# Technical Training Associates Presents

# Refrigeration Fundamentals For HVACR Technicians

***By Jim Johnson***

A Practical Approach To Understanding…

…Heat Transfer
…Refrigeration System Components
…Refrigerants & Temperature Pressure Charts
…Evaluating & Troubleshooting Refrigeration Systems
…EPA Certification Preparation

Refrigeration Fundamentals For HVACR Technicians


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WARNING!

The reader is expressly warned to consider and adopt all safety precautions that might be indicated by the activities described in this e-book, and to avoid all potential hazards. By following any instructions contained herein, the reader willingly assumes all risks in connection with such instructions.

# REFRIGERATION FUNDAMENTALS FOR HVACR TECHNICIANS

## Service Procedures, System Evaluation, Troubleshooting & EPA Regulations

Topics and Contents

# HEAT TRANSFER & THERMODYNAMIC LAWS

In any vapor compression refrigeration system, there are fundamental laws of heat transfer that allow it to function.

The first one to keep in mind is that heat always moves from warmer to cooler. The second one states that heat moves in three ways:

1. Conduction, which is the movement of heat through a solid.
2. Convection, which is the movement of heat through a liquid.
3. Radiation, which is the movement of heat through the air.

And, the third and fourth laws of thermodynamics (think simply, laws of heat transfer) are the reason the refrigerants, which are often referred to by their brand names, such as Freon, within the system work the way they do. These two laws state two simple concepts:

When a substance boils, it absorbs heat.

When a substance condenses, it rejects heat.

Now, it’s not our intent to turn you into an engineer by discussing laws of thermodynamics. After all, you’re likely not going to be designing refrigeration systems, only troubleshooting and repairing them. But, the foundation of effective troubleshooting is having a complete understanding of the equipment you’re working on, so with that thought in mind, we’ll give you some background on the laws of thermodynamics.

Heat always moves from warmer to cooler. This one is simple….imagine that you have a black automobile and you've taken it to Death Valley, California, and it's August. Even if you've never been to Death Valley, you can guess why it earned its name. In August, temperatures can easily top 120-Degrees Fahrenheit. So, if you parked your automobile in the sun, say, at high noon, then waited for a few minutes before pressing your palm directly onto the hood, you would get a graphic illustration of the movement of heat from warmer to cooler. Obviously, your body temperature is 98.6, and the temperature of the hood of that black car at noon in August would be much higher than that. You would feel the attempt of the transfer of heat from the car into your body.

And now, consider this….

If you took that same automobile to International Falls, Minnesota on December 31st, and parked it, waited a few minutes, then put your *tongue* on the hood of the car, you would again be proving that heat always moves from warmer to cooler. You're still at 98.6 in this scenario, but the car…well, likely closer to a temperature somewhere below zero, which would mean that the heat from your body would try to transfer to the car. (By the way, we don't recommend that you actually try this. We just wanted to make a point.)

How does this information help you understand the refrigeration process? Well, consider the common-sense idea that in any refrigeration system, indoor coil, the coil inside the refrigerator, walk-in, reach-in or whatever, is always going to be cool to the touch. Which means that even if we didn't implement the idea of forced-air and moving air through a coil, the law of thermodynamics that states "heat always moving from warmer to cooler", would allow the refrigeration system to begin to work.

And, now, on to the second law….Heat moves in three ways.

To say that heat moves by conduction is to say that heat can move through a solid. If you were to build a campfire and place a six-inch section of a three-foot-long piece of metal into the flame, you would soon be demonstrating the transfer of heat by conduction. Eventually, the entire metal piece would get hot, even though only the tip of it was placed in the fire. What this means is that refrigeration system coils that are made up of copper, aluminum or steel are nothing but solids, and heat can be transferred through them.

To say that heat moves by convection is to say that heat moves through a liquid. Want to prove this one? Set a pan of water on the stove and turn the heat on. Wait 5-minutes, then put your finger (really, don't do this…again, we're just making a point) into the water. Don't touch the pan or the stove, just the water. Even though the water you're touching isn't in direct contact with the heat source, or even the pan, it's hot, which means that the heat traveled through the liquid. For a practical application of this point, remember that at certain times in the refrigeration process, the refrigerant traveling through the tubing of the system is sometimes a vapor, and sometimes it's a liquid.

To say that heat moves by radiation is to say that heat moves through the air. If you want to prove this simple law of heat transfer, go outside at noon on a sunny day. The heat generated by the light energy from the sun will warm you by passing through the air until it gets to you.

Which brings us to the last two laws of thermodynamics…the ones about boiling and condensing.

When a substance condenses, it rejects heat. OK, so the outdoor coil of a comfort cooling refrigeration system is called…. a condenser, and if you were to feel it while the system was operating, it would feel warm to the touch. And that coil doesn't have to be outside. It could be the condenser on the back of your refrigerator, or a condenser located anywhere outside of the conditioned space the refrigeration system is working to cool.

When a substance boils, it absorbs heat. To nail this one down, substitute the word evaporate for boil. (Same thing, isn't it?) Now consider that the indoor coil on a comfort cooling system, or *inside* coil on anything is called an evaporator, and you know what the refrigerant does in this coil. When it evaporates….changes in state from a liquid to a vapor, it absorbs heat. It has to. It's the law.

