using trenchers or backhoes digging trenches three to six feet below the ground, you then lay a series of parallel plastic pipes.

The trench is then back filled, taking care not to allow sharp rocks or debris to damage the pipe. A typical horizontal loop will have 400-600 feet of pipe per ton of heating and cooling capacity. The land area required for horizontal ground loops will range from 1500-3000 square feet per ton of heating/cooling depending on soil properties and earth temperatures.

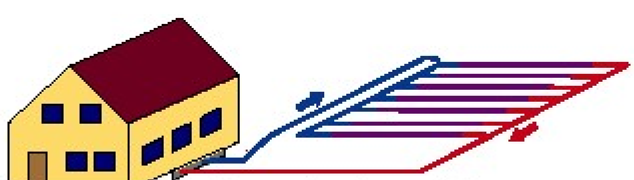


Pipe in trench

Where there are restrictions is available land the individual pipes may be laid in a relatively dense pattern and connected in series or parallel as show below.



Connection in series

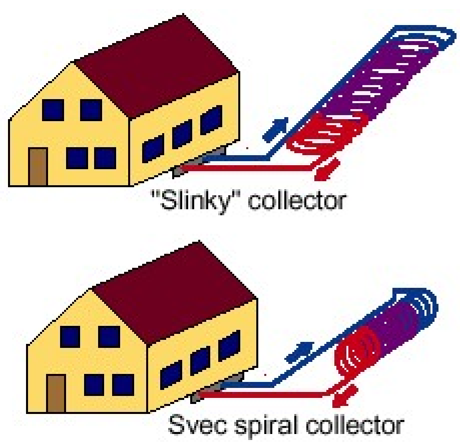


Connection in parallel

Below is a picture of a horizontal ground loop "mat" that is ready for backfilling to the depth called for in the system design.

"Closed" Loop Earth Connection

Slinky loops are used to reduce the heat exchanger per foot trench requirements but require more pipe per ton of capacity. This pipe is coiled like a slinky, overlapped and laid in a trench. Two-pipe systems may require 200-300 feet of more pipe per ton of nominal heat exchange capacity. The trench length decreases as the number of pipes in the trench increases or as slinky overlap increases.

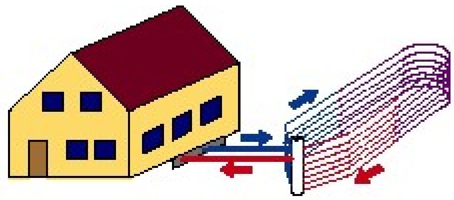


"Slinky" coils laid flat

Upright slinky coil installation

Trench Collector Closed Loop Earth Connection

To save surface area some special ground heat exchanger have been developed. They use a smaller surface area and a deeper trench for the installation of a number of circuits of narrow diameter pipe as shown.



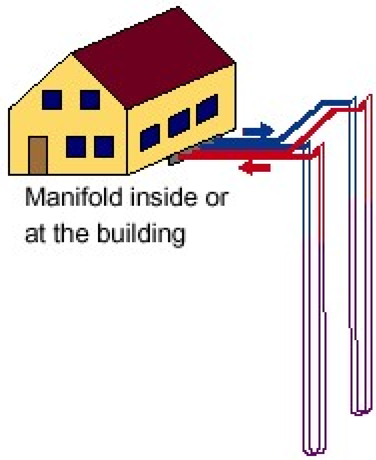
<u>Vertical Closed Loop Earth Connection</u>

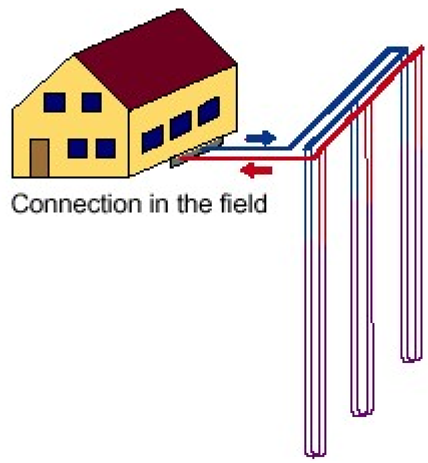
This type of loop is used where there is little yard space, when surface rocks make digging impractical, or when you want to disrupt the landscape as little as possible.

