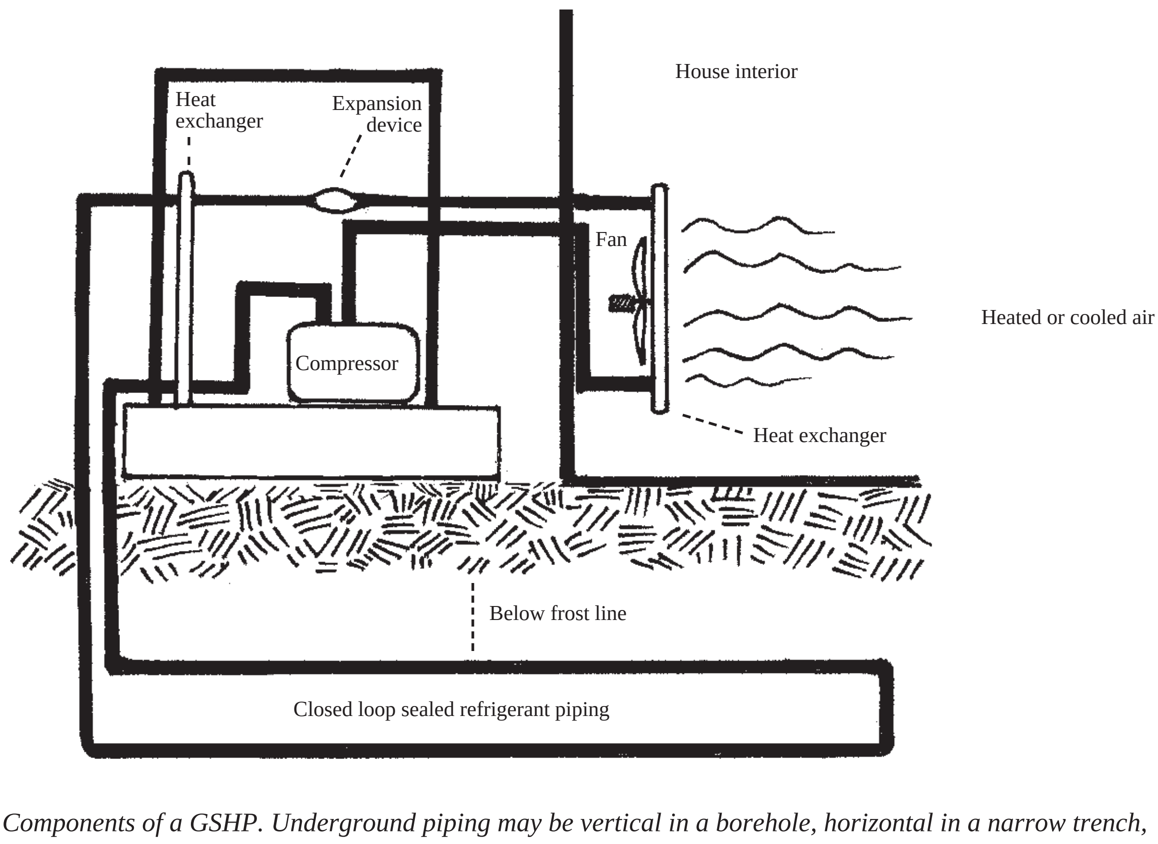
Heat and cool inexpensively with a ground source heat pump

