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GROUND-SOURCE HEAT PUMPS

by Jim Soden

Hvac installers heat-fuse a joint in a ground-loop pipe.

This efficient technology uses underground heat transfer loops to cut heating and cooling costs

As a second-generation heating and air-conditioning contractor, I've installed hundreds of conventional hvac systems. But I also like to experiment, so when I first heard about geothermal, or ground-source, heat pumps back in 1979, I decided to try the technology out. Those early geothermal systems I installed are still working, providing low-cost heating and cooling. I now specialize in the technology, and with support from local electric utilities, I install over 120 systems a year — two or three a week.

Ground-source heat pumps work on the same principle as a refrigerator or air conditioner: They concentrate and move heat rather than creating it. But unlike the air-source heat pumps commonly used in the South for heating and cooling, ground-source heat pumps don't have to extract heat from cold outside air in winter, or pump heat into hot outside air in summer. Instead, they move heat into or out of underground soil, which stays at 55°F year-round. This makes ground-source heat pumps more efficient than air-source types. Ground-source heat pumps also work in any climate — they're used from Canada to Florida.

Geothermal systems cost more up front than conventional hvac systems. The difference, usually between $2,000 and $5,000, is mostly from the drilling or excavating needed for the underground part of the system. But geothermal is cheap to operate (see table). In my area, heating costs are cut by a third and cooling costs are cut in half when you switch to geothermal. The payback period for a geothermal installation is usually three to five years.

Elements of a Geothermal System

A geothermal hvac system has three main parts: the ground loop, the heat pump itself, and the air handling system.

The ground loop. This continuous underground loop of plastic pipe is the unique element in a geothermal system. Circulating coolant in the loop collects heat from the earth in the winter and returns heat to the earth in the summer.

Ground loops can run horizontally in trenches or vertically in drilled holes. For each ton of capacity (that is, for 12,000 Btu/hr. of heating or cooling ability), the system needs 300 to 500 feet of ground-loop pipe. You can run more than one pipe in each trench, but any way you configure it, a typical house will need 300 to 500 feet of trench (Figure 1), or two or three bore holes 200 to 300 feet deep.

Whether I trench or bore depends on job specifics. Most of the houses I look at are on lots big enough for the trenches. But in retrofits, we often drill instead of trenching because the owners don't want their landscaping disturbed. Even in new construction, trenching may be impractical. Sometimes the backhoe hits a lot of boulders; in that case, drilling is usually easier. Other times we dig up a lot of shale, which isn't suitable for backfilling the trench because it can cut the pipe. If we

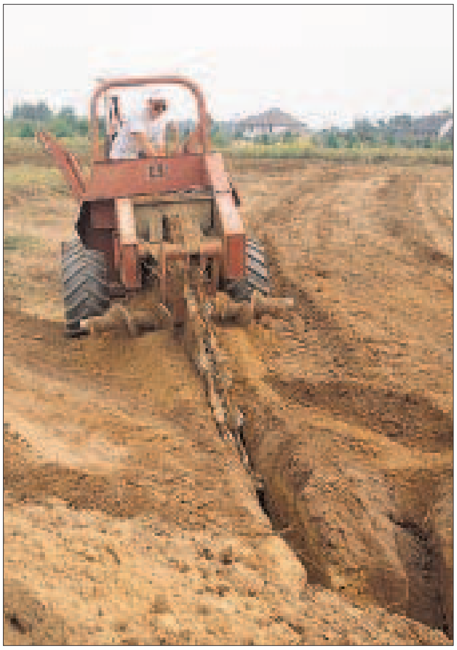

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Figure 1. *To put in a ground loop, the author digs several hundred feet of trench (left). On smaller lots, ground loops can be installed in vertical boreholes (right).*

can't backfill with the material from the trench, it's more cost-effective to drill than truck in suitable fill.

I used to use polybutylene pipe for the ground loops, but it's hard to work with because it tends to spring back into the coil shape it was stored in. These days we use polyethylene pipe because it stays flat when you lay it in a trench.

We try to avoid joints in the ground loops, using continuous pieces as much as possible. But some joints are unavoidable, either because the runs are too long or there are T-intersections. *Every joint in the ground loop must be heat-fused,* and it must be done right (Figure 2). No good installer would ever use a mechanical or glued joint in a ground loop, because it would probably fail in service.

After the pipe is in place, we fill it with coolant from inside the house (Figure 3). Some of the ground loops I install have water for the coolant fluid. Others have an antifreeze called Enviranol, a biodegradable, nontoxic mixture containing water, ethanol, a pine scent, and a blue dye. The scent and the dye help identify the fluid in case there's a leak.