Vertical holes 150 to 450 feet deep - much like wells - are bored in the ground, and single or multiple loops of pipe with a U-bend at the bottom is/are inserted before the hole is backfilled. Each vertical pipe is then connected to a horizontal underground pipe that carries fluid in a closed system to and from the indoor exchange unit.

Vertical loops are generally more expensive to install, but require less piping than horizontal loops because the Earth's temperature is more stable farther below the surface. Typical piping requirements range from 400-600 feet of borehole per system ton of heating cooling, depending (as always) on the soil properties and ground temperature conditions. This requirement usually results in 1-2 boreholes per ton of system load, again, the exact requirement being dictated by the thermal properties of the soil.

An important design factor is the spacing between boreholes. A rule of thumb is that boreholes should be 15-20 feet apart to avoid having the thermal conductivity of the boreholes conflicting with each other. Vertical ground loops typically require 150-300 square feet of land area per system ton of heating/cooling capacity.

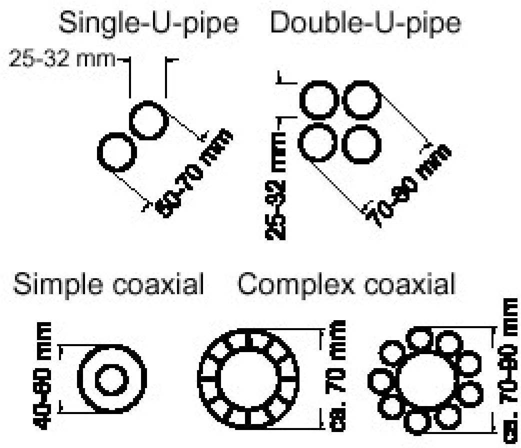




(Note that that in the two diagrams above there are 2 u-tube heat exchangers installed in each borehole!)

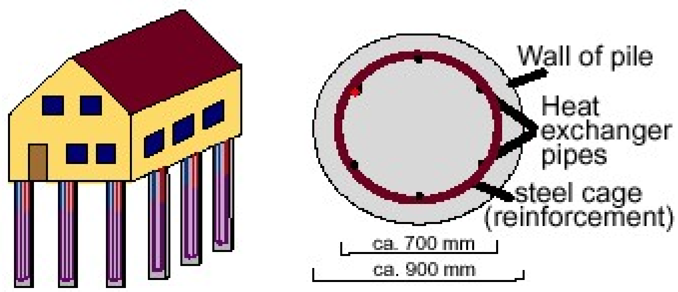
Several types of borehole heat exchangers have been used or tested. The geothermal industry has developed simultaneously in several countries and a variety of techniques are used. In Europe, where land is generally at a higher premium than in the U.S. techniques to minimize surface land requirements have driven the development. For example, placing a single U-tube per borehole as apposed to placing 2-3 U-tubes per borehole.

Likewise several types of borehole heat exchanger designs are used in different countries, although the single U-tube or U-pipe design seems most common in the U.S. (see below).



Energy Pilings

Foundation pilings may be equipped with ground loop heat exchanger piping. This system may be used with pre-fabricated or cast on-site pilings, and in piling sizes from 16” to 3’.



Grouting the borehole of a vertical closed loop geothermal system

In the early days of geothermal development it was not understood how important the grouting of the vertical borehole was to the success of the entire installation. The borehole must be able to efficiently act as a heat sink and heat source. This ability is the borehole’s *thermal conductivity efficiency* and it is impacted significantly by the grouting approach used. The following paragraph reviews some approaches to borehole grouting of geothermal systems. Local regulations dictate the final method selected.

Where the local water table is known to be reliably near the surface, the borehole can be backfilled with pea gravel, which allows groundwater circulation around the U-tube elements. Where the soil is dry or where there are large seasonal fluctuations in the groundwater level, or where local regulations require permanent sealing of the borehole, a *thermally enhanced* grout should be used to backfill around the U-tube. Thermal performance also can be enhanced by the use of spacer clips at 5-foot

intervals along the length of the piping element, which force the legs of the U-tube against the borehole wall.

