How Ground/Water Source Heat Pumps Work

Steve Kavanaugh, Professor Emeritus of Mechanical Engineering, University of Alabama

Ground Source Heat Pumps (a.k.a. Geothermal Heat Pumps) are becoming more common as the costs of energy and equipment maintenance rise. When properly designed and installed they not only reduce energy use but lower maintenance costs and extend equipment life since they have no exposed outdoor equipment. They are very simple devices and have only a slight difference from traditional heat pumps. While the added cost of a ground loop, lake loop, or water well is significant, the simple water/ground source heat pump itself should cost no more than a standard heat pump and much less than the interior components of larger building HVAC systems.

Figure 1 is a diagram of a closed-loop ground source heat pump (GSHP), which is also known as a ground-coupled heat pump (GCHP). A piping loop is buried in the ground, which is considerably warmer than the outdoor air in the winter. Water is circulated through the loops and into the building where the heat pump removes the heat from the water and delivers it to the air (details of how this is done are provided later). Since the water entering the heat pump is relatively warm (it is in contact with warm ground), the coefficient of performance (COP) of a GSHP is much higher than a heat pump that uses cold outside air as a heat source. GSHPs can have COPs above 4.0 when there is an efficient connection between the ground and piping loop. The process is reversed in cooling. Heat is removed from the inside air and delivered it to the water loop which rejects this heat to the ground. GSHPs also provide high cooling efficiency since the ground is much cooler than the air during the summer.

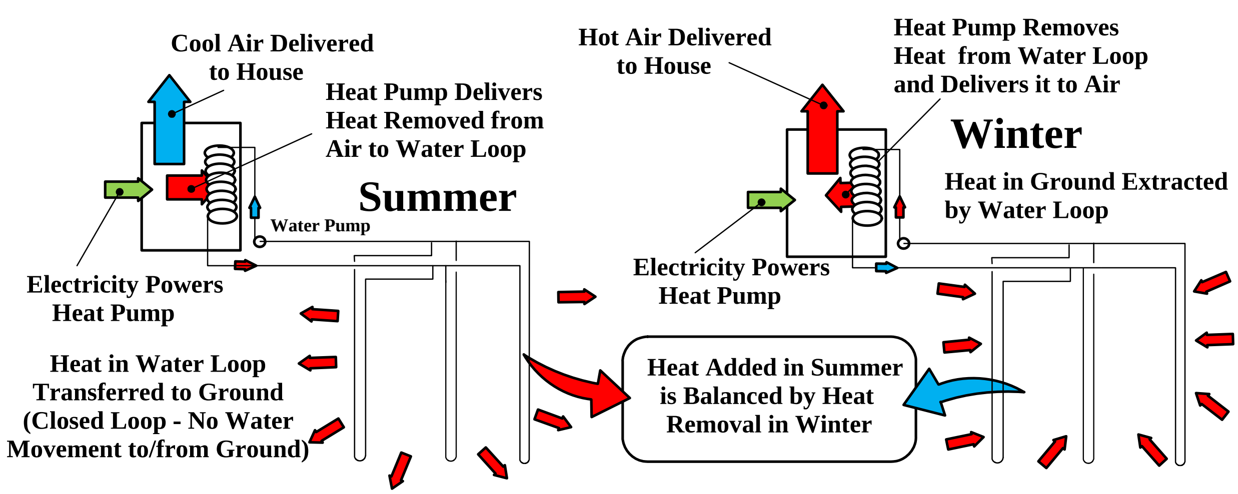

Figure 1. Ground-Coupled Heat Pump (Closed-Loop GSHP)

Figure 2 depicts a surface heat pump system (SWHP) that uses a coil submerged in a lake to replace the ground loop. SWHPs can be even more efficient in cooling than GCHPs if the lake is more than 30 feet deep. However, even deep lakes are colder in the winter than the ground, so the ground coil system performs slightly better in heating. SWHPs are typically less expensive than GCHPs if a suitable body of water is nearby. Some buildings that require water retention ponds have been able to incorporate a slightly deeper and larger reservoir.