The choice between water and antifreeze depends on the system — loops that will run warmer than 35°F usually get water. Typically, water gains or loses about 8°F on its way through the heat pump. In winter it enters the house at around 55°F and exits at about 47°F. In summer, it will be sent back out close to 63°F. Because loop lengths and soil conditions vary, some systems run colder; the colder a fluid is, the more readily it extracts heat from the ground.

Scheduling. For new construction, the best time to install the ground loop is between rough and finish grading. When you're building more than one house at a time, you can save money if you arrange to do all the ground loops at once.

The Heat Pump

A heat pump works like an air conditioner, but it can both heat and cool. In winter, it removes heat from the circulating fluid in the ground loop and pumps the heat into the air supplied to the house. In summer, when the house needs cooling, the cycle is reversed: The pump cools the circulating air and dumps the heat into the ground-loop fluid, which returns it to the earth.

Whether in the heating or cooling mode, the geothermal heat pump also heats domestic water at the same time. The desuperheater, a small coil just before the condenser coil that removes excess heat from hot refrigerant, supplies the heat for the water.

Most heat pump models heat water only when the house is calling for heat or cooling; the rest of the time, water is heated by resistance coils. But new models coming onto the market provide full-time dedicated water heating. These models are more efficient — the more you get away from resistance heat, the greater the efficiency gains.

The geothermal heat pumps I install are supplied by Water Furnace, of Fort Wayne, Ind. (Figure 4). Units for residential systems range in capacity from 10,000 Btu to 75,000 Btu. If a house needs more than 75,000 Btu, we set up multiple zones and use multiple units.

I use only Water Furnace units because I have confidence in the company's quality control program. After putting in hundreds of them, I have very few maintenance calls. That is not to say that other manufacturers aren't producing good equipment, though — for a list of sources for geothermal equipment.

In choosing a supplier, you'll want to

Annual Operating Costs For Ground-Source Heat Pumps

City	Heating Cost	Cooling Cost	Water	Total Annual Cost
Boston, Mass.	$717	$86	$431	$1,234
Albany, N.Y.	931	68	413	1,412
Trenton, N.J.	641	125	381	1,147
Atlanta, Ga.	367	233	331	931

Note: *The figures shown are operating cost estimates for a Water Furnace geothermal heat pump system installed in a 2,500/sq. ft. house with R-19 wall insulation and R-30 ceiling insulation. The values were generated by the computer program the author uses to size the systems. Power company audits in New Jersey show that homeowners' actual operating costs come within 2% of computer estimates. The estimates in the table are based on electric rates of 13¢/kwh; actual operating expenses will vary depending on local electric rates.*

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Figure 2. *Plastic pipe for the ground loop penetrates the foundation wall below the frostline (above). A rubber clamp secures the pipe to the PVC sleeve in the foundation wall. All T-joints in the ground loop pipe are made with an electric heat-fusing tool — mechanical or glued joints will not hold up (left).*

keep quality in mind. These are relatively expensive items, and it's worth buying a product that is backed 100% by the manufacturer.

You'll also want to compare efficiencies. A more efficient heat pump can pull the same amount of heat out of a shorter ground loop, so it isn't worth saving money on a cheaper but less efficient unit — you'll spend it all and more putting in a bigger ground loop.

Heat pumps are efficiency-rated by the Air Conditioning and Refrigeration Institute (ARI) in terms of Coefficient of Performance, or COP. The COP is the ratio of heat output to electrical input. Air-source heat pumps typically range between 2 and 3 when outside air temperatures are 35°F to 40°F. When outside air goes below freezing, air-source COPs drop off dramatically. The ground-source units we install have a COP of anywhere from 3 to 5, regardless of outside air temperature. It's the high COP that makes these systems so economical to operate.

The Air-Handling System

The fans and ductwork that deliver hot or cool air to the house in a geothermal system are similar to the system found in any forced-air furnace or central air conditioner. The difference is that the heat comes from a condenser coil, not from a flame. (There's plenty of heat output, though — older air-source heat pumps produced 85°F air that felt cool coming out of the registers, but today's ground-source systems heat air to over 100°F, so it feels warm to the skin.)

Water Furnace units have a two-phase compressor and a variable-speed fan. Usually, the system comes on when the room temperature drops by a degree or two, and the fan moves air very slowly, so that hot air just oozes out of the registers. But if there's a bigger temperature drop — say someone leaves a door open while unloading groceries — the compressor kicks into high and the fan comes on at full speed. Then the system supplies high volumes of hot air until the thermostat is satisfied.

