Installing a Geothermal Heating and Cooling System

Ground-source heat pumps rely on buried water loops to heat and cool efficiently and economically

BY WILLIAM J. EVANGELIST

Not for urban house lots. A horizontal ground loop for a geothermal heating and cooling system requires a generous backyard. The trench for this house is roughly 400 ft. long and 6 ft. deep.

Back in the early 1980s, my mechanical-contracting business installed air-to-air heat pumps and gas furnaces. Period. Then I started designing a new house for myself. I oriented the house for passive-solar heat, chose premium windows and doors, and after some intensive research, settled on a geothermal heat pump to heat and cool the house. It was the clear first choice.

Soon after I moved in, my brother built a house. He also wanted a geothermal system. Two neighbors were next. Before I knew it, geothermal heating and cooling had become my full-time business, and business is good.

In eastern North Carolina, where I live, air-source heat pumps are common. During the winter, however, these heat pumps have to work harder to extract heat from the air, and they become less efficient. When outside temperatures fall to about 30°F, electrical-resistance heaters kick in, making heat pumps relatively expensive to run. Although geothermal heat pumps are similar, they are more efficient. Both types work on the principle of vapor compression—just like air conditioners and refrigerators (sidebar p. 106). Electrically operated pumps and compressors move heat from one medium to another. But because no fuel is burned, the heat pump

DESIGN BASED ON THE SITE

Ground-source heat pumps can rely on any one of four underground water systems, depending on conditions at the site. They include pond loops (top), horizontal loops (center) and vertical loops (bottom). Another option is an open loop (not shown) in which well water is used and then discarded.

does not have to be vented. The same unit can heat a house during the winter and cool it in summer. Although many ground-source heat pumps run forced-air heating systems, some models can power hydronic heat or radiant-floor heating systems as well.

Geothermal systems pick up heat from water circulating through plastic pipe buried in the ground. They work well no matter where you live because underground temperatures stay relatively constant all year, even where outdoor temperatures vary widely. Once you get down about 6 ft., the temperature of the earth in this region is a steady 55°F.

Typically, the installed cost of one of our heat pumps is at least 20% and as much as 80% more than an air-to-air heat pump or a gas furnace plus central air-conditioning. However, the energy use can be 40% to 60% less. There's little maintenance required, and geothermal units are quiet. Mechanical equipment is inside the house, which is not the case with air-to-air heat pumps or central air-conditioning units, so the landscape is much more appealing.

System is sized according to heating and cooling demand

Heat-loss and heat-gain calculations are the key to choosing the right equipment. For an existing house, I measure wall lengths and ceiling heights, note the size and type of windows, check the orientation of the house to the sun and determine what kind of insulation the house has. For a new house, all the information I need to determine the loads should be on the house plans.

Using a room-by-room calculation helps me to size the ductwork properly. WaterFurnace, the brand of heat pump we use (Fort Wayne, IN; 800-436-7283; www.waterfurnace.com), allows us to offer zoned heating and cooling with a single piece of equipment. These units use multiple thermostats, motorized dampers, and variable-speed blowers and compressors. They can be installed in basements, crawlspaces, attics, closets or garages. Slightly larger and heavier than the air-to-air heat pumps, ground-source heat pumps are still light enough to be placed on standard framing in a second-floor installation.

I also ask whether anyone in the family has allergies that may require special air filtration. Set-point temperatures for both heating and cooling—where the equipment will turn on and off—also are important in sizing the equipment correctly. We typically use 70°F for the heating set point and 75°F for the cooling set point, but even relatively small changes in these numbers can affect the size and cost of the equipment we use.

Our system also helps to heat domestic hot water with a built-in device called a desuperheater. These systems generally supply between 50% and 70% of hot-water needs.

