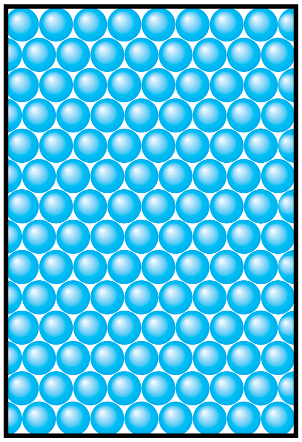
How HVAC Works

Heat - What is it?

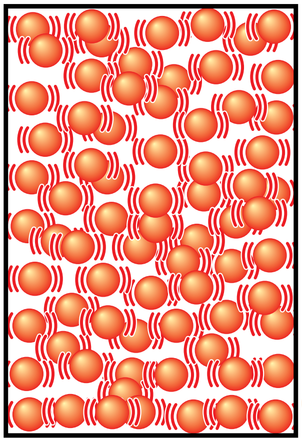
Heat is more than a physical concept - it is a feeling. Heat is taught to us at a very young age as a danger to be avoided. Yet, have you ever stopped and thought about what heat really is? How does it move? What are some of the ways we can move it?

Heat, commonly described in degrees of temperature, such as Fahrenheit (°F) or Celsius (°C), describes the random motion or "vibration" of molecules. When a substance becomes hotter, its molecules move faster. How fast these molecules move determines whether the substance is a solid, a liquid, or a gas.

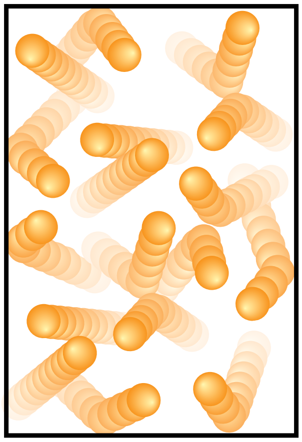
In a solid, molecules are locked together in position. In a liquid, molecules move and share a loose relationship with each other. Molecules in a gas, share no relationship with each other because they move very fast.



SOLID: Molecules are rigidly bound and do not move.



LIQUID: Molecules are loosely bound, they vibrate and move around.



GAS: Molecules are not bound and move freely, really bouncing off the walls!

Heat and temperature do not describe the same thing. Heat is an absolute quantity measured in British Thermal Units (BTU's), much like "one cube" describes a quantity of sugar. Temperature (measured in degrees Fahrenheit or Celsius) is a relative measurement similar to how "sweetness" describes "one cube" of sugar dissolved in a cup of coffee. Both "one cube" and "sweetness" are describing a quantity of sugar, but "sweetness" is describing the sugar relative to the coffee. If I added more coffee to the cup, the amount of sugar would be the same, but the "sweetness" would decrease.

Heat on the Move

Heat is always on the move. Since heat is a measure of the molecule's speed, hot molecules move faster than colder, slower molecules.

Speed = heat.

1 When a fast, hot molecule collides with a slower, colder molecule, like a fast car colliding with a slow car. . .the slower molecule speeds up (it becomes hotter) like the cars, but never as fast as the car that hit it, and it "cools" the faster car, too!

2 Heat always goes from hot to cold because a slow molecule cannot make a fast molecule go faster! Have you ever heard of a car going 15 mph catching up to and hitting a car going 30 mph?

30 mph 15 mph

15 mph

30 mph

Cab Environment

Understanding the three ways heat moves helps you consider all the heat sources that an air conditioner contends with.

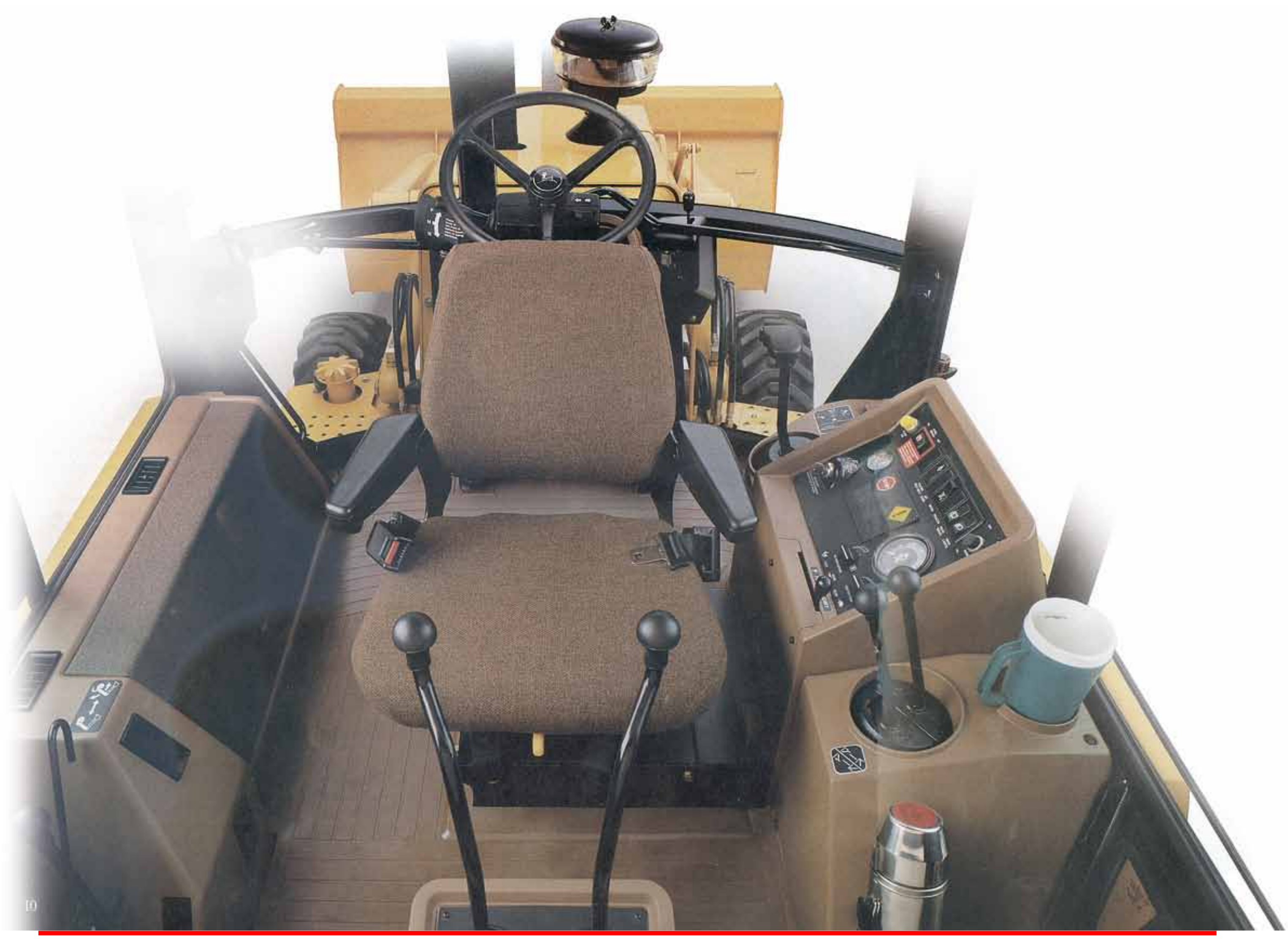
- **Conduction** is when heat is transferred through a solid such as the metal fins of an evaporator.
- **Convection** is when a colder gas displaces a warmer gas causing them to move around and circulate.
- **Radiant** heat is when the sun's rays hit a solid surface causing it to heat up.

