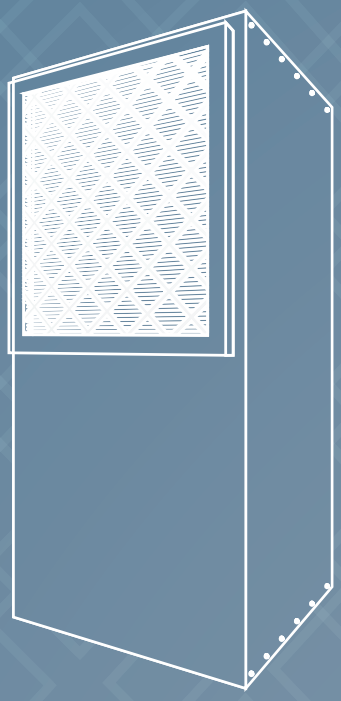


How Ground Source Heat Pumps Work

GEO CONNECTIONS

How Ground Source Heat Pumps Work

A heat pump is a mechanically simple system that is conceptually difficult to relate to. The boiler plate answer for how geo works is...

> "We take heat from the ground and dump it into the house in heating mode and we take heat from the house to dump into the ground in cooling mode. Because the earth has a near constant temperature geo allows us to use less energy in moving this heat than an air source heat pump."

That doesn't really answer the question of how the heat pump works but it seems to satisfy the majority of people. Without getting into too much detail, and without omitting so much the explanation is useless, here is basically how a heat pump works.

The Ground Rules

1. Heat can only travel from high temperatures (sources) to low temperatures (sinks).
2. Heat can not travel if there is no difference in temperature between the source and the sink.
3. Everything inside the heat pump is in a closed system.
4. In a closed system the amount of fluid contained is unchanging.

T is Proportional to P

Ground Rules #3 and #4 make our life much simpler. The fact that we are operating in a closed system means that the **V**olume of fluid and the **n**umber of moles of fluid are constant.

Since **R** is also a constant, **P**ressure and **T**emperature are the only two terms that can change in our equation and they are directly related by a constant value. In other words, when pressure increases so does temperature.

This is the key to understanding vapor compression cycles. You can change the temperature of a fluid just by changing its pressure.

The Ideal Gas Law

The ideal gas law is the key to understanding the vapor compression cycle (the cycle used by all heat pump systems including your refrigerator and a/c). With this simple equation we can relate pressure to temperature which explains how a compressor and some tubes and one little valve can heat a space without using a flame and cool a space without adding ice.

$$P \cdot V = n \cdot R \cdot T$$

P — **pressure**
The uniform force per unit area exerted on the working fluid.

V — **volume**
The amount of working fluid in the closed system.

n
The **number** of moles of gas which describes the amount of working fluid.

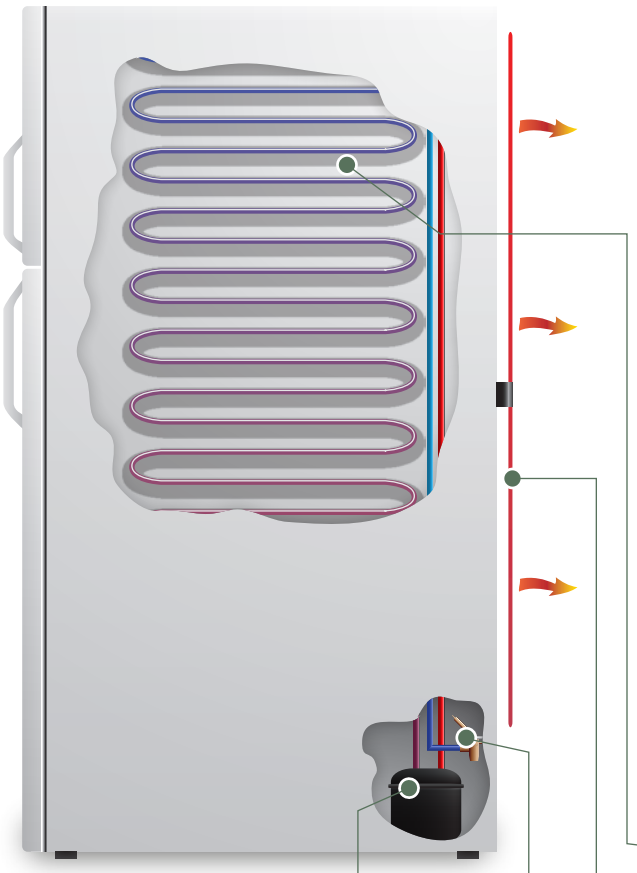
R
The universal gas constant 8.314 J/K·mol.

