Air Conditioning | Heating | Refrigeration
the NEWS
THE HVACR CONTRACTOR'S WEEKLY NEWSMAGAZINE SINCE 1926
November 21, 2011 | www.achrnews.com, Twitter, Facebook + LinkedIn
A bnp media PUBLICATION

Geothermal Comes in More than One Flavor

By John Tomczyk
For *The NEWS*

Geothermal heat pumps remove heat from one place and transfer it to another. They use the earth, or water in the earth, for their heat source and heat sink.

This heat for the earth comes from the earth's crust. In fact, less than 4 percent of the stored energy in the earth's crust comes from its hot molten center.

Since the tax credit program became available, all types of geothermal options have been on the minds of the building community. Direct GeoExchange technology uses copper refrigerant lines buried in the ground with refrigerant flowing through them, rather than a water or glycol heat exchange fluid. These buried copper pipes, or earth loops, act as the evaporator when in the heating mode. When in the cooling mode, the buried copper pipes act as the condenser.

Direct GeoExchange is a term used by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the Air Conditioning, Heating and Refrigeration Institute (AHRI). (For the purposes of this story, all discussion about earth loops refer to direct GeoExchange technology.)

The earth loop, often referred to as the refrigerant loop, may be installed in three different configurations (Figure 1): diagonal, vertical, and horizontal.

The loops are placed by use of diagonal drilling rigs and technicians feeding down a copper earth loop (Figure 2).

The refrigerant (earth) loops are connected to a refrigerant distributor or manifold. The manifold's function is to divide the refrigerant flow equally to each loop and maintain balance within the refrigerant ground loop system. There is a vapor and a liquid manifold for each refrigerant ground loop. The vapor manifold is the larger of the two manifolds because it transports evaporated refrigerant vapors back to the compressor. The liquid manifold has smaller tubing than the vapor manifold because of the liquid refrigerant's higher density. Most earth loops are grouted with a plasticized grout for good heat transfer with the earth and to protect any underground aquifers nearby. The grout puts a seal around the earth loops that are lowered into the small bore holes. This grout seal prevents any surface water from running down into an aquifer by way of the bore holes that house the earth loops.

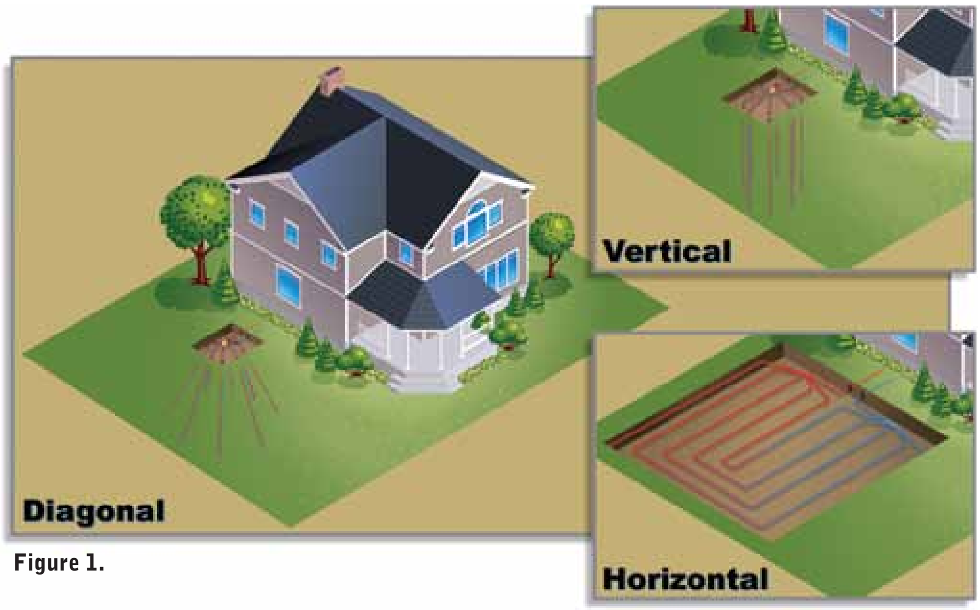


Figure 1.