We recommend setting the fan to run at low speed continuously. This is more comfortable for occupants because the air movement prevents hot or cool spots.

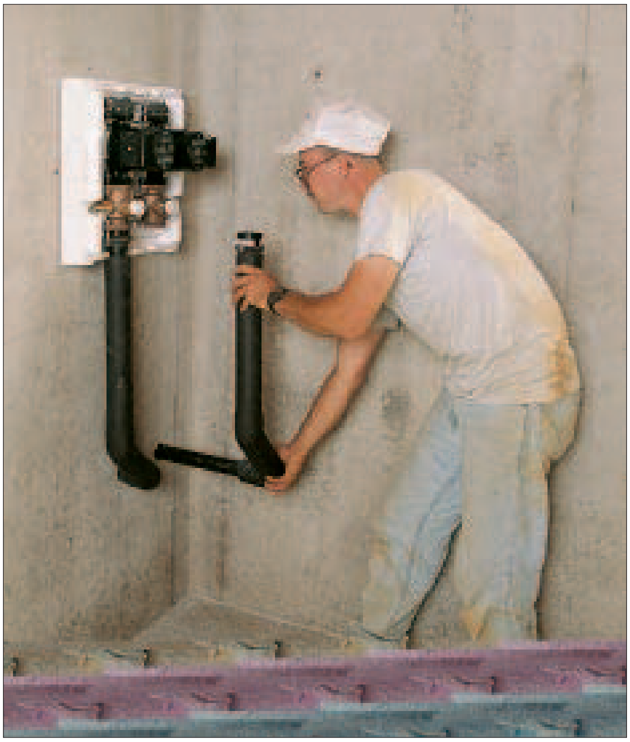
We usually make our ducts out of inch-thick fiberglass duct board, stapled together and sealed with tape. If a customer asks for it, we run metal ductwork, but we still insulate with duct board and seal with tape.

In homes designed with lots of open space, I avoid the need for vertical runs of ductwork by using a multi-zone system with two independent units— one downstairs and one upstairs. The two units can either share a ground loop or have separate loops. The ground loop fluid can run to the upstairs unit

IGSHPA

Suppose you want information about ground-source heat pumps — the address of a manufacturer, or the name of a qualified installer in your area. Or perhaps you want training to become an installer. You can turn to the International Ground Source Heat Pump Association, which goes by the handy name of IGSHPA. Formed in 1987 at Oklahoma State University, the group's membership includes manufacturers, distributors, installers, electric utilities, and other interested parties. IGSHPA trains and certifies geothermal hvac contractors, conducts research to improve the systems, and provides informational materials. The group has also started a program to register all systems that are installed, so that if a supplier or installer goes out of business, others in the industry will be able to maintain or repair the systems.

You can contact the International Ground Source Heat Pump Association at Oklahoma State University, 482 Cordell South, Stillwater, OK 74078; 405/744-5175.



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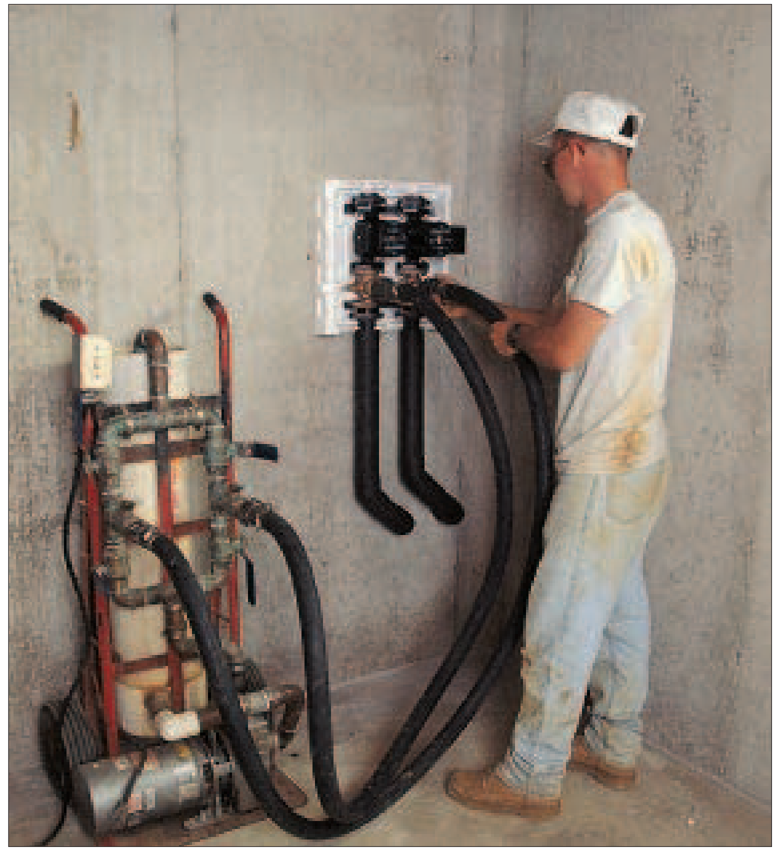