The ground loop can be one of four different designs

Geothermal heat pumps can use any one of four types of ground loops (drawing left). The design is based on the conditions at the building site. At my own house, I was able to use the 30-gal. per minute (gpm) well that had been drilled for our domestic-water supply in what is called an open loop. This arrangement is possible only if the well produces enough water volume to meet the demand of the heat pump—1½ gpm per ton of heating and cooling (a ton is the equivalent of 12,000 Btus). That amounts to at least 5 gpm for a

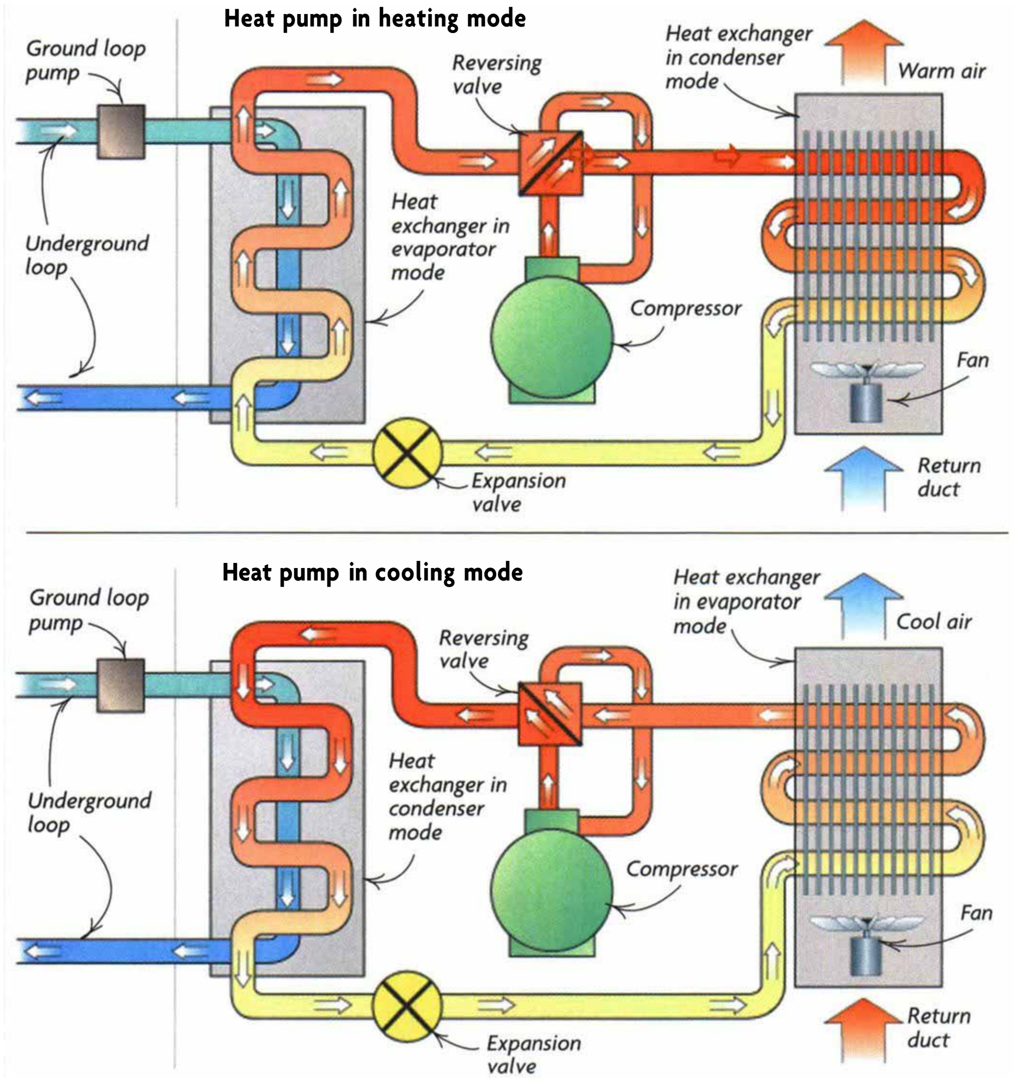
Drawings: Paul Perreault

How the heck does a geothermal heat pump work? By Scott Gibson

Any fool would want to know how cold water can heat a house in the winter. In two words, the answer is "vapor compression," a principle of refrigeration that has been in practical use since the mid-19th century.

Heat pumps are refrigeration devices running backward. They do not generate heat like a conventional furnace or boiler; they just move heat from one place to another. At the heart of a ground-source heat pump is a sealed loop containing a refrigerant (drawing right) that interacts with both water circulated through underground pipes and with air from the house. Working pressures and temperatures of water and refrigerant systems inside a heat pump can vary widely, depending on the size of the system and entering air and water temperatures. The numbers used in the following scenario do not apply to all ground-source heat pumps or all installations.