For example, understanding radiant heat will help you consider how the sun places an additional load on an air conditioner.

Truck cabs and off-road machinery cabs are hard to heat and cool. They have large glass areas and are not always well insulated. Hot and cold weather directly affect the temperature inside the cab. This means that any air conditioner system must have the capacity to do a lot of heating and cooling.

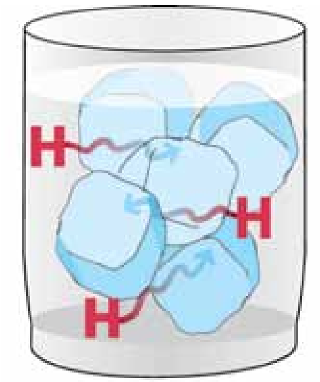
The purpose of an AC system is to keep the driver comfortable (which sometimes seems to be an impossibility). Most people feel comfortable in the 70˚F to 80˚F range. Because truck drivers and heavy duty vehicle operators are in their cabs for long periods of time, the cab temperature is very important for their comfort.

The ideal cab environment has a modest humidity level and should reach and remain at a temperature of 70˚F to 80˚F within several minutes of operation. Most air conditioners cycle on and off by the action of a thermostat or a low pressure switch. This switch cycles the compressor clutch and regulates the evaporator core temperature. This cycling action maintains a comfortable temperature range for the driver and any passengers.



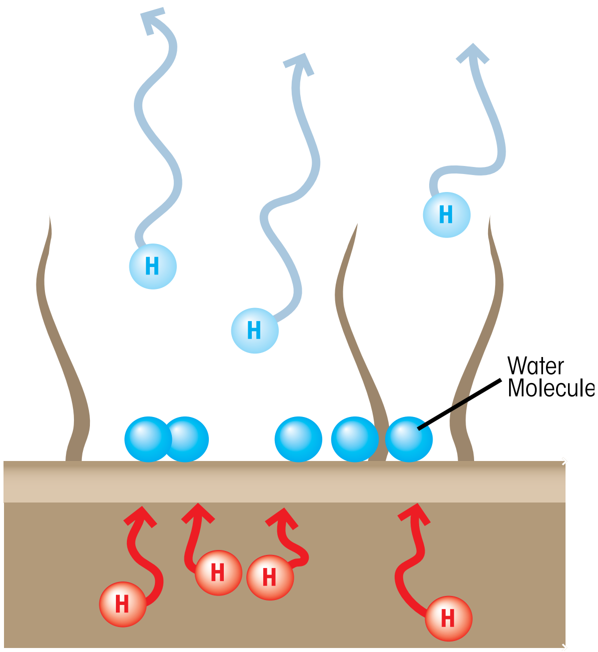
How do we remove heat?

Removing heat is simple. Since heat always goes towards a colder object, all we have to do is give heat a cold thing to flow into. A good example of this is a iced drink. To cool the drink down, we put in ice cubes. Since ice cubes are colder than the warm liquid, the heat will flow into the ice cubes. The ice cubes absorb the heat and melt, removing the heat from the liquid. Now the drink is much more enjoyable.



Heat flows into the ice cubes, causing them to melt.

Another simple way to remove heat is to use water. If you go the beach on a hot day, you may notice that folks who sunbathe frequently spray themselves with water to keep their skin cool. When they spray water on their skin, the heat from their bodies speeds up the water molecules and causes them to boil. When the water molecules boil, they change to a gas and escape into the air taking the heat with it. Overall, the water gets hot, the skin gets cool. We call this process "evaporation."

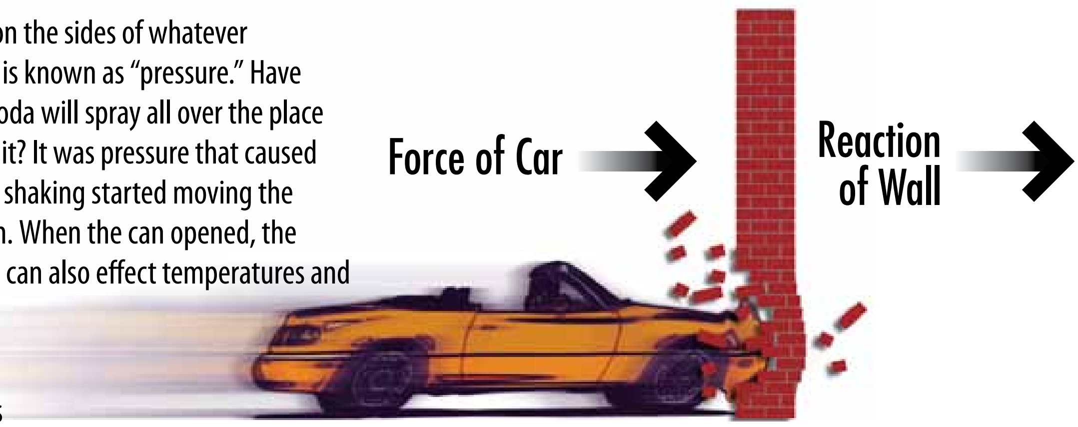


One of the main reasons for developing refrigeration systems was to produce beer. Beer yeast must ferment at temperatures around 45º F. Because of this cold ferment temperature, brewers were forced to make beer in Milwaukee because of the longer cold season. With refrigeration, brewers can now brew beer as far south as Florida's Busch Gardens.