The main ports to each manifold are connected to the heat pump's compressor unit by means of a line set comprised of one vapor and one liquid tube. To ensure equal distribution of refrigerant, it is critical that the manifolds are installed vertically.

Many configurations for earth loops exist for diagonal, vertical, and horizontal applications. The choice of the specific configuration depends on several factors regarding the design and application of these direct geothermal systems. One such design incorporated a diagonal earth loop configuration consisting of four 50-foot earth loops per ton of capacity. The earth loops were bored at a 45 degree angle, putting their deepest depth at about 35 feet in the earth.

In closed-loop, indirect geothermal systems, there is one extra heat transfer, and thus one extra temperature difference to deal with. With closed-loop, indirect geothermal systems, the heat transfers occur from:

1. The earth to the water loop located in the ground.

2. The water loop to a refrigerant loop.

3. The refrigerant loop to the air inside the house.

However, direct GeoExchange systems use one less heat exchanger. One less heat exchanger means one less temperature difference does not have to be created and maintained within the geothermal heat transfer

Figure 2.

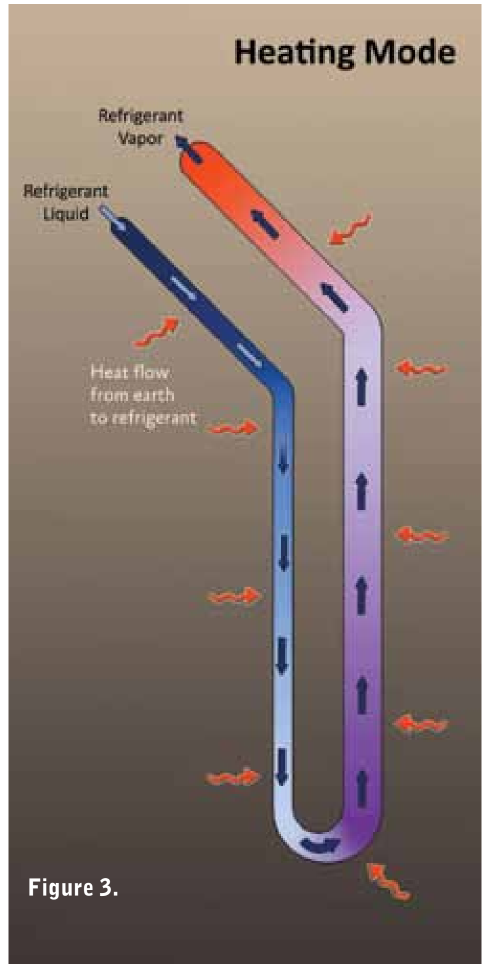


Figure 3.

system. Now, in direct GeoExchange systems, there are only heat transfers from:

1. The earth to the refrigerant loop.
2. The refrigerant loop to the air inside the house.

Heating Mode

In the heating mode, liquid refrigerant from the heat pump's indoor coil (condenser) is expanded and enters the smaller diameter tube of the refrigerant (earth) loop or evaporator. Heat is then transferred from the warmer earth into the refrigerant loop. While absorbing this heat, the refrigerant in the loop is boiled (evaporated) to a vapor as it progresses through the refrigerant (earth) loop (Figure 3).

The refrigerant vapor then exits the earth loop and is returned to the compressor unit. The refrigerant vapor is now compressed by the heat pump's compressor to a higher pressure and temperature. The compression process usually raises the refrigerant vapor temperature from about 40˚F to about 160˚. The hot, superheated refrigerant vapor is now delivered to the indoor coil (condenser) where it gives off heat to the building's indoor air with the assistance of a blower (Figure 4). As the refrigerant vapor gives off heat, it gradually condenses back to a 100 percent liquid state.

As mentioned earlier, the compression process raises the temperature of the refrigerant vapor to about 160 degrees. Because this hot, superheated vapor leaving the compressor is hotter than the home or building's inside air temperature, heat transfers into the air as the air passes over the fan coil located in the air handler (Figure 4). This warms your home or building.