Boosting earth's natural heat. A ground-source heat pump relies on the principle of vapor compression to extract heat from a closed, underground loop of water-filled polyethylene tubing. Inside the heat pump, a sealed refrigerant system is the heat-exchange medium. During summer, the direction of the refrigerant is reversed, allowing the pump to extract heat from the air.



FROM A LIQUID TO A GAS AND THEN BACK AGAIN

At the beginning of the heating cycle, water circulated through underground pipes then enters a heat exchanger. At the beginning of the heating season, the water temperature might be 50°F or 55°F. By the end of the season, it may have cooled to 30°F. Even at that temperature, the water is warmer than the refrigerant. When the two meet in the heat pump's evaporator, the refrigerant warms up and changes from a liquid to a gas. The refrigerant is sucked into an electrically driven compressor at 55 to 65 pounds per square inch (psi), where it is heated to 94°F and released at 180 psi. This gas now enters a condenser, where it gives off heat to a stream of air moved by fans. This 95°F air is what gets ducted around the house and keeps you warm. The refrigerant goes through an expansion valve, where it cools further and once again becomes a low-pressure liquid.

That takes care of cold weather. In summer, when the problem is too much heat, the flow of the refrigerant is reversed, and the heat pump becomes an air conditioner. Air from the house circulates through the heat pump, where it is cooled and dehumidified. The refrigerant transfers the heat to the circulating water in the ground loop, so the earth becomes a heat sink. Excess heat also is routed through another heat exchanger called a desuperheater (not shown in drawing), where it warms domestic water. In the cooling season, hot water is essentially free.

The refrigerant in WaterFurnace heat pumps is R-22, a hydrochlorofluorocarbon (HCFC). HCFCs have a lower ozone-depletion potential than chlorofluorocarbons (CFCs), whose production was banned in the 1990s.

—Scott Gibson, a free-lance writer in Middlebury, CT.

2,000-sq. ft. house. Well water is pumped into the unit, where its heat is extracted and then discharged, in my case into a creek.

If there's enough well capacity and getting rid of the water is not a problem, this system is usually my first choice because it has the lowest installed cost. In this area, an open-loop system for a 2,000-sq. ft. house would cost between $6,000 and $10,000. Although an open-loop design can include a return well for water that has run through the heat pump, this system gets expensive.

When a well doesn't produce enough water to support the heat pump, a closed-loop system is used. There are three kinds: a pond loop, a vertical loop and a horizontal loop. The simplest is a pond loop, which consists of coils of $^3/_4$-in. polyethylene pipe that are submerged in a pond. Of course, you've got to have a pond (8-ft. minimum depth). But if you do, the cost would run between $9,000 and $13,000 for the same 2,000-sq. ft. house.

A vertical loop is the way to go when there isn't a lot of land to work with. Typically, two $1^1/_4$-in. pipes with a U-bend at the bottom are dropped into a 6-in. dia. hole, which is then backfilled with high-solids bentonite grout. Depths range from 100 ft. to 400 ft., depending on the design of the system. An average 2,000-sq. ft. house would need between 350 ft. and 400 ft. of depth, either in one deep shaft or two shallower ones. This system is the most expensive approach because of the drilling costs, and a system such as this one would probably cost between $14,000 and $19,000.

I put in more horizontal systems than any other kind. You don't need a pond, and it's less expensive than a vertical bore. The only catch is that you need a little bit of land (photo p. 104). We dig a 6-ft. deep trench about 2 ft. wide and lay in $^3/_4$-in. polyethylene pipe at the 6-ft. level and at the 4-ft. level. We need about 150 ft. of trench for each ton of heating and cooling load, so the house I've been using as an example would need about 400 ft. of trench. A system such as this one would cost between $11,000 and $15,000.