Fluid choices available for the closed loop geothermal systems

The burial depth, type of soil, horizontal, vertical, or submerged ground loops and geographic location all impact whether or not antifreeze protection will be needed in the ground loop fluid. Water alone is the most preferred choice for a closed ground loop system circulating fluid, as it poses no environmental hazard.

When antifreeze protection is required there are two types of antifreeze solutions that are used: propylene glycol and methyl alcohol. These heat-transferring solutions are mixed with water to form a solution for the specific climate and ground conditions. GTF (geothermal heat transfer solution) is the most widely used and industry accepted. GTF is a mixture of methyl alcohol and water.

Useful Life of Closed Loop Ground Connection

The high-density polyethylene pipe is used in a closed loop system has a 50-year warranty. Independent tests show a useful life span of over 200 years. Thermal fusion and stab fittings are the only acceptable method used to connect pipe sections. Thermal fusion connections are either socket or butt fused together to form a joint stronger than the original pipe. Using barbed fittings, clamps and glued joints are unacceptable and will eventually cause the loop to leak and fail.

CASE STUDY OF ONE OF THE LARGEST CLOSED LOOP GEOTHERMAL SYSTEMS IN THE WORLD

The Richard Stockton College of New Jersey boasts one of the world's largest single closed loop geothermal HVAC systems, totaling 1,741 tons of installed geothermal heating/cooling capacity. The project design featured 400 heat exchange wells located in boreholes to a depth of 425 feet.

The wells were installed in a 3.5-acre area that included all of the college's Parking Lot # 1 plus some adjacent open space. Use of the parking lot reduced the disturbance of undeveloped land on the campus. The local groundwater regulatory authority was initially concerned about protection of three underground aquifers that would be crossed by the wells.

Construction plans needed to demonstrate that there would be no compromise of ground water and that the aquifers would continue to be sealed from interchange with each other and with surface water. The college's decision to use only pure water (without glycol) as the heat exchange medium also helped assuage the commission's concerns.

Approximately four feet of surface soil was removed from the loop area and stockpiled before starting the drilling and trenching operations. After completion, the area was returned to its use as a large parking lot. The wells were located on a grid and spaced roughly 15 feet apart. This work was done by a group of local well drillers.

The boreholes were four inches in diameter. Within the four-inch borehole, the installers placed two 1.25-inch high-density polyethylene pipes with a U-shaped close-return coupling at the bottom. Installation of the pipes was complicated by the fact that the boreholes filled with groundwater and the pipes were buoyed upward. Installers overcame this problem by attaching weights to each loop and filling the heat exchange pipes with water.

After the pipes were installed in the boreholes, the holes were backfilled with a bentonite clay slurry to seal them and to enhance heat exchange. In total, the loop system comprises 64 miles of heat exchange pipe. In addition, 18 observation wells were located throughout and around the well field for long-term observation of ground water conditions. In the heating mode, the loop serves as a heat source and, in the cooling mode, as a heat sink.

In the first few years of operation, the average temperature of the well field drifted upward by several degrees. It now appears to have stabilized. This occurred because the cooling load annually releases more thermal energy to the ground than the heating load requires. Even in the cooler winter months, the system often operates with some units heating while others are in the cooling mode.

Because of its size and design, the geothermal system has made the campus a destination for many visitors/engineers and prospective owners from around the world. Visitors from China, Japan, Korea, Sweden, Germany, France, England, and other nations have visited the College to learn about the system’s design and operation.

One thing the college would incorporate into the system' design if it was being done now is a <u>cooling tower</u>. One college official stated: "Either a wet or dry model cooling tower, to precondition the well field in the winter months for cooling later in the summer. "*For situations like ours, where cooling hours significantly outweigh heating hours, a cooling tower could add even more to system efficiency or capacity. That's something we didn't include in our original plans, but today we would."*

(cooling towers are discussed under hybrid geothermal systems)

The same college official made this comment: "It is critically important to have a good design and good implementation. Make sure that the engineer gets all the support needed to understand geothermal technology and design. That's the single most important thing."

(end of case study)

<u>Submerged closed loop earth connections</u>

If a large river or moderately sized pond or lake is available, the closed-loop piping system can be submerged. Some commercial and institutional buildings have artificial ponds for aesthetic reasons, and these may have adequate surface area and depth for fully immersing a closed-loop heat exchanger.