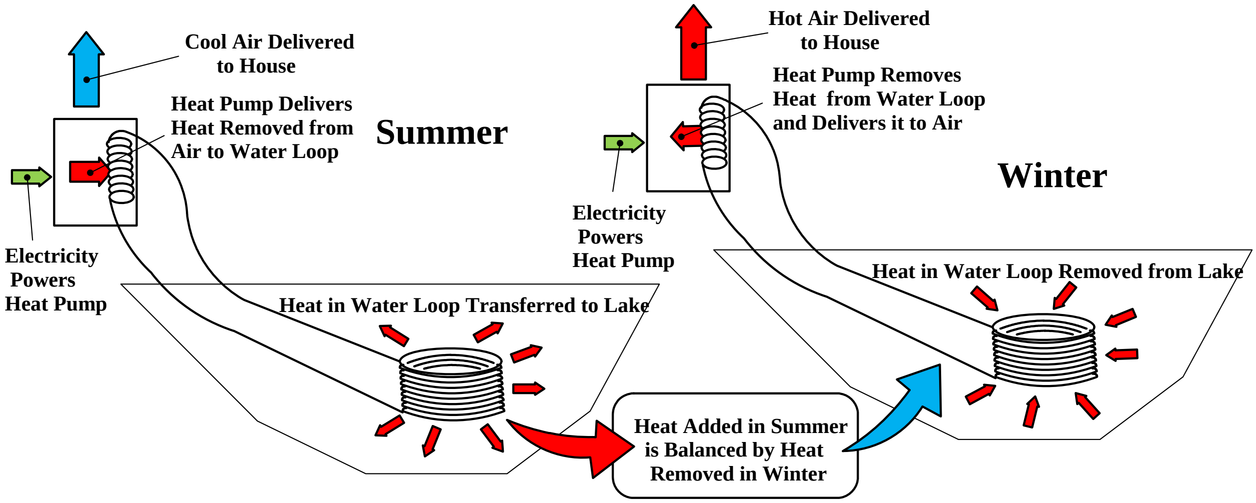

Figure 2. Lake Source Heat Pump (Closed Loop Type)

Figure 3 depicts a ground water heat pump (GWHP) system a third common type of GSHP. Water is pumped from a well through an isolation heat exchanger and is returned to the aquifer through an injection well. The heat pumps reject (cooling) and absorb (heating) heat from the groundwater through the heat exchanger and a closed piping loop in the building. This arrangement protects the heat pumps from the groundwater if the quality is suspect. Any required cleaning can be easily done at the stainless-steel heat exchanger. Use of injection well disposal ensures the water table level is not adversely affected. GWHPs are typically less expensive than GCHPs and SWHPs in medium-sized and large buildings. Efficiency is comparable to GCHPs and SWHPs since the added pumping requirement is usually offset by favorable ground water temperatures.

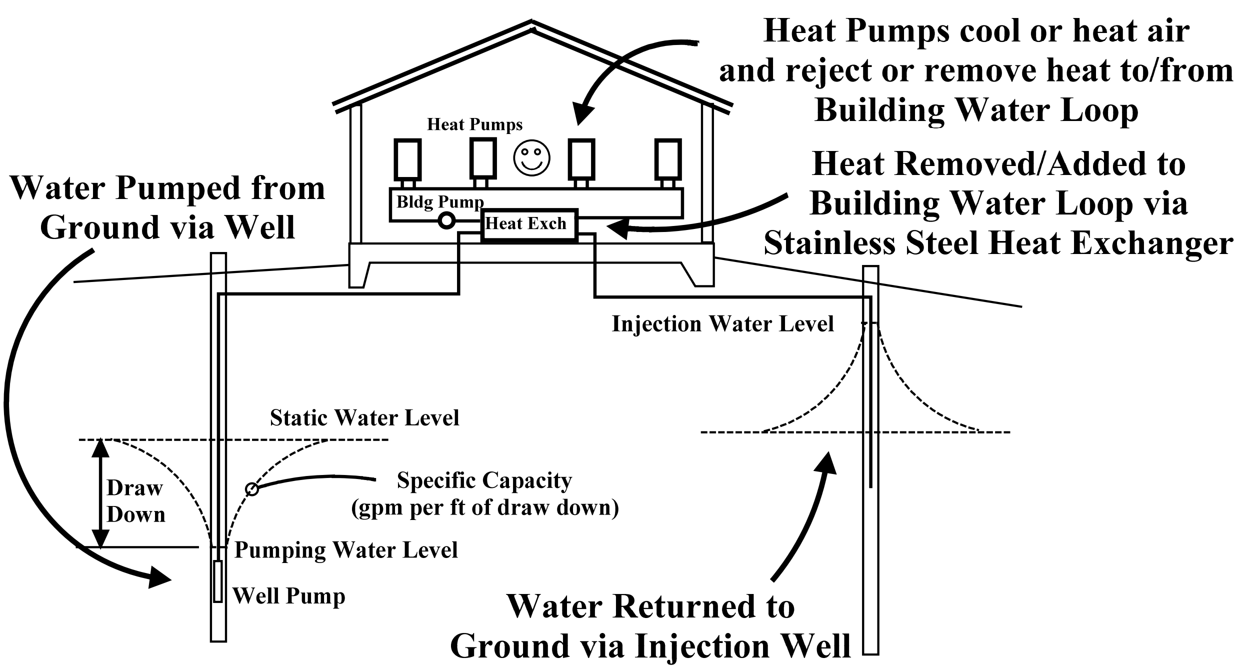

Figure 3 Ground Water Heat Pump System (Open-Loop)

How an Air-Conditioner Works

A water source air-conditioner or heat pump is a variation of a traditional air source heat pump. The explanation that follows first describes how a cooling-only water source air-conditioner works. A description of a heat pump (heating and cooling) will follow. A similar document, “How Air-conditioners and Heat Pumps Work”, is also available.