Introduction to Pressure

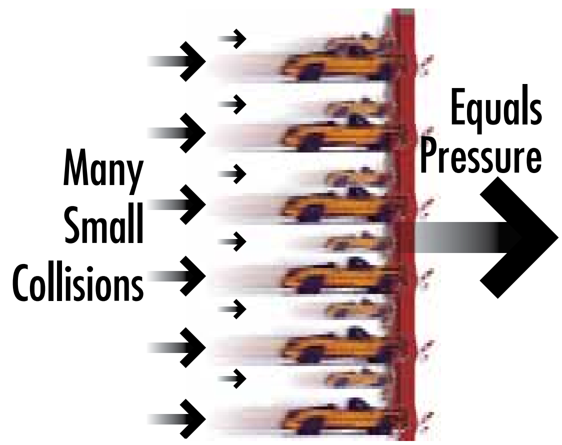
Under pressure

Gases and liquids exert a force on the sides of whatever container they are in. This force is known as "pressure." Have you ever noticed how a can of soda will spray all over the place when you shake it up and open it? It was pressure that caused that mess. The energy from the shaking started moving the molecules around inside the can. When the can opened, the pressure was released. Pressure can also effect temperatures and the boiling points of liquids.



Let's take a look...

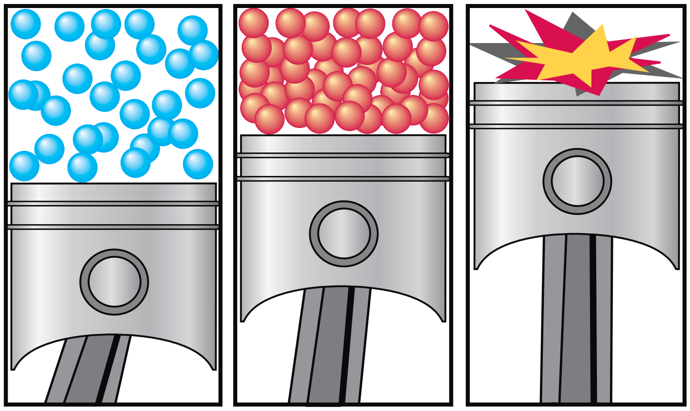
Everything in the atmosphere is under pressure because of millions of tiny collisions. The force of these crashes add up to a terrific force called "pressure." For example, if a car hits a wall, the wall reacts and crumbles in the direction of the crash. If we reduce the scale of the crash to the size of molecules and add millions more, the wall will react the same as before. This reaction is known as pressure. Pressure and heat are very similar but heat is the speed of a molecule and pressure is the reaction of what the molecule runs into (such as a wall). Heat and pressure are also related to each other, or one will cause the other and vice versa. We'll discuss that next.



Compression Heating

When we described heat, we said that heat is transferred from a fast moving or hot molecule to a slow moving or cold molecule. When a gas is compressed, the pressure caused by a moving object (like a piston) can speed up molecules and make them hotter. Have you ever wondered why a diesel engine doesn't need a spark plug? Diesel engines ignite their fuel-air mixtures by using compression. The force of the diesel engine's piston raises the pressure so much that the fuel-air mixture gets hot enough to explode.

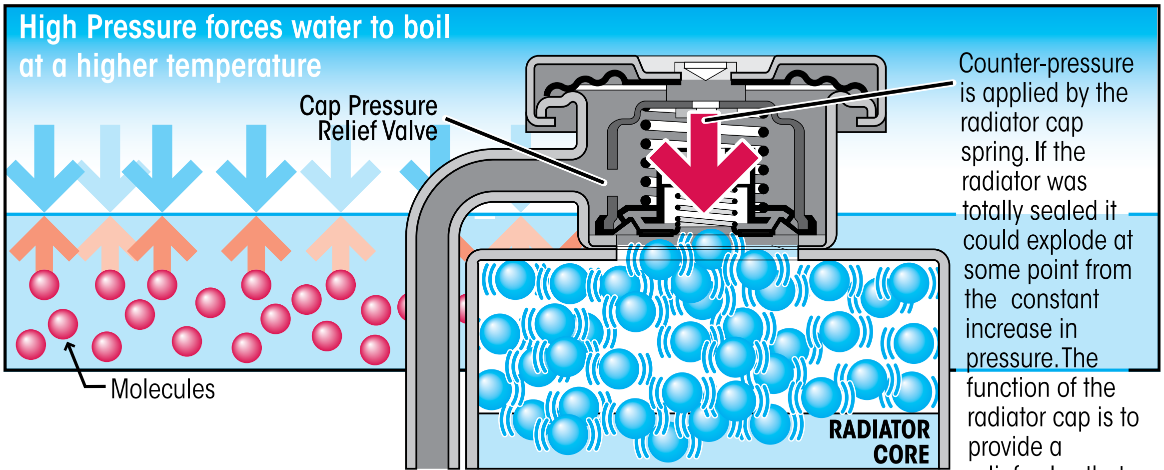
In AC systems, the compressor takes in cool low pressure gas and discharges hot, high pressure gas. At work is the compressor piston, crashing into millions of gas molecules causing them to speed up and get hot. Remember, an increase in pressure means an increase in temperature.



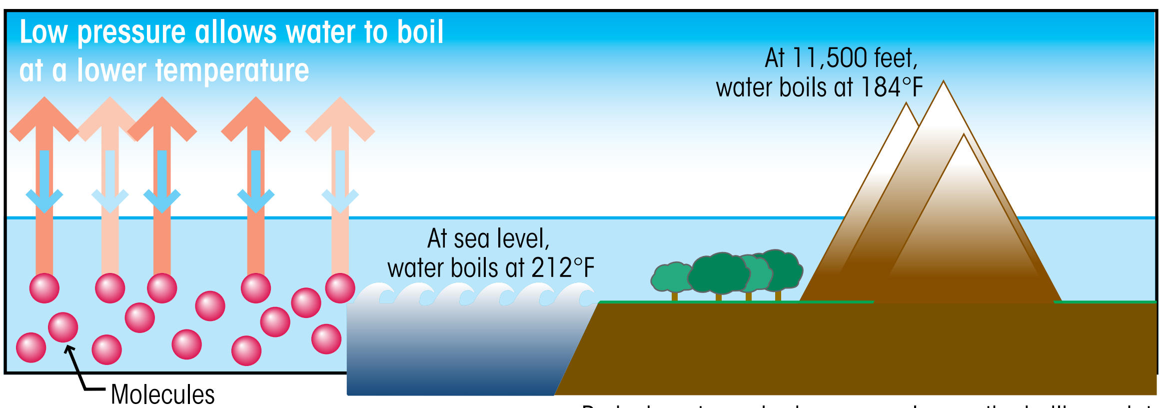
Boiling Over

Boiling is the process of rapid evaporation, where liquid molecules escape as vapor and take heat away. Engines frequently operate at temperatures well over the boiling point of water (212°F). If an engine is at 220°F, why doesn't it boil over? The reason is simple, the water cooling system in the engine is under pressure because it is capped off. When pressure is placed on a substance, it is harder for it to boil. If more pressure makes it harder for a substance to evaporate or boil, what happens when we decrease pressure?