Submerged-loop systems typically require about 300 linear feet of piping per system ton. Depending on the pond depth ponds can support GHP systems ranging from 15 to 85 tons per acre of pond surface area. This range corresponds to a unit area requirement of 500 to 3,000 square feet per system ton. The minimum acceptable pond depth for submerged ground loops is 10 feet.

Concrete anchors are used to secure the piping coils, preventing their movement and holding the coils 9 to 18 inches above the pond floor, to allow good convective circulation of water around the piping. It also is recommended that the coils be submerged at least 6 to 8 feet below the pond surface (Figure 13), preferably deeper, in order to maintain adequate thermal mass in times of extended drought or other low-water conditions.

Pond loops are a special kind of closed loop system. Geothermal transfer fluid is pumped just as a closed loop ground system. First cost economics are very attractive and there is no aquatic environmental impact.

HYBRID CLOSED LOOP GEOTHERMAL SYSTEMS

Hybrid Closed Loop Earth Connection with Supplemental Cooling Pond

Pond loops can also be utilized as part of a hybrid GHP (geothermal heat pump) system where an additional heat sink is needed to add to the efficiency of the system. (*Note that in the Richard Stockton College Case study above the College suggested in would have included an additional heat sink into its system if it was being built today!)*

GHP systems for school buildings in the southern areas of the U.S. can be expected to reject significantly more heat to the ground loop than they extract from it during the course of a year. To avoid overheating the ground loop area and thus decreasing the system's cooling efficiency, this seasonal imbalance can be accommodated a supplemental means of heat rejection such as a pond.

Research at Oklahoma State University suggests that it is less costly to build artificial ponds than to install cooling towers (discussed below), particularly if the pond is built on school property and additional land does not have to be purchased for pond construction.

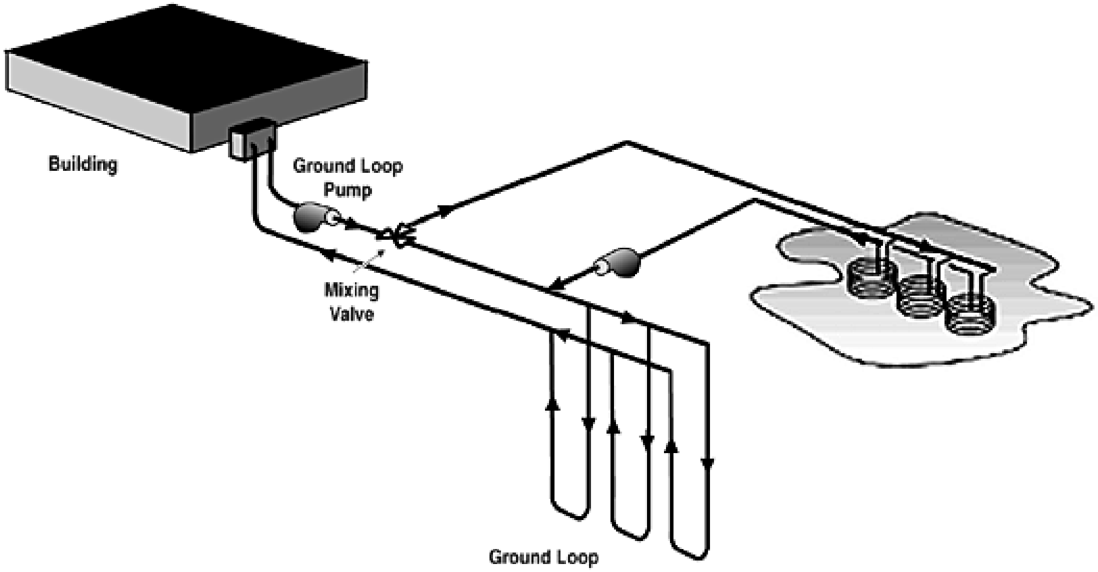


Diagram of a hybrid GHP system with supplemental cooling pond

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Hybrid closed loop earth connection with cooling tower

A cooling tower is an alternative to consider in cases where an artificial pond cannot be built for supplemental heat rejection. In this type of hybrid GHP configuration, the cooling tower can be connected directly to the ground loop, or it may require an isolation heat exchanger, depending on the type of cooling tower.