The cooling-only unit consists of several primary components as shown in Figure 4:

- A compressor that is driven by an electric motor (typically located indoors)
- A condenser coil with tubing for water flow and tubing for refrigerant flow.
- A circulation pump that moves water through the condenser coil and outdoor water loop.
- An expansion device (usually located indoors) that lowers system pressure.
- An evaporator (or indoor) coil with tubing and many fins that cools and dehumidifies air.
- An indoor fan to circulate air over the cold evaporator tubing and fins
- A refrigerant fluid to operate at the needed pressures and temperatures
- Outdoor water loop (ground loop, lake loop or water well).

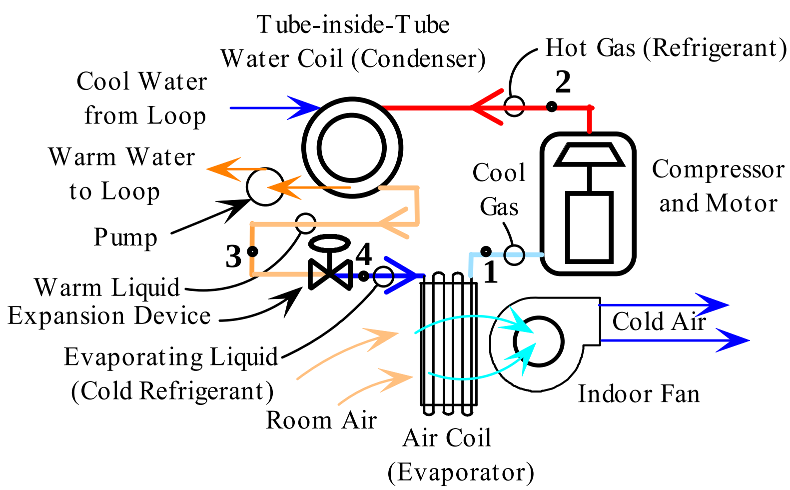

Figure 4. Cooling–Only Refrigeration Cycle

These components function in the following manner.

- The compressor “sucks” the refrigerant from point 4 through tubing in the evaporator coil. This action causes the liquid refrigerant to “evaporate” and become cold (≈45ºF). The evaporating refrigerant inside the tubes cools the air being circulated over the outside of the tubes and fins by the indoor fan.
- In order to move the refrigerant from point 1 to point 2, it must be raised to a higher pressure by the “compressor”. The compressing causes the refrigerant to become hot (a similar effect occurs with an air compressor and this can be verified by quickly and carefully touching the discharge line).

- The hot refrigerant is sent through the outside tubing of a tub-inside-tube water coil condenser. Water is circulated by the pump through the inside tube and cools the refrigerant and causes it to return to a liquid (condense). The water is typically 50ºF to 90ºF and is cooler than the hot refrigerant (90ºF to140ºF).
- The liquid refrigerant leaving the condenser (point 3) passes through an expansion device which lowers the refrigerant pressure before it returns to point 4 to repeat the cycle.

<u>How a Heat Pump is Different</u>

A heat pump is merely an air-conditioner with one extra valve that allows the condenser (hot coil) and evaporator (cold coil) to reverse places in the winter. Figure 5 shows close-ups of this "reversing" valve and where it is located in the heat pump system. In the cooling mode, the valve slides to a position that permits the hot gas from the compressor to flow through the top port to the left bottom port to the water coil. Thus, the heat pump will act like the air-conditioner described in the previous page. The valve also permits the refrigerant to travel from the indoor air coil to the compressor in cooling and from the water coil to the compressor in heating.