Cooling Mode

In the cooling mode, superheated refrigerant vapor is pumped by the heat pump's compressor into the larger diameter (vapor) earth loop tubing. In this mode, the refrigerant temperature entering the refrigerant (earth) loop is higher than that of the surrounding earth itself. Heat will now be transferred from the refrigerant in the earth loop to the earth. As this superheated refrigerant loses heat to the surrounding earth, it becomes saturated and gradually starts turning to a liquid (condensing). More and more of the vapor is condensed as it travels through the earth loop until it reaches 100 percent liquid. The refrigerant now exits the earth loop as a liquid. This liquid is now re-expanded to a lower pressure and temperature in the indoor coil (evaporator). Heat is absorbed into the indoor coil from the house or building with the assistance of a blower (Figure 5).

Refrigerant Management System

The refrigerant management system consists of the two components: liquid flow control and active charge control.

The refrigerant management system components have three main objectives:

1. Improve the system efficiency, reliability, and serviceability.
2. Continuously return lubricating oil back to the compressor without returning liquid refrigerant.
3. Stabilize liquid and vapor refrigerant flow in long refrigerant (earth) loop runs, under all heat loading conditions.

To operate at optimum efficiency, the three major components of all heat pumps (compressor, condenser, and evaporator) require the refrigerant to be in a particular physical state appropriate for each component. The compressor needs liquid-free refrigerant vapor from the evaporator containing little or no superheat at its inlet.

The condenser needs the saturated refrigerant vapor to complete its condensing just before it reaches the condenser outlet. The condenser's bottom passes are not used for subcooling liquid. This allows for only desuperheat and condensing in the condenser. This prevents liquid refrigerant from backing up in the condenser's bottom producing subcooled liquid, which takes away valuable internal volume for condensing. The condensed liquid seal at the condenser's outlet also makes sure that there is no uncondensed vapor passing through the condenser.

The evaporator needs liquid refrigerant at its inlet. As the liquid in the evaporator evaporates, the last drop of liquid refrigerant should complete its evaporation process just as it reaches the evaporator outlet. This is the optimum "flooded" evaporator condition which produces maximum system efficiency without having any evaporator superheat at the tailpipe of the evaporator. By not having any evaporator superheat, the entire evaporator remains active to phase changing (evaporating) refrigerant. Also, any liquid refrigerant which passes through the evaporator should not reach the compressor.

Liquid Flow Control

In the configuration being described, the liquid flow control replaces all other expan-