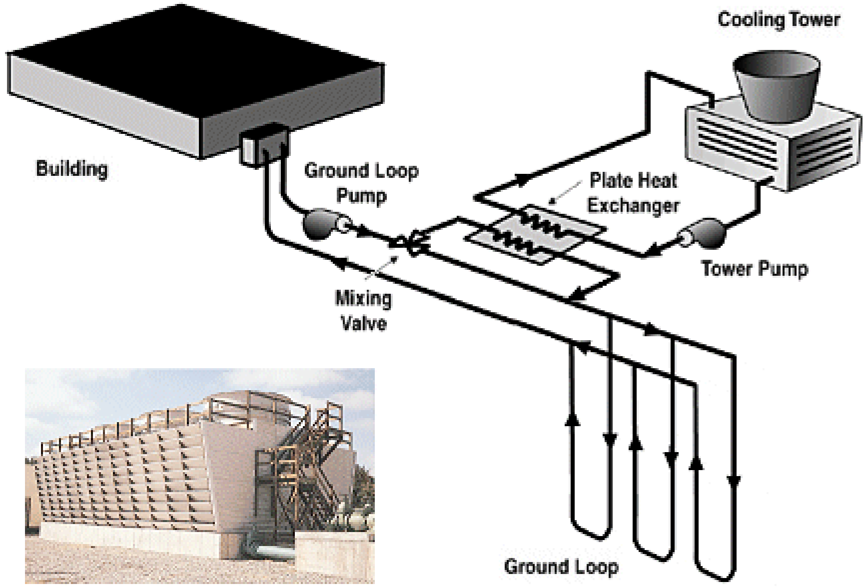

Diagram of a hybrid GHP system with supplemental cooling tower

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Hybrid loop with solar collector

For GHP systems being designed for colder weather parts of the U.S. heating load might be the driving ground loop design factor. In such cases, supplementing a GHP system with solar thermal collectors will reduce the required size of the ground loop and increase heat pump efficiency by providing significantly higher building loop temperatures than could be attained by the ground heat exchanger alone. In most cases, the solar thermal collector can be connected directly to the ground loop, as shown.

A liquid/liquid isolation heat exchanger would be required, however, if the solar recirculating loop needs a different level of antifreeze protection than the ground loop or uses a different antifreeze additive.

Solar thermal collectors almost always use propylene glycol for both antifreeze and anti-boiling protection, whereas methanol is the preferred antifreeze additive for closed ground loops, where environmental and health regulations permit its use.