By B.B. Bunting and Don Fallick

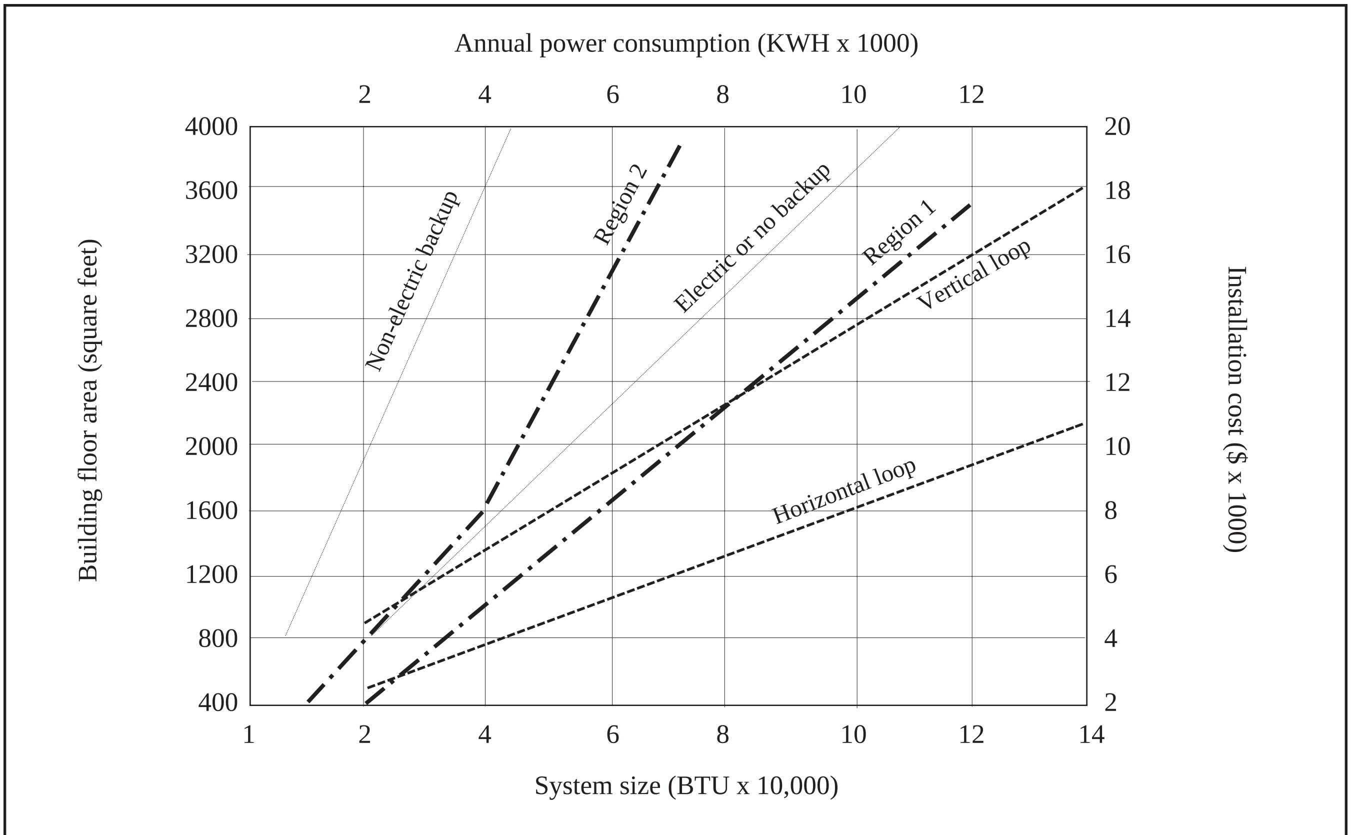
A few feet beneath the ground, just below the frost level, the earth maintains a constant temperature of about 50 to 60° F year-round. A heat pump can tap this reservoir of constant temperature to heat your house in the winter and cool it in the summer. Heat can be concentrated to provide domestic hot water as well, with minimal use of electricity, no pollution, no air-conditioner, no furnace, and no other fuel. It sounds like magic, but the technology is both available and affordable in the form of a ground source heat pump (GSHP).

The heart of a GSHP system is a pump which circulates a refrigerant solution through long pipes buried in the ground below the water table. The pipes are completely sealed, so the refrigerant never contacts the environment, but it can still pick up heat from the moist earth. Heat from the soil causes the low pressure refrigerant to vaporize. Above ground, a compressor concentrates the heat, raising the fluid temperature high enough to heat domestic hot water, and to heat the house through a heat exchanger and standard central heating system. The fluid then is allowed to cool and expand to its original density, ready for another trip underground. Because the system removes heat from the ground and pumps it into the house, it is commonly called a heat pump. But that's not all it can do.

In summer the pump runs in reverse. Refrigerant heated by a heat exchanger in the house is pumped into the ground, where it transfers its heat to the cooler earth and returns, in effect pumping "cool" into the house. The same pump can transfer heat in either direction, so there is no need for separate water heater, furnace, and cooler. The whole system consists of only the underground pipe, heat exchangers, compressor, pump, expansion chamber, and a hot water tank. Its simplicity makes it much more reliable than most central air conditioners, and much cheaper to operate than even the most efficient furnace.



Components of a GSHP. Underground piping may be vertical in a borehole, horizontal in a narrow trench, or in the form of a continuous coil in a wide trench. Piping may be above or below the water table. Compressor and expander can be in the building being served or in a shelter outside.



TO FIGURE APPROXIMATE SYSTEM COSTS

1. Determine your region. Region 1 is temperate areas, Region 2 is areas with temperature extremes. Also determine whether you will have a vertical or horizontal loop, and the type of backup heating system you will have, if any.
2. From building size at left of chart, read right to proper region line, then vertically to intersect the vertical or horizontal loop line, as appropriate. Read installation cost at right.
3. From building size at left of chart, read right to appropriate backup system line, then up to annual power consumption. Multiply this figure by your local power company's charge per KWH to find annual operating cost.
4. From intersection of building size and region line found in #1, read vertically down to heat pump size at bottom of chart. Compare to operating and installation costs of non-electric heating systems of same BTU rating.

Design considerations

A GSHP system may cost as much as $2000 more than an equivalent conventional heating/cooling system. Costs for a typical 2000 square foot house will vary, depending on soil type and moisture content and other design considerations, but might average about $6000 to $8000. This figure can be reduced by a third or more if the homeowner does his own excavation. But GSHP's great benefit is that it requires no fuel at all to operate—just the electricity needed to run the pump and compressor, which is approximately the same amount of electricity you'd use to run a standard hot-air furnace. If your heating and hot water systems use $500 worth of fuel per year, for example, it would take only four heating seasons to recoup the higher installation price. After that, there would be a savings of $500 or more in operating costs every year. GSHP systems must be buried deep, and are built to last, so the savings normally continue for the life of the building.