Less pressure makes it easier for substances to boil or evaporate because there is less force keeping the molecules together as a liquid. For example, if you boil water high in the mountains, it would take up to 28° F less heat because there is less air pressure at high altitudes. Pressure is a valuable concept in our AC system. With it, we can create boiling and evaporation at very low temperatures and create condensation (changing from a gas to a liquid) at very high temperatures. These principles are what makes AC possible.



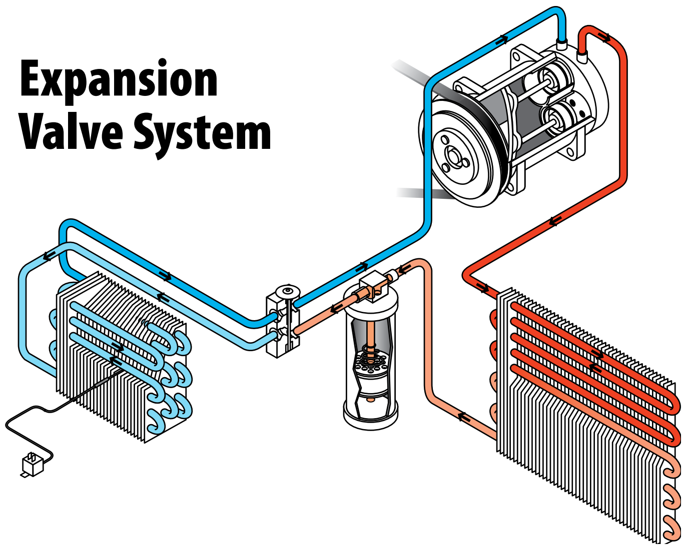
Water molecules are not allowed to expand into vapor because of the counter-pressure applied by the radiator cap. So water can be heated above it's normal 212˚F boiling point.



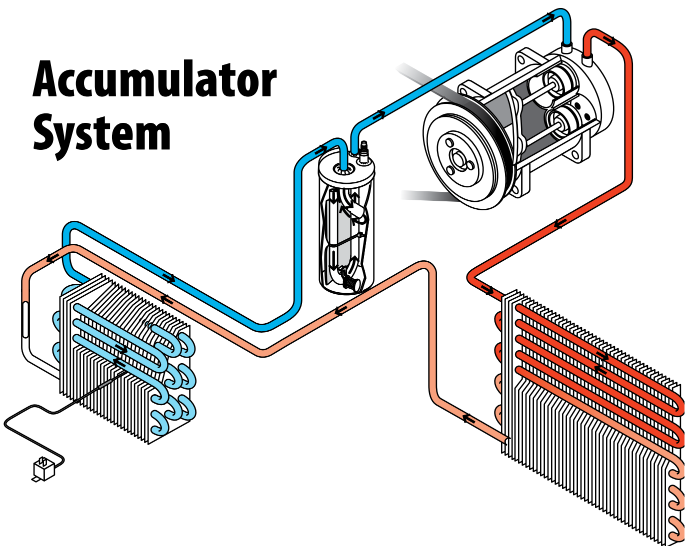
Reducing atmospheric pressure lowers the boiling point

Introduction to A/C Operation

Expansion Valve System



Accumulator System



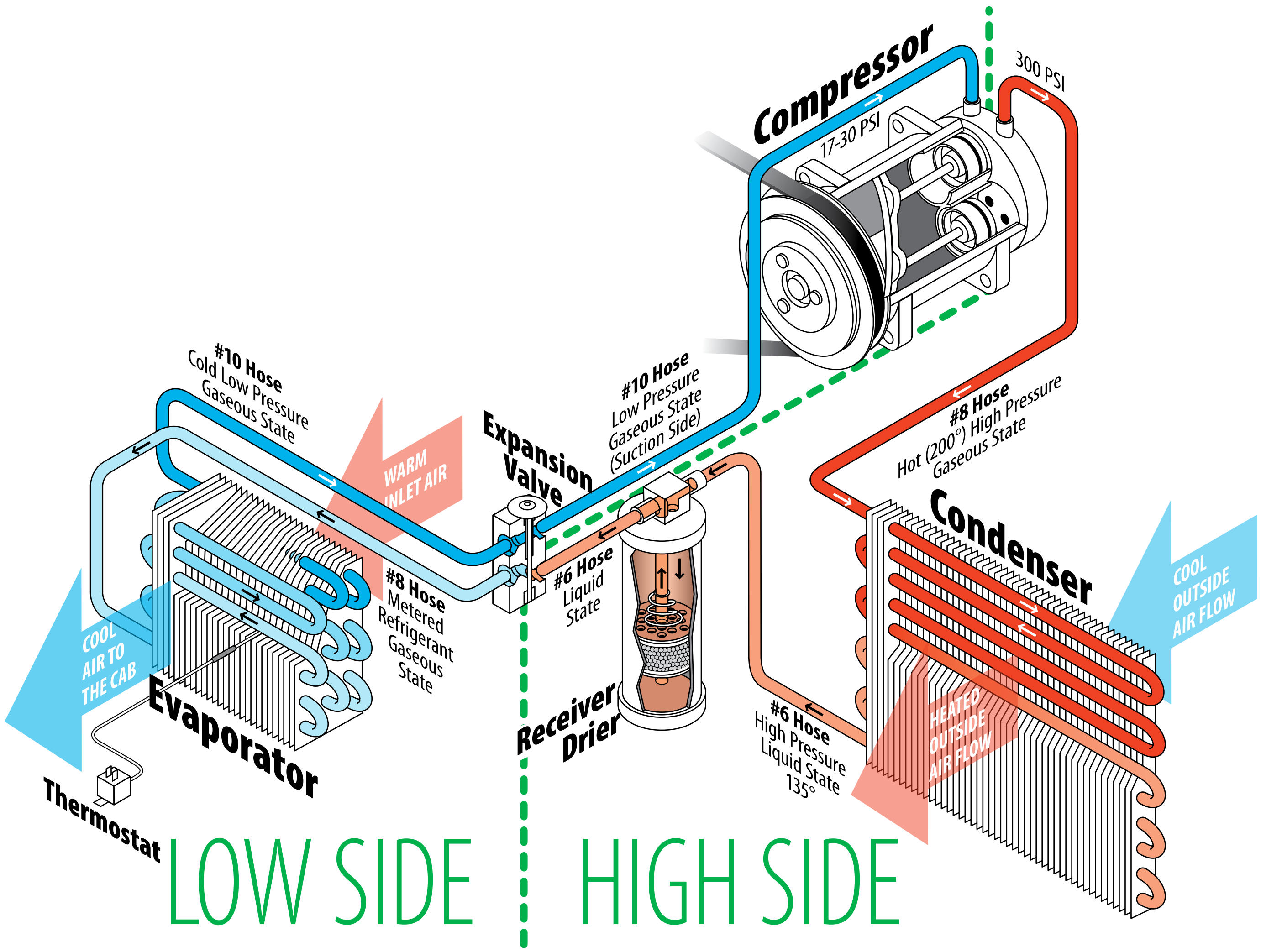
AC Systems are much like a mother, who uses a sponge to soak up milk from a spilled glass. She soaks it up and then wrings the milk out of the sponge and into the sink. Similarly, an AC system soaks up heat in the cab using evaporation and then squeezes the heat into the outside air using condensation. Let's take a closer look.