T — **temperature**
The amount of heat in the working fluid.

Its Temperature Differences That Matter

The purpose of a heat pump is to move heat from where it is, to where we want it. For a heat pump to move heat, there must be a difference in temperature between where the heat is, and where we want it to go.

The heat pump is the middle man in a system containing a low temperature sink, a high temperature source, and the heat pump itself. The heat pump moves energy from the source to the sink using a 'working' fluid. The working fluid is inside the heat pump and it is the fluid that the heat pump directly works on. A perfect example of this in action is your home refrigerator.



Your kitchen acts as the sink and is probably around 70°F. The inside of your fridge is the source and probably around 36°F. If Ground Rule #1 is true, then we shouldn't be able to move heat from inside of the fridge to the kitchen because the kitchen is hotter. This is why we need the heat pump and its working fluid.

We need the working fluid to be hot as it goes through the condensor coil on the back of the fridge so we can reject heat to the kitchen so, the heat pump increases the pressure which; because of that handy gas law, causes an increase in temperature.

We need that same fluid to be colder than the fridge as it passes through the interior coil so we can absorb heat energy from the inside. So, the heat pump decreases the pressure on the fluid using an expansion valve which decreases the temperature.

Heat pumps just keep repeating this process over and over again until a desired temperature is acheived in the conditioned space. Repeatedly changing pressures to create changes in temperature in this way is known as the vapor compression cycle.

COMPRESSOR

The compressor increases the working fluids pressure to raise its temperature above the kitchen's.

EXPANSION VALVE

This de-pressurizing nozzle reduces working fluid temps so heat can be picked up from the inside of the fridge.

CONDENSOR COIL

This coil outside the fridge circulates hot working fluid rejecting heat into the kitchen.

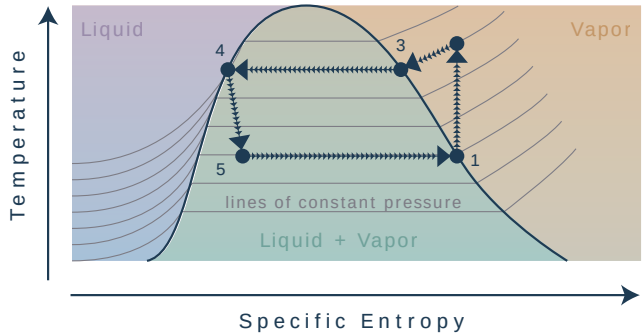
EVAPORATOR COIL

This coil inside the fridge circulates cold working fluid that picks up heat from the inside thereby cooling off six-packs of b... soda.

The Vapor Compression Cycle

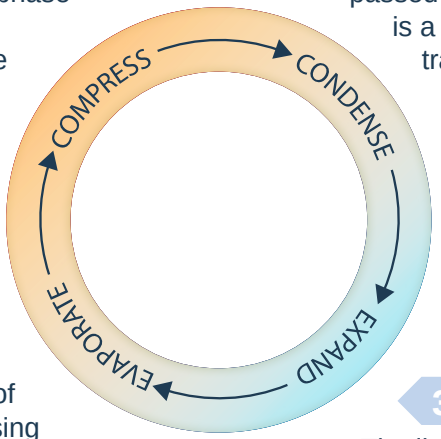
The graph below describes the vapor compression cycle using 5 state points which describe what is happening with the working fluid in our closed system in terms of temperature, pressure and entropy. To achieve these state points the working fluid goes through 4 processes described below.

NOTE: The x-axis of the graph describes the entropy of the fluid. To understand the basic cycle, it is not necessary to understand entropy but if you're curious check out this article.



1 COMPRESS

Using a compressor, the heat pump takes working fluid that is in the vapor phase and increases the pressure. This causes that proportional increase in temperature described above and moves us from state point 1 to 2.