Check for underground utilities before you start digging

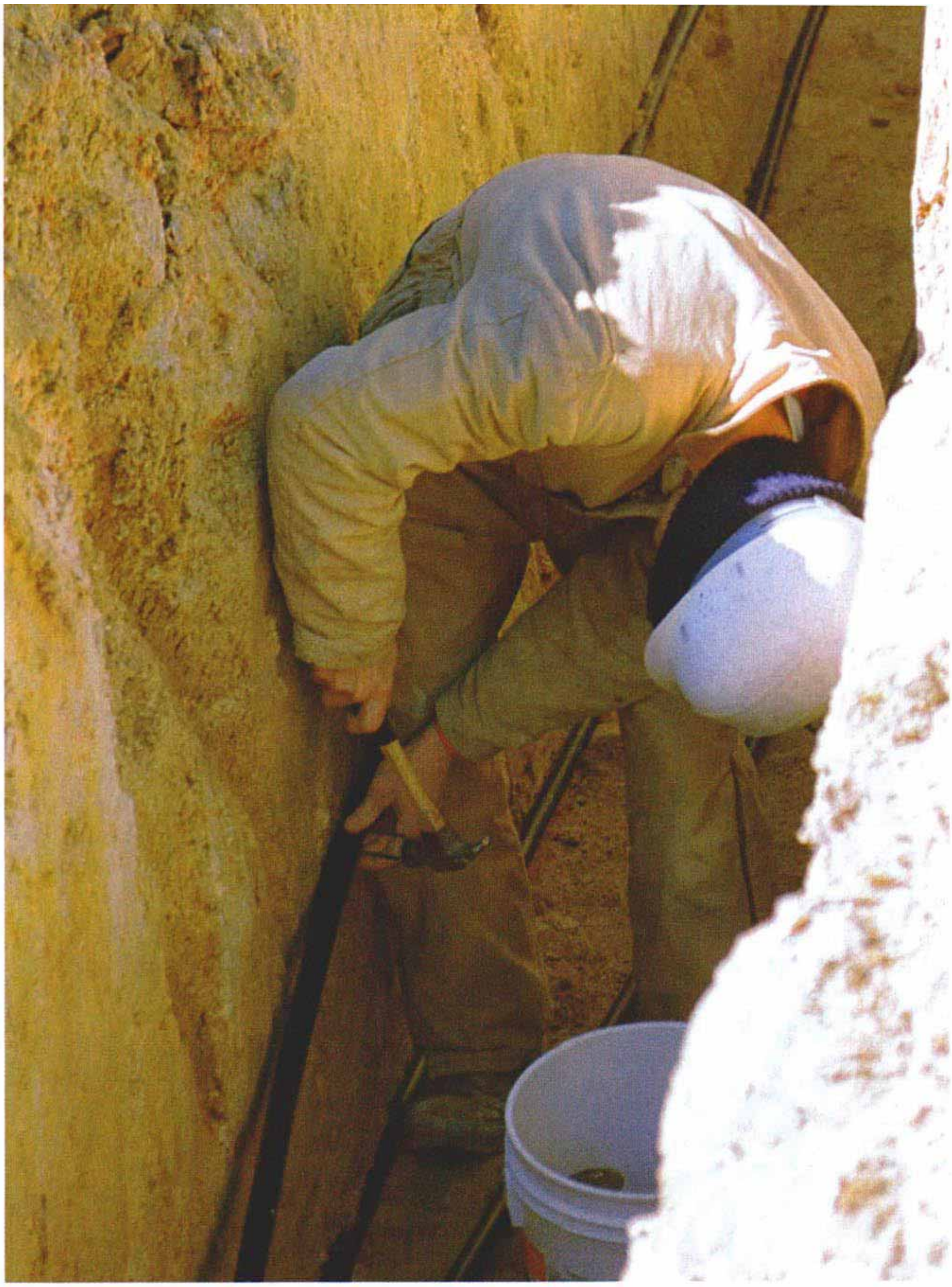
Before any excavation begins, we measure and mark off the area for trenching, and we always contact local utilities for information on buried gas, water and electric lines. In this installation, we were lucky. There was plenty of room behind the house for the trenches. I decided to go with two separate trenches that are parallel for about half their length. As I neared the tree line, I turned the trenches back toward the house, so from the air,

Heat pumps can live virtually anywhere. Even a crawlspace with crouch-only headroom is large enough for this style of heat pump. Other models stand upright. Supply and return ducts are insulated.