Air conditioners have two basic layouts: the **expansion valve system** and the **accumulator system**. Red Dot primarily uses the expansion valve system.

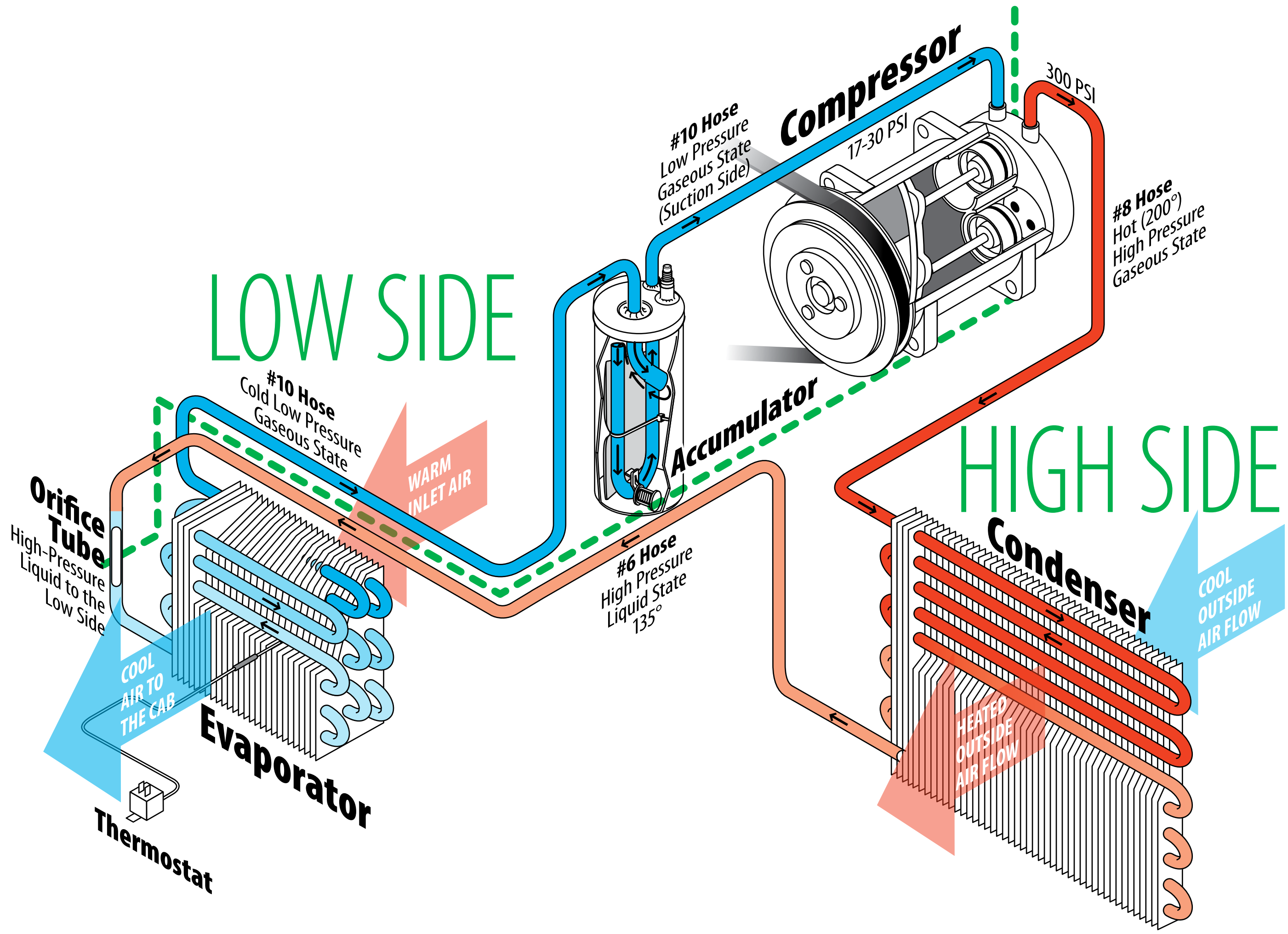
With five basic components

1. **Expansion device:** A restriction in the liquid line of the system, purposely designed to cause a pressure drop.
2. **Evaporator:** A device that removes heat from the cab air by exchanging it into boiling refrigerant.
3. **Compressor:** Provides the mechanical energy to move refrigerant and manipulate pressures. This is the heart of the system.
4. **Condenser:** Designed to exchange heat from the refrigerant to the outside air. Similar to the evaporator.
5. **Drier Filter Device:** A storage container for extra refrigerant that usually contains a drying agent called desiccant and a filter to screen out contaminants.

Expansion Valve System



Accumulator System



Low-Side Operation

Since the low side has a very low pressure, the refrigerant can begin to boil off into a gas. When the refrigerant changes from liquid to gas it gathers heat from the cab air. The pressure difference is created by an expansion device.

