GROUND SOURCE HEAT PUMPS

Using electricity for heating is generally expensive and (from a system point of view) not very efficient, especially if the electricity is generated by fossil fuels. However, in some places there are few options. If so, it is possible to get 2 to 3 times more heat out of a system than energy that is put in. Black magic? Not really, heat pumps do this regularly.

What is a heat pump?

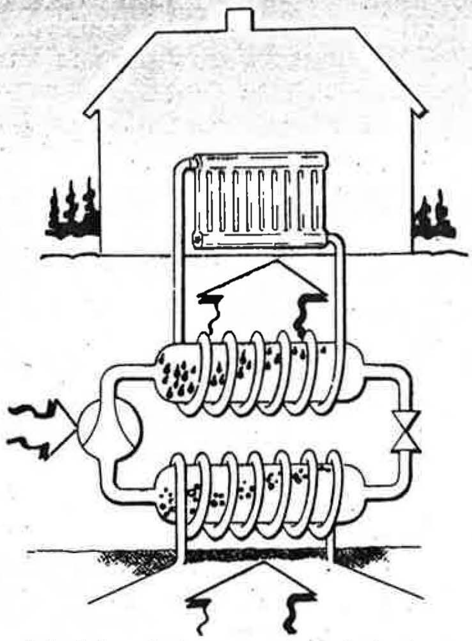
Anyone who has a refrigerator or an air conditioner has seen a heat pump in action, even though the term *heat pump* is not used. Refrigerators and air conditioners are heat pumps which remove heat from colder interior spaces to warmer exterior spaces for cooling purposes. Heat pumps can also move heat from a low-temperature source to a high-temperature space for space heating.

An air-source heat pump, for example, extracts heat from outdoor air and puts it indoors. In the winter when the temperature drops below 0°C, there is not enough heat in the air so the unit only acts as an electric resistance heater.

Recently much development work has been done on *ground source heat pumps*. They work the same way, but the source of heat is the energy contained in the ground, or in groundwater, which is tapped to provide energy for space heating or cooling.

How does a heat pump work?

The process of elevating low temperature heat to over 100°F and transferring it indoors involves a cycle of evaporation, compression, condensation and expansion. A refrigerant, usually Freon, is used as the heat-transfer medium which circulates within the heat pump.

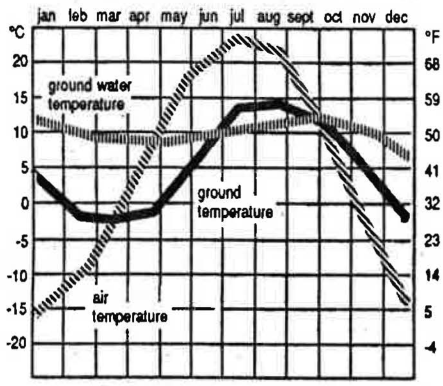


Principle of the operation of the heat pump.

The cycle starts as the cold liquid refrigerant passes through a heat exchanger (evaporator) and absorbs heat from the low-temperature source. 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°F. In the process, the hot gas then circulates through a refrigerant-to-air heat exchanger where heat is removed and delivered to the home at about 100°F. As it loses heat the refrigerant changes back to a liquid. The liquid is further cooled as it passes through an expansion valve and begins the process again. To become an air conditioner (for cooling), the flow is reversed.

To maximize efficiency, a constant source of low grade energy is necessary. Fortunately, ground and groundwater temperatures remain relatively constant below the surface. Despite air temperature fluctuations, below grade temperatures generally range from -2°C to 16°C year round. (The lower down, the more constant they stay).

A ground source heat pump removes heat from a heat exchanger buried in the earth (or from ground water). In the evaporation and condensation cycle of a heat pump it upgrades the available heat to useful temperatures to provide space and water heating. This is then delivered to the building by conventional ducted air or hydronic systems.



Ground Water, Ground, and Air Temperatures

In summer the cycle is reversed allowing the heat pump to act as an air conditioner, extracting hot air from the interior for heating water and returning the surplus to the ground. This 2 way cycle is important, as during the heat extraction cycle, ground temperature is lowered, actually freezing the ground. If the system does not get a chance to recharge, the frozen ground actually becomes permafrost, losing its effectiveness as a heat source.

The ground source heat pump is not a new idea. It's been used in Sweden and other European countries for many years, not only in homes but also for commercial and institutional uses.

Ground-source heat pumps have been used in rural locations, but increasingly they are being installed in suburban housing developments.