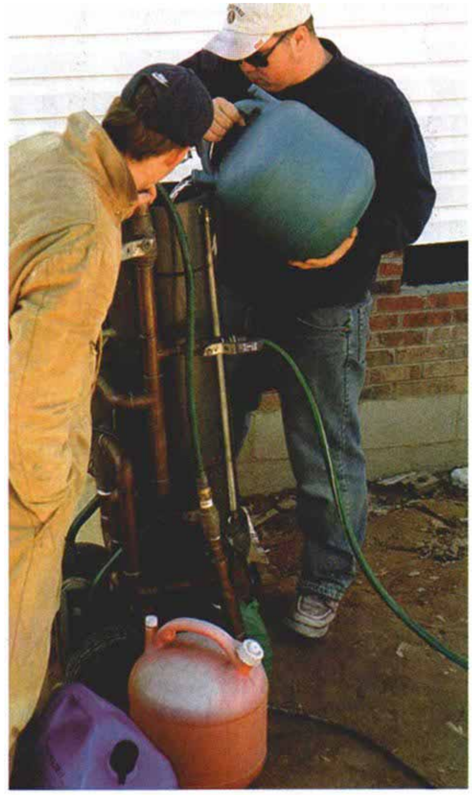
Sealing foundation against leaks. Where supply and return lines penetrate the foundation, the author uses plastic sleeves and boots to seal out water. Corrugated plastic drain line protects the water loop from damage.

Color-coding keeps loops straight. Manifolds divide the single supply and return lines into four separate circuits. Colored vinyl tape identifies each circuit, two stripes for supply and a single stripe for return.

Heart of the system is underground. After coils of tubing have been pressure-tested, they are rolled into a waiting trench. Note that the shoulders of the trench have been stepped back to minimize the threat of a collapse.



Two loops in the same trench. To make the most of the heat potential in soil that surrounds buried tubing, loops that share a common trench must be separated. One is placed at the full 6-ft. depth; the other is stapled to the wall 2 ft. above it.



Air out, antifreeze in. A flush cart is used to add water and antifreeze to the system while removing trapped air. The ethanol antifreeze boosts the system's efficiency and allows for shorter runs of tubing.

each of the trenches would have appeared to be a big J.

In the crawlspace near the heat pump, we installed a flow center, which is the pump assembly for the loop water (top photo, p. 107). We ran one supply line and one return line from the flow center through the foundation wall (center photo, p. 107) to what we call a header pit outside. That's the area, about 6 ft. below grade, where these lines are connected to manifolds that separate supply and return lines into a number of separate circuits.

In the installation shown in these photos, there are four loops of polyethylene pipe, two loops in each trench. Each manifold has four ports (bottom photo, p. 107). On the supply side, each port channels water into a loop; on the return side, the manifold gathers water from each loop and sends it back to the heat pump via the return line. Before the polyethylene is actually laid in the trenches, we pressure-test and color-code each loop. The coding, strips of colored vinyl tape, keeps us from confusing the big rolls of tubing when they are hooked up to the manifolds. All tubing connections are heat-fused, making a joint that is as strong as the tubing itself.

Putting the loops in the ground is simple. A roll of tubing starts at the header pit. It is unrolled down the trench (photo facing page), turned around in an enlarged pit at the end of the run, then returned to the header pit. Tubing at the 6-ft. level at the bottom of the trench is held in place temporarily with soil while we run the second loop. Tubing at the 4-ft. level is attached to the walls of the trench with landscaping staples (photo above left). When all is in place, the trench can be backfilled. I tamp down the soil with the backhoe's bucket as I go to minimize settling.

To charge the system, air must be removed from the lines

Before the header pit can be filled in, several steps remain. We must fill the lines with water, add ethanol to prevent freezing and then pressure-test the circuits again. To add water and remove air from the loops, we use something called a flush cart from WaterFurnace. When the system is full of water, we use the same device to add ethanol—about 20% of the total volume of the loop (photo above right). The ethanol prevents freezing and makes the system more efficient so that we can use shorter trenches. As ethanol is added, an equal volume of water is taken out of the loop, keeping the system free of air pockets.

Finally, we install interior grates and thermostats and start the system. We brief customers on how to operate the system and provide maps of buried water loops. ❑

William J. Evangelist's company, Evangelist Service Company (www.geoevangelist.com), is in Apex, North Carolina. Photos by Scott Gibson.