Pressure-Temperature Drop

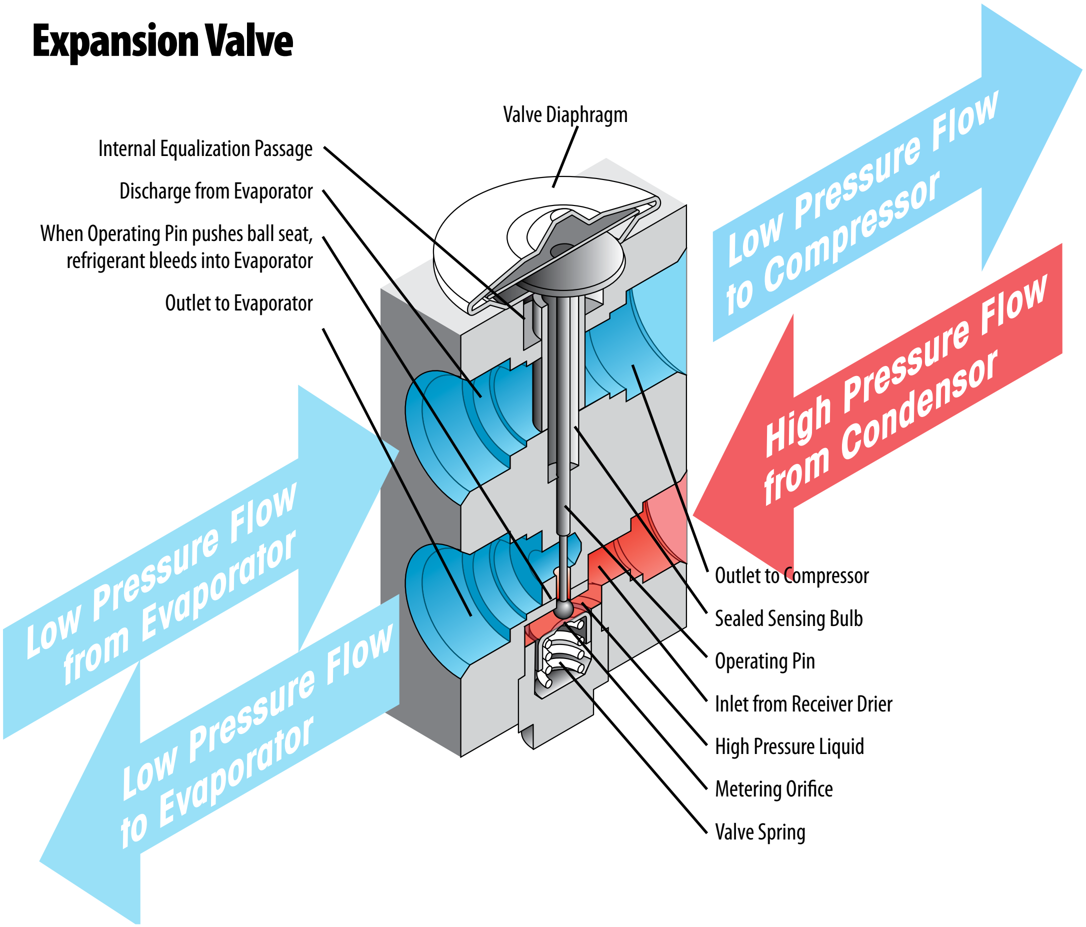
There are two types of expansion device is the component that begins the evaporation process:

1. Thermostatic Expansion Valve (TXV) (left)

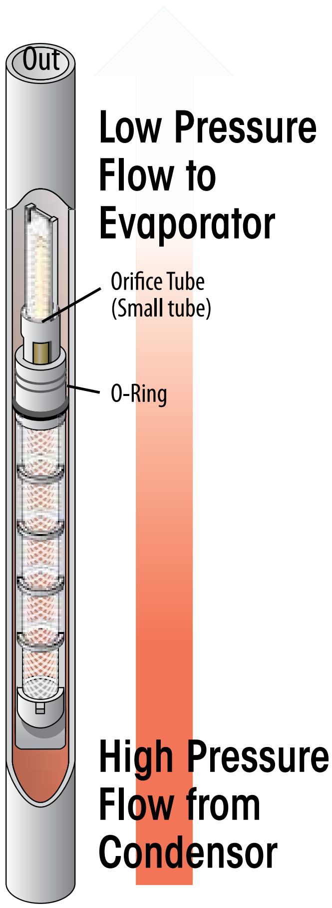
2. Orifice Tube (right)

The expansion device creates a pressure drop by restricting the flow of refrigerant around the system. Slowing down the flow of refrigerant causes the compressor to partially evacuate one side of the system. This low pressure void is called the "Suction side" or the "Low side" of the system.