2 CONDENSE

The high pressure and temperature vapor is passed through the condenser. A condenser is a heat exchanger that facillitates the transfer of heat energy from the working fluid to a lower temperature sink thereby condensing the working fluid to liquid and heating the low temperature sink taking us from state point 2 all the way to 4*.

3 EXPAND

The liquid working fluid that leaves the condenser is passed through an expansion valve. The expansion valve causes a decrease in the pressure of the fluid which coincidentally drops the temperature moving us from state point 4 to 5.

4 EVAPORATE

The working fluid is in a mixture of vapor and liquid states after passing through the expansion valve and entering the evaporator. The evaporator is another heat exchanger coil where the working fluid picks up heat from a high temperature source and evaporates into a completely vapor phase before returning to the compressor.

***What is happening between state point 2 and state point 3?**

Between states 2 and 3 the fluid is going through a process called 'de-superheating'. We are taking superheated vapor and cooling it down without changing it from a gas to a liquid. This process is often used in geothermal as a means of hotwater generation in a device cleverly named the desuperheater.

Great But How Does A Geothermal Heat Pump Work?

Now that we have covered the basics we can relate it to a geothermal system. In addition to the heat pump we also need to define two more components of the complete geothermal system; namely, the conditioned space and the ground heat exchanger.

Each part of the entire geothermal system has its own fluid that is used in the heat transfer process so for convenience lets label them heat pump fluid, air and loop fluid. These fluids are not mixed. They interact through contact with other surfaces.

In a geothermal heat pump, we have the same basic components that we described for the vapor compression cycle. A compressor, a condensor an expansion valve and an evaporator all contained inside of the cabinet. The purpose of the heat pump is to move the heat energy from the source to the sink.

The vapor compression cycle creates large temperature differences between the heat pump fluid and the air as well as the heat pump fluid and the loop fluid. These temperature differences are what allow heat to transfer from one medium to the next (see Ground Rules #1 & #2).

The conditioned space is the inside of your home and has a fluid either air or water that we want to heat or cool. We don't typically cool water so for the rest of this explanation we will assume that we are using a water-to-air heat pump.

The ground heat exchanger is the system of pipes that are installed in the ground containing an entirely different working fluid from that of the heat pump. The loop fluid's job is to facillitate the transfer of heat between the ground and heat pump. The loop fluid is pumped through the loop field and either absorbs heat from the ground for heating or dumps heat into the ground for cooling.

The Heating and Cooling Cycles

The Heating Cycle

1. The compressor raises the pressure of the heat pump fluid which coincidentally raises its temperature.
2. The hot vaporized heat pump fluid is pumped through the condenser. The air to be heated flows across the condenser. This condenses the heat pump fluid to a liquid and warms up the air.
3. The condensed heat pump fluid is pumped through the expansion valve which cools it down and turns it into a liquid/vapor mix.
4. The cooled heat pump fluid flows through the evaporator coil while warm loop fluid flows around the coil. The loop fluid is warmer than the heat pump fluid so the loop fluid gets cooler while the heat pump fluid evaporates.

This process continues until the space is heated to the desired temperature.

The loop fluid is circulated through the ground heat exchanger at the same time the heat pump is running. Everytime the loop fluid leaves the heat pump it is cooler than when it entered because it is giving its heat energy to the heat pump fluid in the evaporator coil.

The loop fluid then picks up more heat energy from the ground as it flows through the ground heat exchanger.

The Cooling Cycle

1. The compressor raises the pressure of the heat pump fluid which coincidentally raises its temperature.
2. The hot vaporized heat pump fluid is pumped through the condenser. The loop fluid flows across the condenser. This condenses the heat pump fluid to a liquid and warms up the loop fluid.
3. The condensed heat pump fluid is pumped through the expansion valve which cools it down and turns it into a liquid/vapor mix.
4. The cooled heat pump fluid flows through the evaporator coil while warm air from the space flows around the coil. The air is warmer than the heat pump fluid so the air gets cooler while the heat pump fluid evaporates.

This process continues until the space is cooled to the desired temperature.

The loop fluid is circulated through the ground heat exchanger at the same time the heat pump is running. Everytime the loop fluid leaves the heat pump it is warmer than when it entered because it takes heat energy from the heat pump fluid in the condenser coil.

The loop fluid then rejects this heat energy to the ground as it flows through the ground heat exchanger.