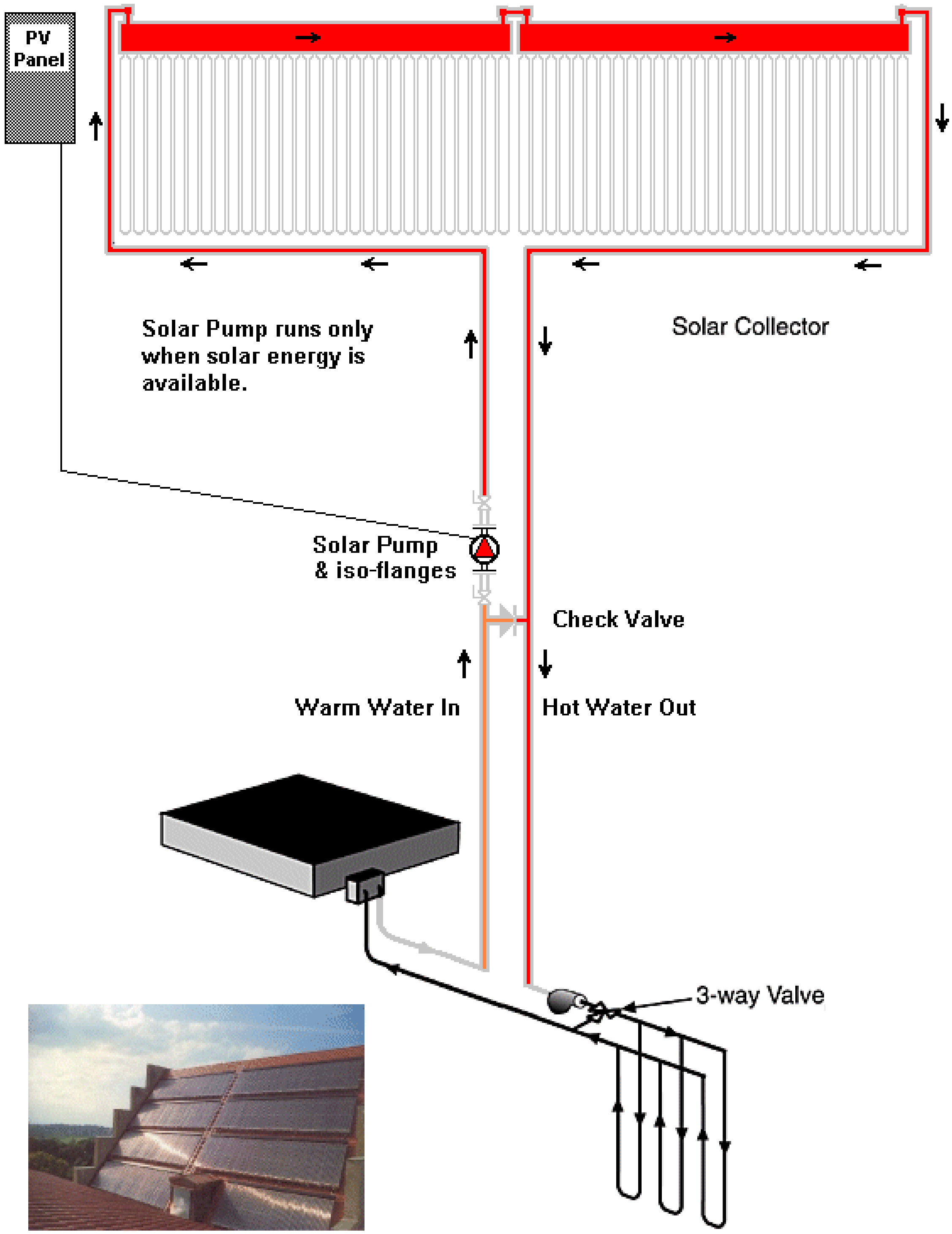


Diagram of a hybrid GHP system with supplemental solar thermal collector

DIRECT EXCHANGE (DX) CLOSED LOOP SYSTEMS

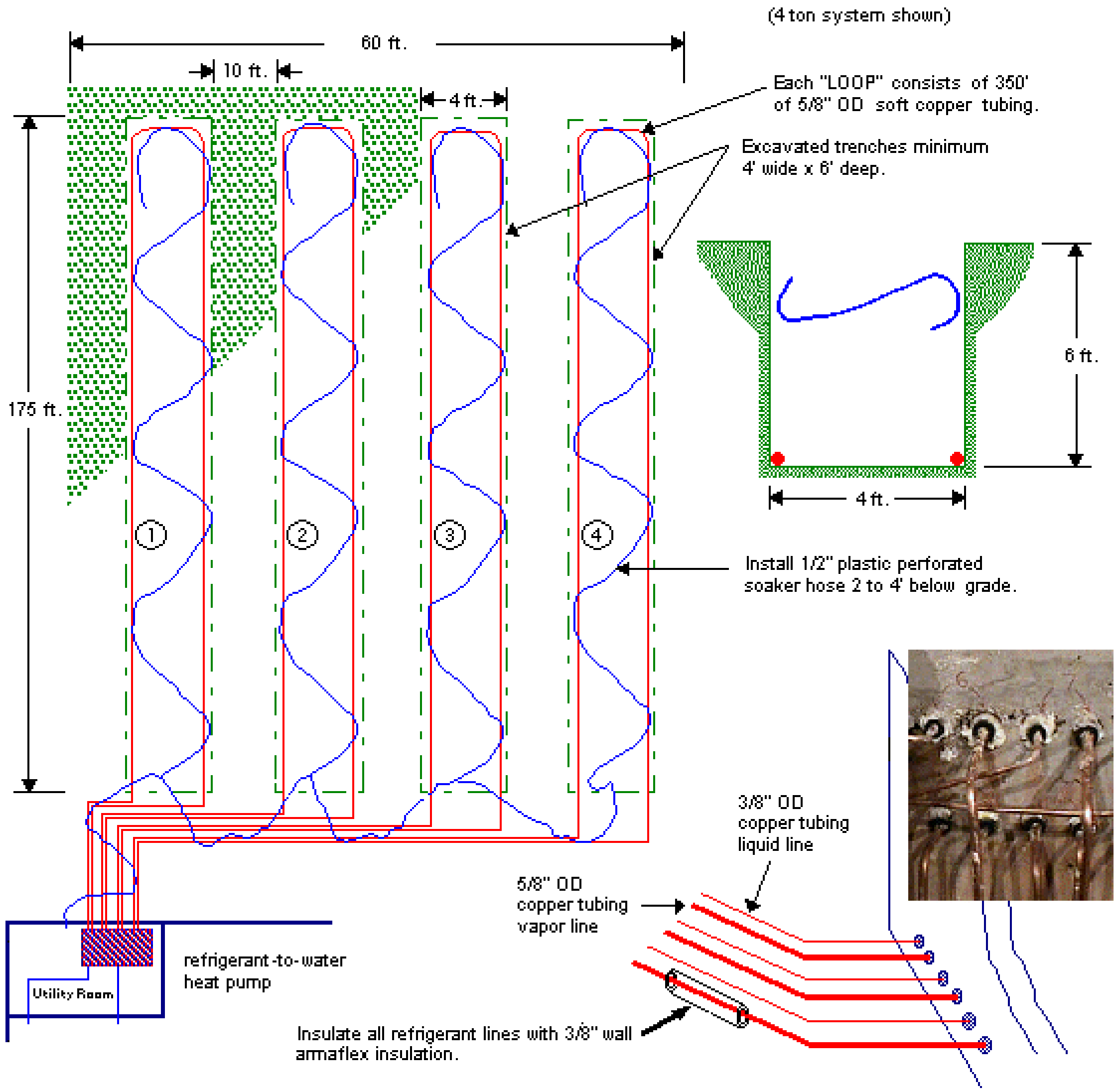
The closed ground-loops described above use water or a water-antifreeze solution as an intermediate working fluid to move heat energy between the ground (or water body) and the building, with a liquid/refrigerant heat exchanger in each heat pump unit.