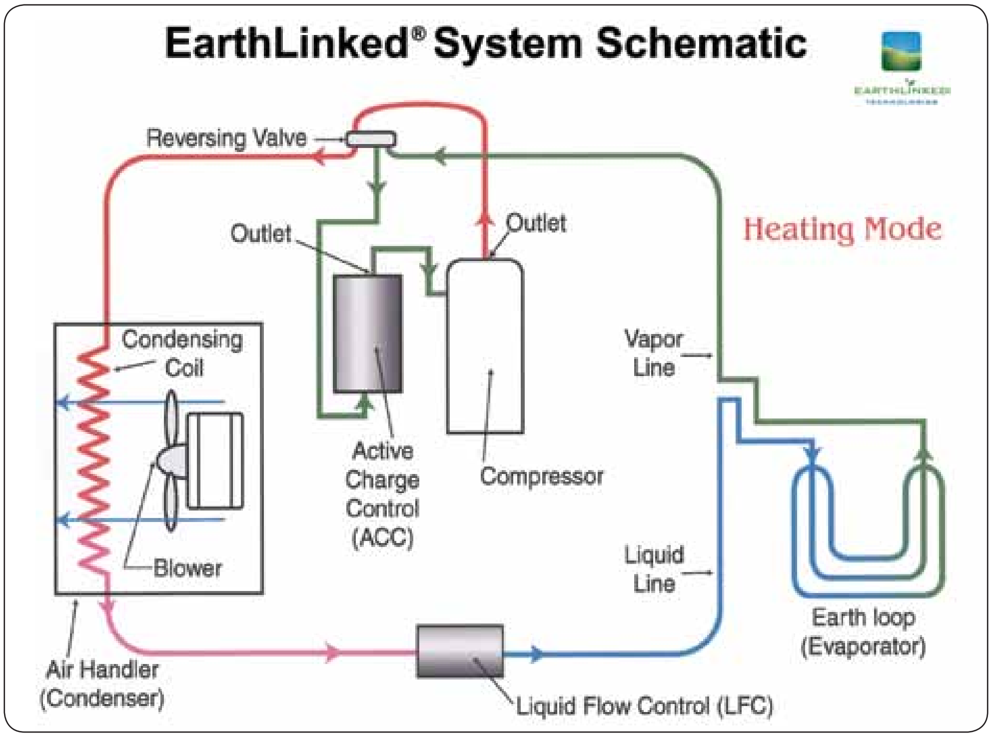


Figure 4.

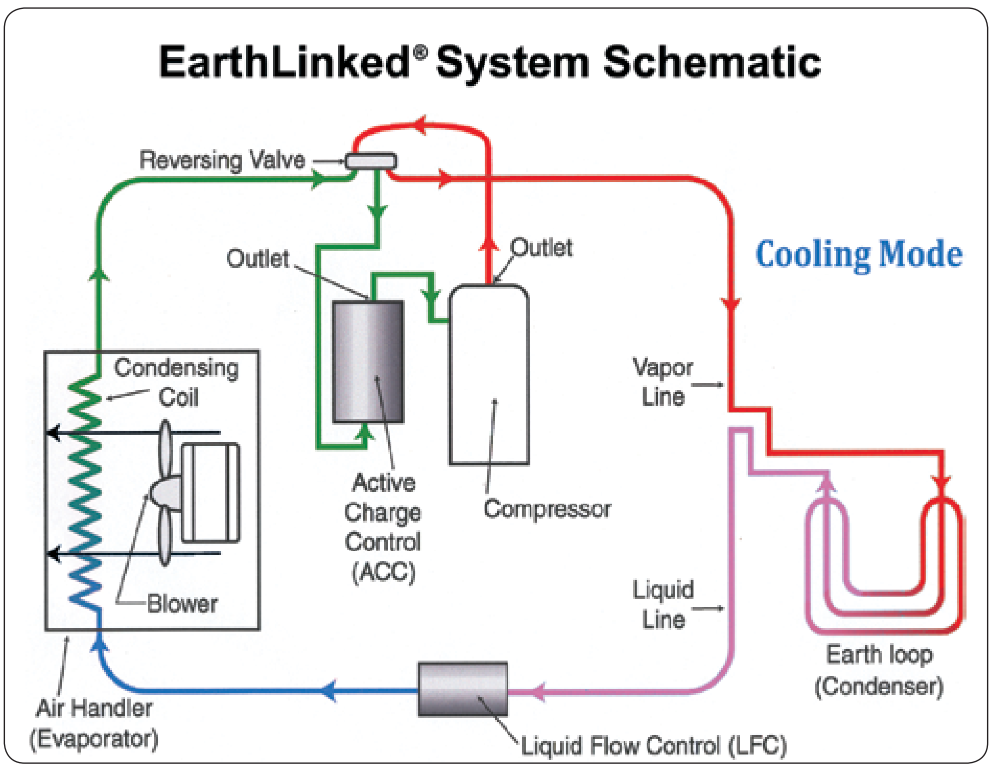


Figure 5.

sion devices including thermostatic expansion valves (TXVs), electronic expansion valves (EXVs), automatic expansion valves (AXVs), fixed orifices, and capillary tubes. The liquid flow control regulates the rate of liquid refrigerant flowing from the condenser to the evaporator by responding directly to the amount of vapor bubbles arriving at the control from the condenser's outlet. The flow control positively meters the liquid refrigerant flow to the evaporator and passes liquid at the rate it is produced in the condenser.

By using the vapor bubbles from the condenser's outlet as a signal as to how much liquid is being produced in the condenser, the control assures that vapor is present throughout the whole condenser, thus eliminating liquid subcooling at the condenser's outlet. By not allowing subcooled liquid to back up in the last passes of the condenser, the condenser will have more internal volume for desuperheating and condensing to take place.