One problem with GSHP systems is the great length of the required underground loop. The typical house mentioned above requires a total loop length of 200 to 400 feet, depending on soil, pipe material, and the particular refrigerant solution used. The pipe should be buried below the water table, with a one-foot minimum radius around each pipe, to allow for transfer of heat. The hole can be horizontal or vertical, and the loop can be divided into several shorter "parallel" loops to reduce costs. Horizontal trenches are cheaper to dig than vertical holes, so trenches are usually preferred where there is room, as long as the proper soil conditions can be obtained. Dry soil does not transfer heat readily, so the wetter the soil, the better. If necessary, water can be pumped into the hole or trench to moisten dry soil. But the soil must be well below the frost line. If the solution freezes, the pump will self-destruct trying to move it.

Different refrigerants require different length loops. Potassium acetate or potassium carbonate solutions require the shortest loops, but alcohol solutions, glycol solutions, and even salt solutions can work. Proprietary (brand name) solutions of potassium acetate or carbonate are available, but pricey. Salt solutions of sodium chloride or calcium chloride are cheap and readily available, but corrode pipes and fittings badly. Ethylene and propylene glycol mixtures have a high viscosity, making them harder to pump. Methyl, ethyl, and isopropyl alcohol solutions are better, and readily available, but don't work as well as potassium refrigerants. An engineer familiar with GSHP will be able to determine the best refrigerant for your particular needs.

A single, long ground loop is simpler to make and easier to test than a complex system of parallel loops. But long pipes must be larger in diameter to reduce pressure loss, so most systems use parallel loops. A two-foot-wide trench can contain two or more complete loops in parallel, reducing excavation costs by almost 50%. In new construction, ground loops can be located in septic system leach field trenches, using the leach field drainage to improve heat transfer. Vertical loops can be placed in well holes, either inside or outside the well casing. Vertical and horizontal loops can be mixed in a single system, if desired. It is much better to have more loop length than necessary, than to have too little, but too long means using excess pump power. Ground loop piping should be constructed of materials recommended by refrigerant manufacturers. Check with the manufacturer or a competent engineer for specifications. Sources of information are listed at the end of this article.

Systems can be designed to accommodate buildings of many different sizes, or can even be shared among multiple users. In rural Colorado, there are about 40 homes currently using GSHP. Many of them share a system among several houses, to reduce costs. In addition, The Rural Electric Association has erected a 50 foot x 100 foot shop heated only by GSHP. It uses the same size heat pump as a 4000 square foot house.

Get it right

Perhaps the best way to reduce the initial cost of a GSHP system is to do most of the work yourself. It is possible for a technically minded homeowner to do much of the design and installation himself. The design and installation guides mentioned at the end of this article are good places to go to begin thinking about a GSHP system. Because there are many factors affecting the performance of a ground source heat pump, it is imperative to get some input from a heating/cooling engineer familiar with GSHP. The actual excavation and plumbing is straightforward, for those with appropriate skills and equipment. But because the system is difficult to repair or replace once installed, an amateur should go out of his way to get help in the design and testing of the system.

High quality equipment and seam welding is an absolute must for longevity and performance. This means using pipes made of Polyethylene 3408 (Schedule 40 or SDR 11) or Polybutylene 2100 (SDR 13.5 or SDR 17). GSHP also requires a really good, well-made, rotary type compressor. These can cost $350 to $700, depending on the size needed, or even more with built-in thermostatic controls. A large compressor with a two-way "flop valve" for reversing the pump direction automatically could run as high as $1000, so it pays to get knowledgeable advice before building. Sources of such help are listed at the end of this article.

Not all such help costs money. For information on your local soil, its moisture content, frost level, and constant temperature level, see your local U.S. Soil Conservation Service engineer, especially if you are considering a horizontal loop system. For vertical loop systems, your U.S. Geological Survey agent would be more helpful.

A GSHP may seem like an expensive option, but it has several advantages, besides using no fuel. Heat pumps are completely sealed, so they pose no environmental threat whatever, aside from the electricity they use. In an active heating/cooling system, where electricity is going to be used to move the heat around anyway, the additional power consumption is minimal. Even this can be reduced, though, by the use of a non-electric backup heat source, such as firewood, passive solar, etc., during the periods of greatest demand.

For more information:

Manual H, Heat Pump Systems: Principles and Applications, Air Conditioning Contractors of America, 1513 16th St. NW, Washington, D.C.

Closed-Loop/Ground Source Heat Pump Systems-Installation Guide, International Ground Source Heat Pump Association, PO Box 1688, Stillwater, OK 74076-1688

Directory of Certified Air-Conditioning Products, Air Conditioning and Refrigeration Institute, Vice President, Engineering, 4301 North Fairfax Drive, Suite 425, Arlington, VA 22203

Check with local heating/air conditioning engineers, or contact B.B. Bunting, 708 N. Fourth St., Sterling, CO 80751, who provided much of the drawings for this article. Δ