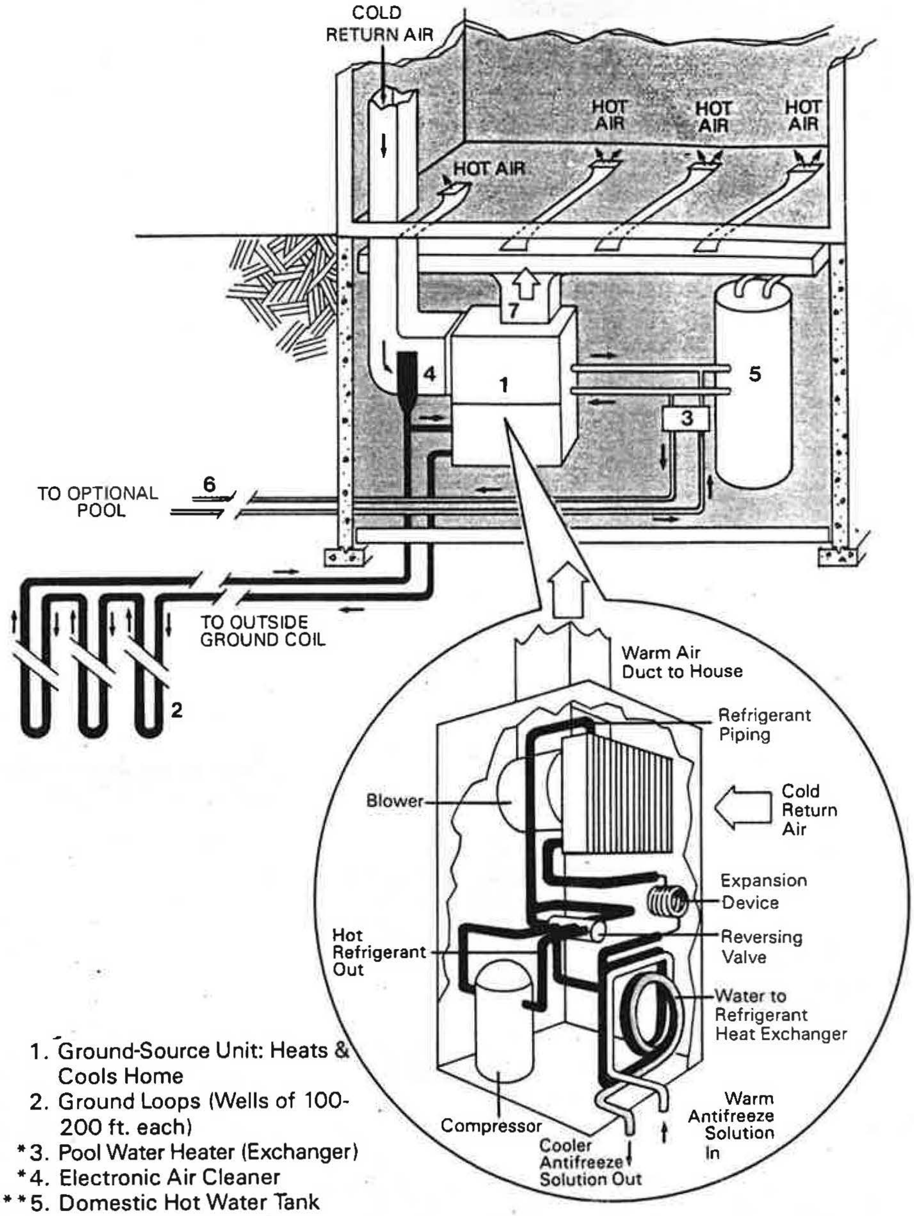
Required Site characteristics

The subsurface geology must be known to determine what the thermal potential can be, and to best design the ground coupling. Thus a geotechnical analysis is a must.

A demonstration project in a subdivision in Ontario ran into some problems when ice lensing developed underground. The pressures generated by the ice lenses were enough to damage the refrigerant piping. It was discovered that the installation process had disturbed the ground enough to set up conditions where ice lenses could form (previously, this was something that was not known in the area). Once the problem was corrected, the systems performed much as expected.

All ground source heat pumps have two parts: a circuit of underground piping outside the house, and a heat pump unit inside the house. The piping circuit can be what is called *Open* or *Closed Loop*, and there are two variations of the Closed Loop: vertical and horizontal (which only refers to the way the underground piping is arranged).