Expansion Valve



Orifice Tube

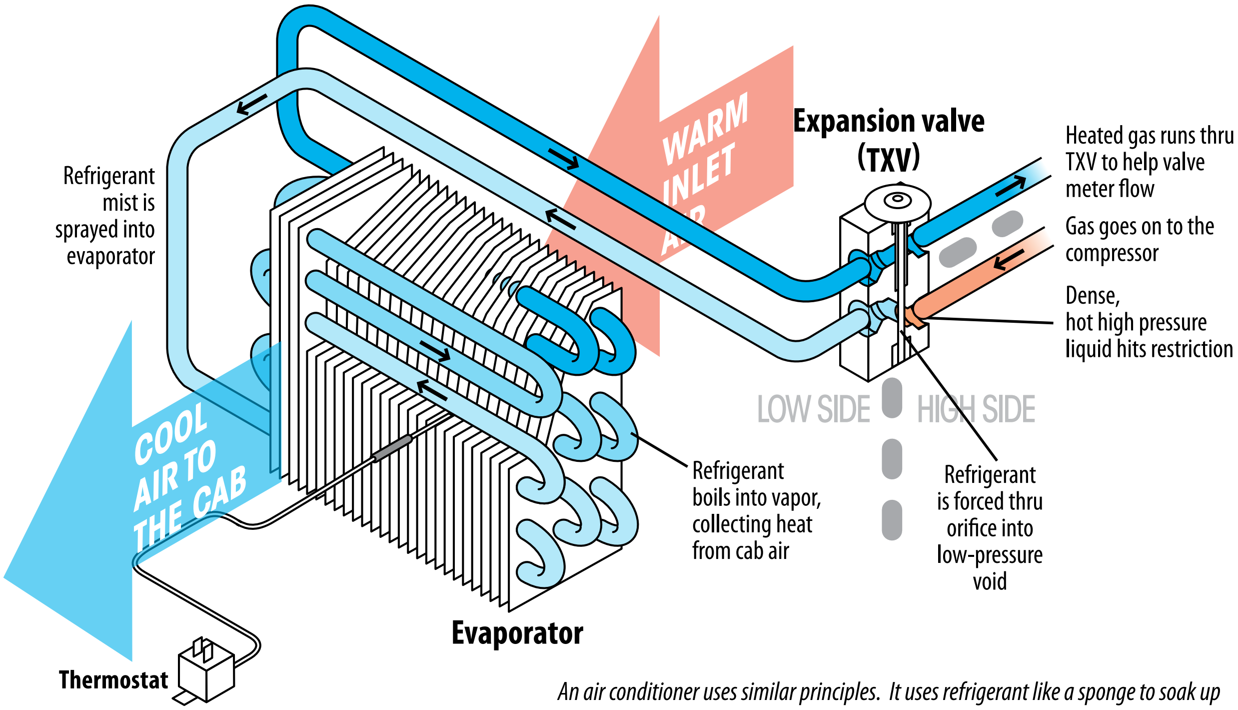


The refrigerant inside of an air-conditioner is essentially a "heat sponge." It very similar to taking a dry sponge and dunking it into a bucket of water. As the water fills the sponge, the sponge expands and becomes heavy with water. Then, when you want to remove the water, you simply squeeze the sponge with your hands and the water comes out.

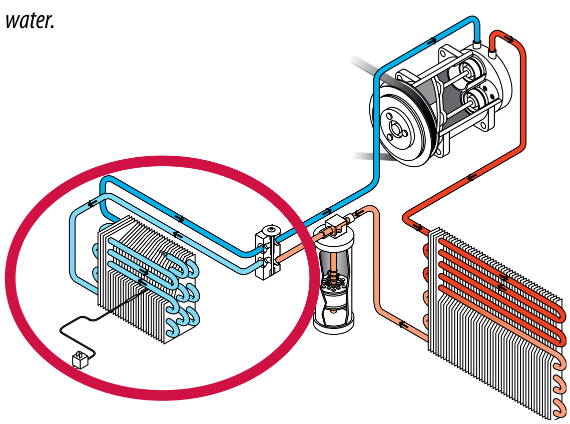
Expansion Cooling

Low-Side Operation

Cold refrigerant absorbs heat from the cab air while the refrigerant circulates inside the evaporator coil. Heat from the cab air passes through the metal of the evaporator and cause the refrigerant to expand by boiling off into a vapor. This boiling is possible because refrigerants used in AC systems have a boiling point of about one pound per square inch per 1°F. For example, the boiling point of refrigerant is approximately 20°F at 20 psi. As the refrigerant expands by boiling into a vapor, it takes massive amounts of heat with it.



An air conditioner uses similar principles. It uses refrigerant like a sponge to soak up heat (just like a sponge soaks up water). When the refrigerant enters into the thermal expansion valve (TXV) it is essentially a dry sponge. When it passes through the small orifice of the TXV it sprays into the evaporator. As the refrigerant heats up in the evaporator, it expands collecting large amounts of heat, like a sponge expands with water.