Figure 3. *In the basement, the author's son connects the end of the ground loop to a manifold (above), then fills the loop with coolant and purges the air from the system (right).*

through a small pipe.

The electric utilities in my state offer rebates to buyers of geothermal systems, and guarantee lower heating bills. Before they'll guarantee a system's performance, however, the utilities insist on running blast tests on the ductwork to make sure it's properly balanced and doesn't leak (Figure 5). (They also run blower-door tests on the homes to measure the tightness of the building.) This is a good idea — flaws in the ductwork can ruin the performance of heating and cooling systems.

Ductwork is just as important in conventional hvac systems as in geothermal ones, but because the utilities in my area aren't testing conventional systems, some contractors neglect ductwork quality. In retrofit work, I often have to rip out the existing ductwork and start over. That takes some explaining to the homeowner, but I don't compromise in that area. There's no sense in hooking a state-of-the-art heating unit up to an incorrectly sized, poorly balanced, or sloppily installed duct system.

Scheduling. We rough in our ductwork at the same time the plumbers are doing their rough-ins: after the house is dried in, but before insulation and drywall are installed. Then, as soon as the ground loop is ready, we can put in the heat pump unit, and the house has heat.

Sizing the Systems

Some hvac contractors oversize conventional systems because it makes "rule-of-thumb" sizing easy, and compensates for leaky ducts. And homeowners sometimes ask for bigger systems, thinking they'll be more comfortable. They don't realize that too big a system will run inefficiently and cause wide swings in temperature.

With geothermal, you should never oversize or use rules of thumb. The systems cost thousands more to install than conventional systems. The customer makes the money back in utility savings, so the point is to size the system just right for the house, and take care installing it. I explain to my customers that this results in the lowest installed cost and the highest efficiency.

System size affects costs most of all in the ground-loop department. The more trench or borehole you need, the more it costs. And it also takes more electric power to move water through a longer loop, raising the operating cost of the system.

We use a computer program provided by Water Furnace to calculate the heating and cooling load of each building. (Similar programs are available from IGSHPA.) The program factors in wall area, insulation levels, square footage of windows and doors, window and door types, and air leakage of the building shell. Then it uses climate data for the area to calculate the peak heat loss and heat gain for the building. The peak load is the load we design for. In my area, it's the heating requirement that determines the system size — if we can heat the house in the dead of winter, we'll have more cooling power than we need in summer. In warmer climates, installers size mainly for cooling.

Resistance backup. Most geothermal systems have a small electric resistance element near the heating coil. The backup coil is sometimes called on to provide extra heat when outside temperatures drop below design loads.

The resistance backup doesn't add much to the initial cost of the system — maybe \$100 or \$200 — but any time it is used, it is much more costly to run than the heat pump. On the other hand, sizing the system to never need the backup would mean installing a longer and costlier ground loop and a bigger heat pump just to meet rare peak heating needs. So we usually compromise and size the system to use electric backup occasionally. In very cold climates, where the electric backup might have to be used more often, you should take a look at insulation levels in the house. It might be more cost-effective to add some insulation to the building shell, thus avoiding the need to use resistance backup.

Advantages of Geothermal

Ground-source heat pumps don't involve any combustion in the home — that means no fuel deliveries, no separate oil or gas bills, no odors, no carbon monoxide danger, and no chimney. Unlike conventional air conditioners, they don't sit outside making a racket — they run quietly in the basement. And because they're indoors protected from the weather, they last longer. The units I sell carry a nonprorated 25-year guarantee, and the ground loops are guaranteed for 55 years.