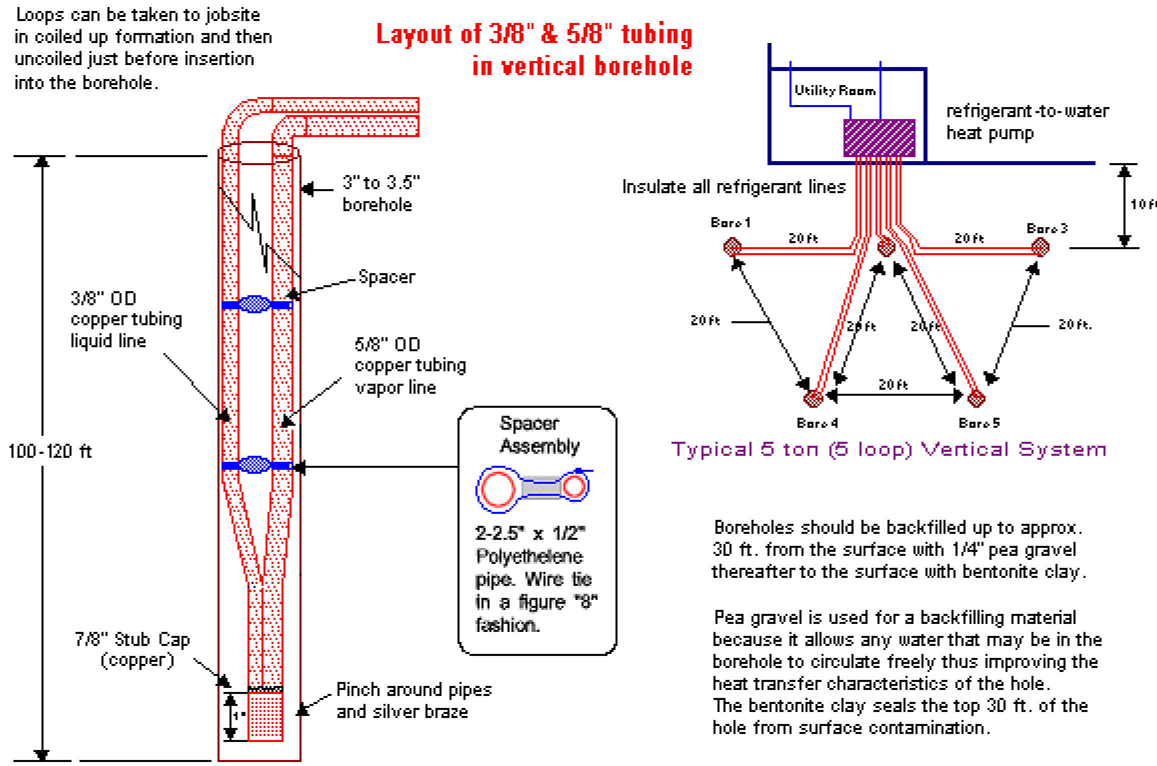
Direct-exchange (DX) systems do not use an intermediate working fluid or heat exchanger. Instead, DX systems employ closed loops of soft copper tubing to directly transfer heat between the ground and the refrigerant -- the heat pump's refrigerant loop is buried in the ground (See diagrams below).