The end result is a larger condenser with lower condensing pressures, lower compression ratios, and higher system efficiencies. The liquid flow control also prevents vapor from blowing through from the condenser to the evaporator because of the lack of a liquid seal (subcooled liquid) at the condenser's outlet.

Some advantages of the liquid flow control are:

- Coordinates with the condenser to set the proper rate of refrigerant flow for the entire system.
- Prevents refrigerant vapor from blowing through the condenser to the evaporator.
- Ensures zero liquid subcooling at the condenser's outlet.
- Reduces the condensing pressure. This gives the system a lower compression ratio, higher efficiencies and a higher mass flow rate of refrigerant.
- Reduces the compressor's power requirements because of lower condensing pressures and lower compression ratios.

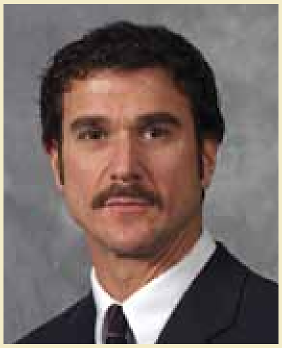
Active Charge Control

The active charge control (ACC) consists of a thermally insulated reservoir that replaces the standard accumulator. Its purpose is to constantly deliver refrigerant vapor and oil to the compressor in the optimum conditions and quantities. The control provides a means of bringing vapor from the evaporator into contact with liquid refrigerant stored within its reservoir.

Inside this control, liquid from the reservoir flows through an orifice into an evaporator tube through which the incoming vapor passes. The liquid is entrained in the vapor stream and circulated back to the reservoir by way of a deflector plate located at the exit of the evaporator tube. If the incoming vapor is superheated, the contact with the liquid evaporates some of the stored liquid, thus reducing the superheat to near zero.

Conversely, if the incoming vapor contains liquid refrigerant, the liquid is trapped in the reservoir. In either event, the refrigerant vapor leaving the active charge control has very little superheat, and because of this, contains no liquid refrigerant. The vapor is almost a saturated vapor when it enters the compressor. The high vapor density entering the compressor results in higher mass flow rates or refrigerant through the compressor and system. Refrigerant coming from the evaporator and into the active charge control is continuously mixed with liquid refrigerant, which passes through an orifice from the liquid reservoir of the control.

Author Notes



John Tomczyk
Professor of HVACR Ferris State University, Big Rapids, MI
Co-author of Refrigeration & Air Conditioning Technology, sixth edition

Use your smart phone or other mobile device to link to more information. Get the free app at http://gettag.mobi.

The end result is a larger condenser with lower condensing pressures, lower compression ratios, and higher system efficiencies. The liquid flow control also prevents vapor from blowing through from the condenser to the evaporator because of the lack of a liquid seal (subcooled liquid) at the condenser's outlet.

The turbulence of the liquid/vapor mixture in the tube causes foaming and misting of the refrigerant/oil mixture. A circulator deflector plate above the inlet tube deflects the mixture radically outward causing a vortex. This action also reduces the velocity of the mixture as it continues to move outward. The refrigerant vapor is drawn upward to the outlet at the upper portion of the tube. Oil mist entrained in the vapor mist also exits the tube at its top.

Any liquid refrigerant droplets and any foam bubbles containing liquid refrigerant are too heavy to be entrained in the vapor stream and fall into the reservoir. Any liquid refrigerant arriving at the active charge control's inlet from the evaporator's outlet is deflected and trapped in the reservoir by the same action. Refrigerant must be evaporated to leave the active charge control, which ensures that no liquid refrigerant returns to the compressor.

The active charge control also acts as a reserve of refrigerant so that the refrigerant charge in the system is not critical. Its function will increase the system's active charge in circulation if the vapor reaching the ACC is superheated. The ACC will also reduce the active system charge if arriving vapor contains liquid refrigerant. Consequently, the system operates with an optimum refrigerant charge in active circulation under all heat loading conditions, providing maximum system efficiency.

The ACC provides a means of quickly and easily determining when the system is properly charged without using gauges, wet and dry bulb readings, or charging charts. A service technician can determine if the system is properly charged simply by observing the liquid level through refrigerant level indicators or sight glasses mounted on the side of the ACC.