In my experience, these systems are highly reliable. I've installed geothermal systems all over New Jersey, and I service what I sell. I wouldn't be installing units 100 miles away from my shop if I had to run out on service calls all the time. During the worst of last winter's record cold, when air-source heat pumps were running on straight resistance coils, I got only four service calls — all calls for minor component failures like switches and transformers, caused by spikes and brownouts in the power grid. These were ten-minute in-and-out calls. Just for my own peace of mind, I called up some of my "worst-case scenario" customers. A typical example was a gentleman whose house was in an exposed field, and whose system had no electric backup. At –8°F, with a 30-mph wind blowing across that field, he had no trouble keeping his house at 70°F. I'm satisfied that my equipment works.

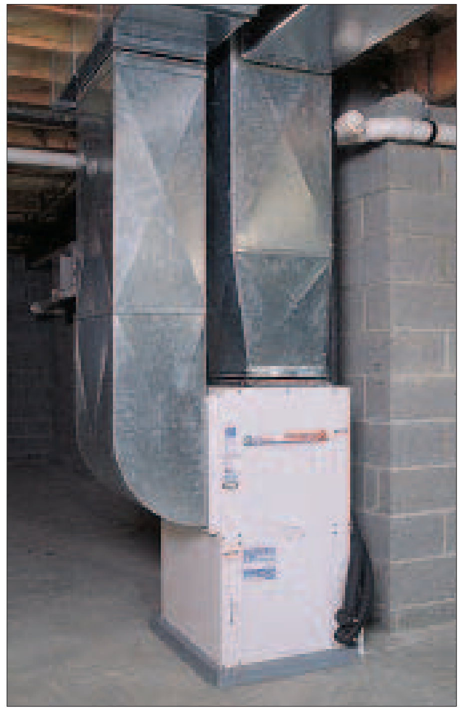

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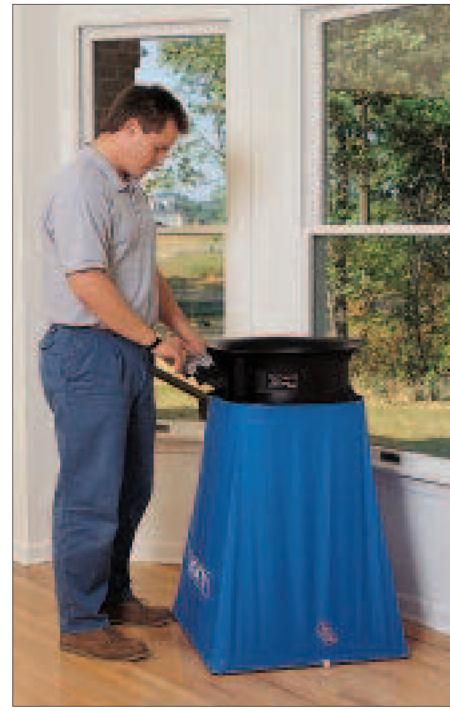
Figure 4. *The heat pump unit is installed in the basement, where it is protected from the weather. Powered by house current, it does not produce combustion gases and does not need venting.*



JERSEY CENTRAL POWER & LIGHT

Figure 5. *Utilities will only guarantee a rebate for a ground-source system if the ductwork passes a duct-blasting test.*

To have this kind of confidence, your installer needs to be trained and experienced. Installing the heat pump unit and ductwork is straightforward for any good hvac company, but they may be unfamiliar with ground-loop installation. In that case, you may be able to find a certified ground-loop subcontractor. IGSHPA provides training and certification for heat pump installers and for ground-loop subs, and maintains a list of qualified people. Your best bet is to go with an IGSHPA-certified contractor. ■

Jim Soden owns Soden's Heating and Cooling in Trenton, N.J.

Manufacturers of Ground-Source Heat Pump Equipment*

Addison Products Co.
7050 Overland Rd.
Orlando, FL 32810
407/292-4400

Carrier Corp.
Carrier Pkwy.
P.O. Box 4808
Syracuse, NY 13221
800/227-7437

Climate Master Inc.
7300 S.W. 44th St.
Oklahoma City, OK 73125
800/299-9747

Florida Heat Pump Corp.
601 N.W. 65th Court
Ft. Lauderdale, FL 33309
305/776-5471

Heat Controller Inc.
P.O. Box 1089
Jackson, MI 49204
517/787-2100

Hydro Delta Corp.
1000 Rico Rd.
Monroeville, PA 15146
412/373-5800

Trane Co.
P.O. Box 7916
Waco, TX 76714
817/840-3244

Water Furnace International
9000 Conservation Way
Fort Wayne, IN 46809
219/478-5667

**The ground-source heat pumps made by these manufacturers are rated by the Air Conditioning and Refrigeration Institute.*