By eliminating the intermediate heat exchanger, the refrigerant's temperature is closer to the ground's temperature, which lowers the heat pump's required compression ratio, reducing its size and energy consumption. Also a shorter ground loop can be used, because copper tubing is six (6) times more efficient at transferring heat than the polyethylene pipe used in conventional closed loops; the thermal conductivity of copper is about 19 Btu/sq.ft-hr-°F per inch of wall thickness, whereas that of HDPE pipe is only 2.7 Btu/sq.ft-hr-°F per inch.

DX ground loops can be installed in a horizontal trenched configuration or a vertical U-tube configuration as shown below. Horizontal-loop DX systems require about 350 feet of copper tubing per system ton, as opposed to 450 to 500 feet per ton for polyethylene ground loops. Similarly, vertical DX systems require only a 3-inch diameter bores to a depth of 120 feet per ton, as opposed to 4- to 6-inch diameter bores to a depth of 200 to 300 feet per ton for polyethylene U-tubes in conventional vertical closed loops.

Layout of Horizontal Direct Expansion Heat Pump System





DX geothermal heat pumps are offered by only two manufacturers in North America and are commonly available in the 2- to 5-ton size range. To date DX GHPs have been installed only in residential and small commercial applications, where a blower forces air through a refrigerant/air heat exchanger, and a duct sytem distributes the warmed or chilled air throughout the building. In larger building applications a refrigerant/water heat exchanger is used to transfer the heat to a pipe system that can distribute warmed or chilled water to hydronic terminal systems such as radiant floor slabs or fan-coil units.

Because of their shorter length, horizontal DX ground loops need only about 500 square feet of land area per system ton, considerably less than the 1,500 to 3,000 square feet needed for conventional horizontal closed-loops. Vertical DX loops, on the other hand, need at least the same land area as their conventional counterparts, or even somewhat more. Vertical DX boreholes should be spaced at least 20 feet apart to minimize the possiblity of ground freezing and buckling in the heating mode or excessive warming and drying of the soil in the cooling mode.

Heat from DX ground loops can bake fine-grained soils, reducing their thermal conductivity and thus the performance of the system. DX ground loops perform best in moist sandy soils or sand bed installations.

Because DX ground loops are copper, they are subject to corrosion in acidic soils and should be installed in soils with a pH between 5.5 and 10.

SUMMARY

Low-grade geothermal technology is a cost effective, environmentally friendly method of providing heating and cooling. Already widely accepted around the world, this technology continues to grow in popularity.

It is clear that many factors impact the design of the most efficient and cost-effective geothermal system for any given application. Proper design requires the use of experienced professionals familiar with the application desired. Drillers can view the geothermal industry as an opportunity for growth and expansion if they become knowledgeable about this exciting field.

This CEU has been prepared for those readers unfamilar with this technology to give them a brief overview of this fascinating field.

END OF TEXT

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