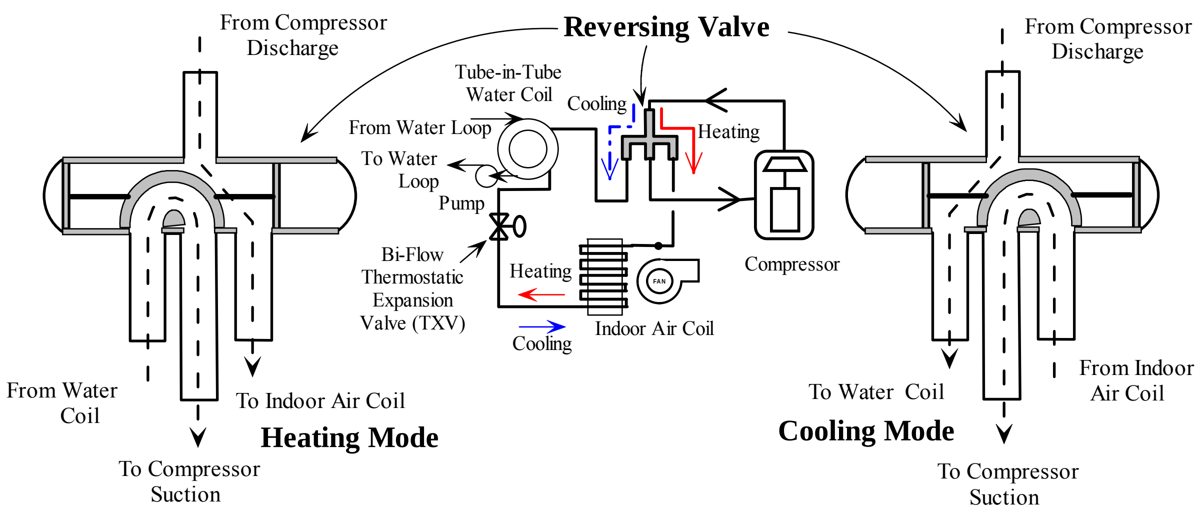

Figure 5. Reversing Valve that Enables an "Air-Conditioner" to be a "Heat Pump"

In the heating mode the reversing valve slides to a position that routes the hot refrigerant from the compressor through the top port to the indoor air coil (which is now the condenser) through the right bottom port of the reversing valve. Thus the air circulated by the indoor fan will be heated. After passing through the expansion device, the refrigerant enters the outdoor coil at a low temperature. Because the temperature of the refrigerant is low, heat can be transferred from the water to the refrigerant inside the evaporator. The advantage of using water from a ground or lake loop is that backup heat is often unnecessary. If the water loop is connected to a properly size ground or lake coil, the heating efficiency is exceptionally high compared to conventional systems.

Figure 6 is a more anatomically correct diagram of a water-to-air heat pump. Note an additional heat recovery coil can also be added to heat domestic water with waste heat in the summer and with excess heating capacity in the winter.

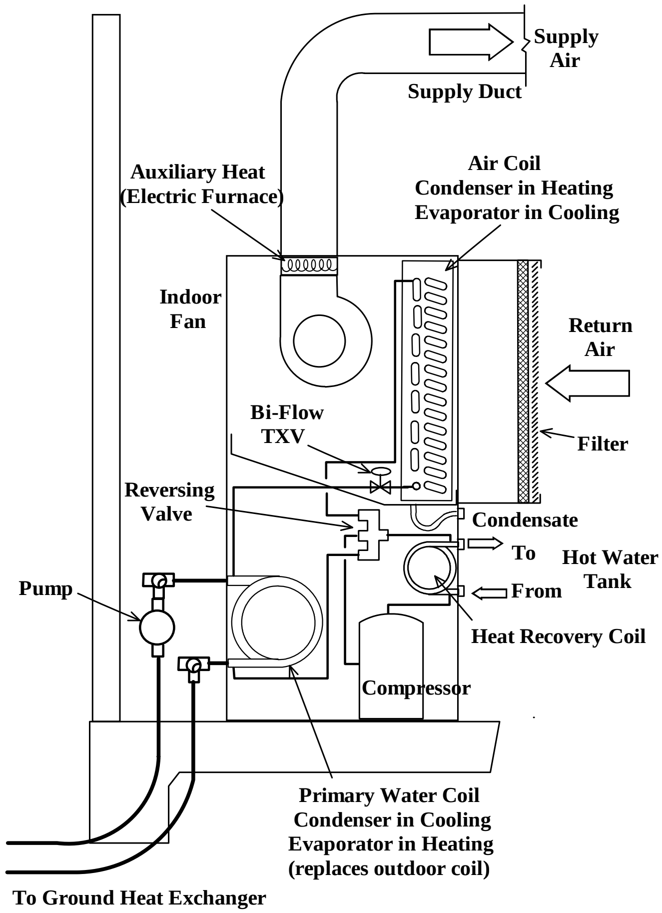

Figure 6. Ground Source "Geothermal" Heat Pump Unit

Reference:

Kavanaugh, S. P., *HVAC Simplified,* American Society of Heating, Refrigerating, and Air-Conditioning and Engineers (ASHRAE), Atlanta. www.ashrae.org