The choice of Open or Closed Loop for a particular house depends on the amount of land available, the soil conditions for drilling and the presence of underground water.



1. Ground-Source Unit: Heats & Cools Home
2. Ground Loops (Wells of 100-200 ft. each)
*3. Pool Water Heater (Exchanger)
*4. Electronic Air Cleaner
**5. Domestic Hot Water Tank
6. Hot Tub or Whirlpool or Outdoor Pool
7. Auxiliary Duct Heater

*Optional.
**Standard on some models.

HEATING MODE

Air Conditioning (cooling)

The direction of flow of the fluid circuit is reversed by means of a reversing valve. The refrigerant now picks up the heat in the house and transfers it to the antifreeze solution, which carries it outside to the underground piping loop. There it is harmlessly dissipated into the cooler ground (or it is used to heat domestic water).

Measuring Efficiency

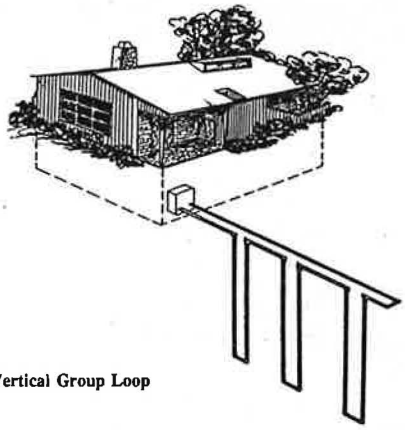
Heat pump efficiency is measured by its *'coefficient of performance'* (COP). The COP is a ratio of heat delivered per unit of energy consumed. A typical earth energy system in Canada has a COP of between 2.8 and 3.2 at 2 C. This means that for every dollar's worth of electricity used in operation, an earth energy system will deliver three dollars worth of usable heat energy to a building; energy to heat during the winter, to cool during the summer and to provide domestic hot water needs year round.

By comparison, electrical resistance heating has a COP of 1, oil heating a COP of 0.65 and medium efficiency natural gas 0.8-.85. A ground source heat pump operating in optimum conditions can provide savings against conventional energy, depending on energy costs and system installation costs.

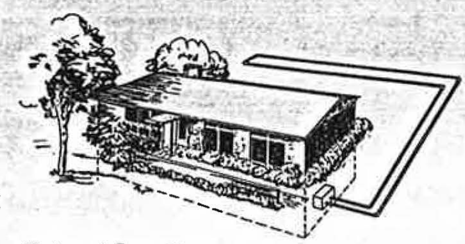
CLOSED LOOP SYSTEMS collect heat from the ground by circulating an antifreeze solution through a continuous piping loop which is buried underground outside the house. The solution, having been chilled by the heat pump's refrigeration system to a lower level than the temperature of the soil, and absorbs heat from the soil (reversed for cooling).

VERTICAL:

A vertical Closed Loop arrangement is an appropriate choice for most suburban homes, given the usual size of lots. Four or five loops of piping are inserted into holes 150mm (6 ins.) in diameter to a depth of 18 - 60m (60-200ft.) depending on soil conditions and the size of the system.



Vertical Group Loop

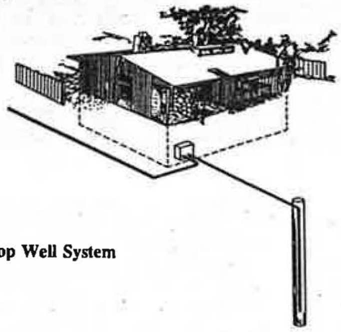


Horizontal Ground Loop

HORIZONTAL:

The horizontal arrangement is more commonly found in rural locations where properties are larger. The piping circuit is laid out horizontally in a trench 1-1.5m deep (3-4 ft.), so the expense of drilling is avoided. The horizontal piping arrangement can also be laid out along the bed of large pond, a river or lake.

OPEN LOOP SYSTEMS take advantage of the heat retained in an underground body of water. Water is drawn up from a well directly to the heat pump's heat exchanger, where its heat is extracted. The water is discharged to the aquifer via a separate well. The properties of the water are very important, as dissolved chemicals could affect the equipment if it is too acidic or alkaline.



Open Loop Well System

Cost?

As with all heat pump systems, the cost is a factor. Installed systems for a single family residence can cost 7-$10,000 or more. But as with all types of mechanical systems, decisions have to be made on consideration of a variety of factors, not necessarily just on initial capital cost of the system.

Further information:
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