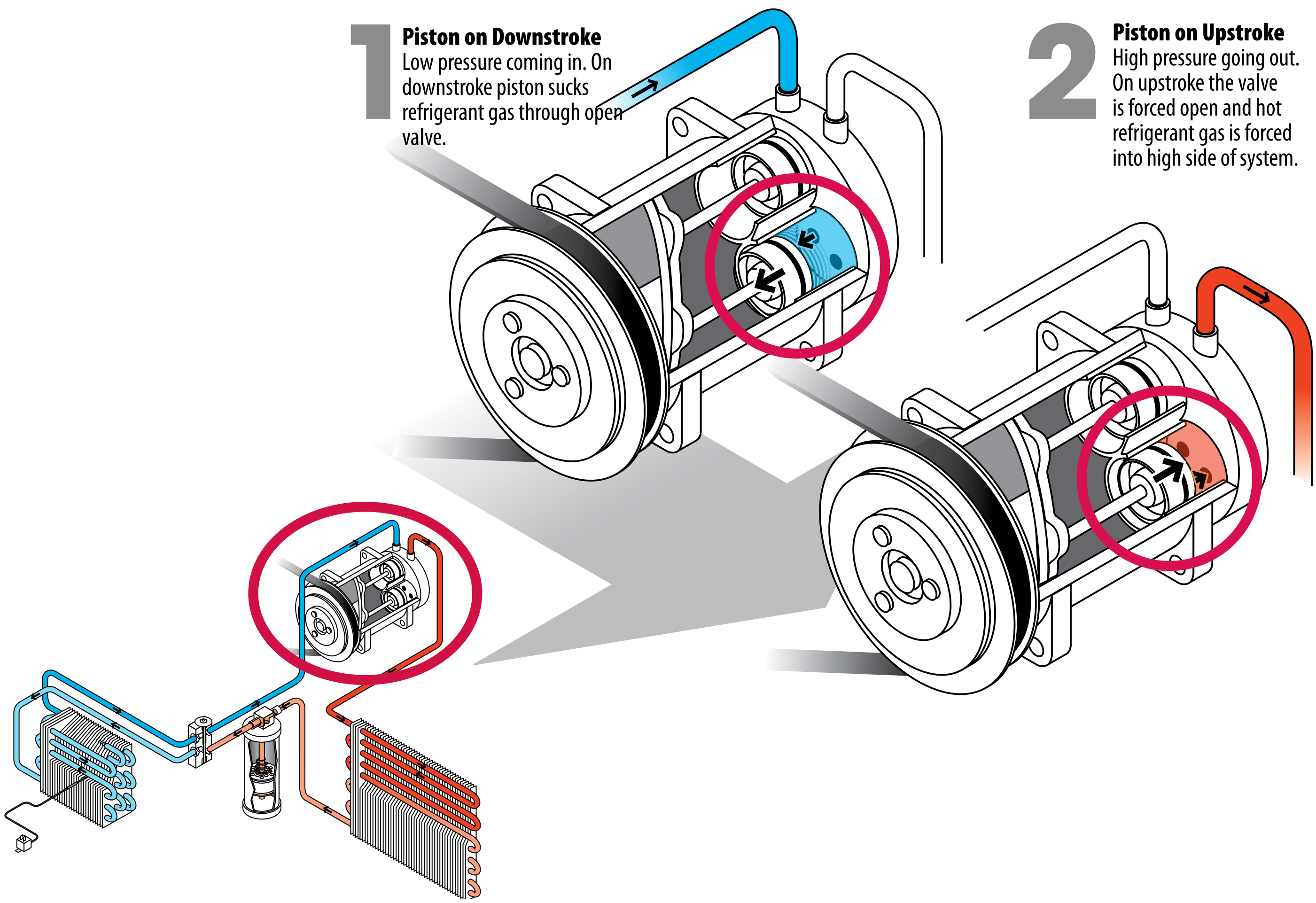


High-Side Operation

So far, we have learned that the low pressures attract heat into the system by expanding refrigerant. The part of the system that rejects heat into the outside air is known as the high side. It rejects heat by condensing hot vapor into warm liquid and through this process, squeezes heat out of the system. Heat rejection is accomplished using very high pressures (up to 350 psi) and large volumes of air.

COMPRESSION HEATING

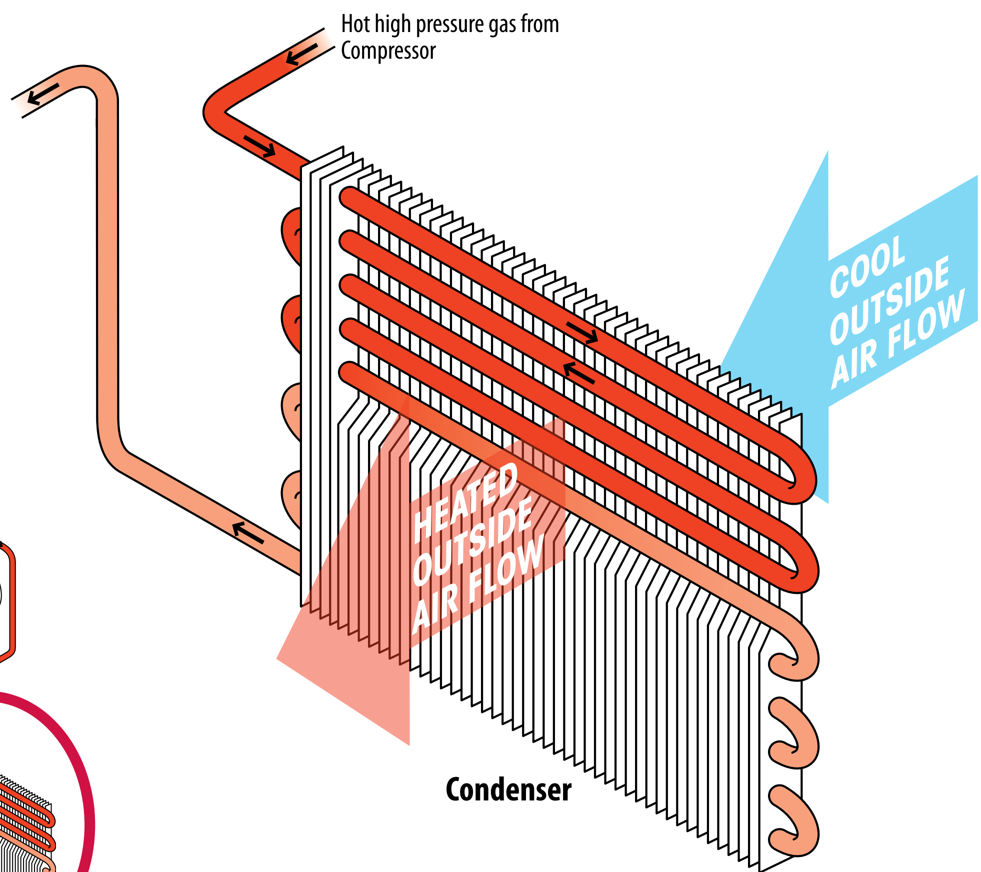
Remember that raising the refrigerant pressure is necessary to begin the process of rejecting heat into the outside air.
On its downstroke (#1 at right), the compressor piston collects the expanded refrigerant inside the compressor. On its up-stroke (#2) the piston forces the refrigerant molecules closer together. The refrigerant vapor is raised in pressure, temperature and boiling point before being forced out of the valve plate assembly. The temperature of the vapor is normally two and a half times higher than the temperature of the outside air. Since heat always flows from hot to cold, the refrigerant must be much hotter than the outside air to be able to move heat out of the system.

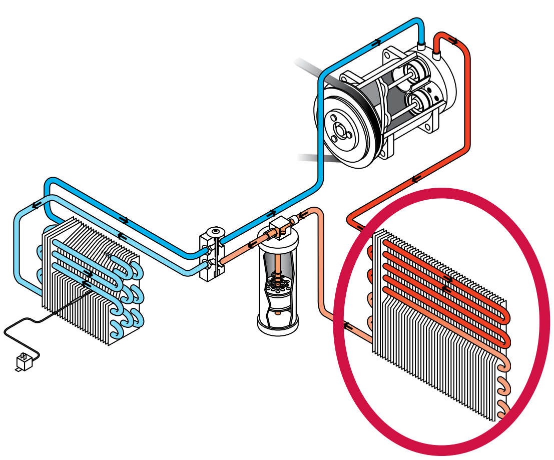


High-Side Operation

Subcooling

The hot, high pressure vapor makes its next stop at the condensing coil. The condenser is just like the evaporator – it is a heat exchanger. It looks a little different from the evaporator because it is more flat and a little larger (an evaporator must fit under the dash). Inside the condensing coil, the gas starts its way from the top to the bottom, cooling down a little with each pass. By the time the refrigerant reaches the lower third of the coil, it cools down enough to change back into a liquid. As a liquid, it continues to cool 15-30°F below its boiling point in a process called "subcooling." Subcooling is an important concept to understand because it will tell what is wrong with the high side of the system. The next modules four, five and six will cover Troubleshooting, Inspection and AC Performance with more detail on subcooling and other topics.





When the expanded refrigerant enters into the compressor, the mechanical force of the piston forces the expanded refrigerant molecules closer together, increasing the pressure (just like when you squeeze a sponge full of water). When the high pressure refrigerant enters into the condenser, the heat is squeezed out into the outside air.

RedDOT® CORPORATION

P.O.Box 58230
Seattle, WA 98138

www.RedDotCorp.com