The difficult thing for many about understanding the evaporator coil concept when learning about refrigeration is that boil/evaporate thing. After all, when somebody says the word "boil" the first thing that comes to mind is that water boils at 212-degrees F (at sea level anyway), and if the stuff in the evaporator coil is in fact boiling, how is it that the coil is cold and not somewhere near 212-degrees F?

The answer is simple….a refrigerant like the ones used in vapor compression refrigeration systems ain't water.

That's all there is to it. Water is a compound with a certain chemical make-up….hydrogen and oxygen, $H_2O$ as we refer to it, and due to that chemical make-up water has a certain boiling point…212-degrees F. When it comes to refrigerants however, that’s a different story.

R-22, for example, a refrigerant that’s been used extensively in comfort cooling refrigeration systems and other applications for decades, has a boiling point that is much different than water. Due to its chemical make-up (chlorine, hydrogen, fluorine and carbon) this substance will boil somewhere near the temperature of -44 (yes, you read it right…MINUS) degrees Fahrenheit.

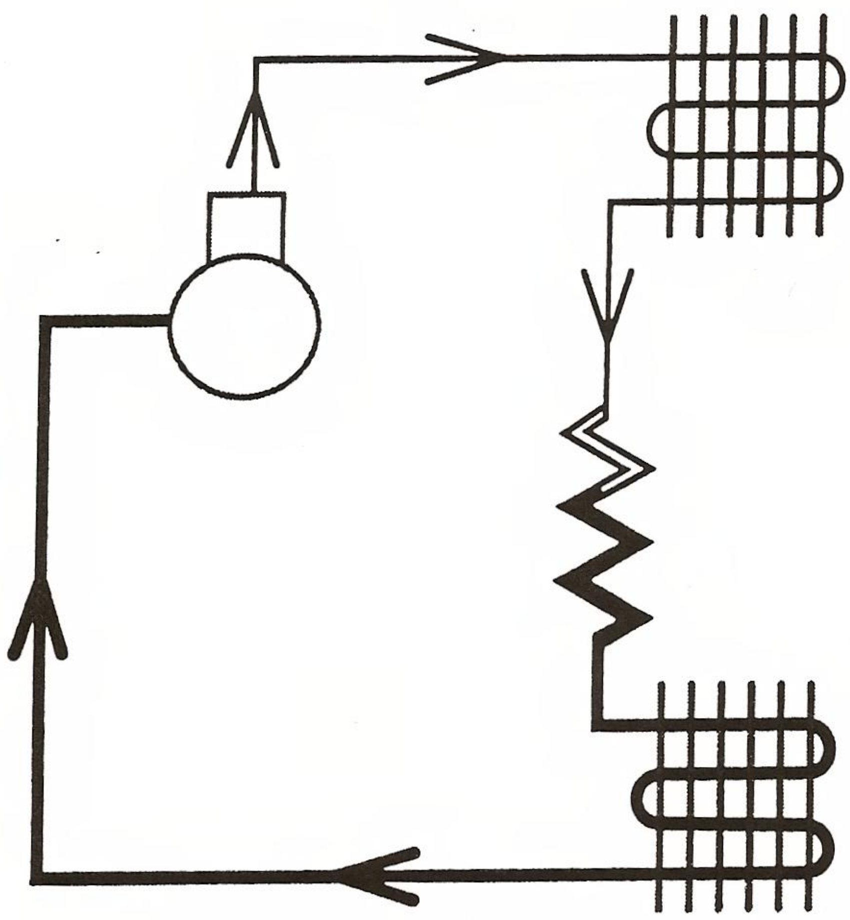
What that really means is that this stuff will boil at any temperature <u>above</u> -44 degrees. So, you could have a coil that is *only* 40-degrees above zero, and R-22 would be boiling (evaporating) and absorbing heat as it does so.

How would we stop R-22 from boiling? Well, here’s an idea.

If we could chill a room down to 46-degrees below zero, we could pour buckets of R-22 out onto the floor and we would be walking around in puddles….no boiling taking place. But, the moment we “warmed the room up” to -44 degrees the puddles of R-22 on the floor would begin to boil. Of course, you wouldn’t want to be standing in those puddles as they began to boil because the substance, as it changed in state from a liquid to a vapor, would begin to absorb the heat out of your feet, then your ankles, and…OK we don’t need to go any further with that image.

The point is, this stuff ain’t rocket science, neither the thermodynamic concepts that allow a refrigeration system to function, nor the four basic components that make up a refrigeration system like the one on the next page are difficult to understand.

To simplify a refrigeration system, no matter what the application, consider that there are only four basic components.



You really can’t make it much simpler than this. That’s the compressor shown up there at the left. When refrigerant leaves the compressor (follow the arrows) it goes into the condenser, then on through a component called the metering device… more on that shortly….then on to the evaporator. Then the refrigerant heads back to the compressor, then back to the condenser, then…. Well, you get the idea.

As far as the four components of any system working together, the two that change the system pressures from low to high, then from high to low, ad infinitum while the system is operating, are the compressor and the metering device.

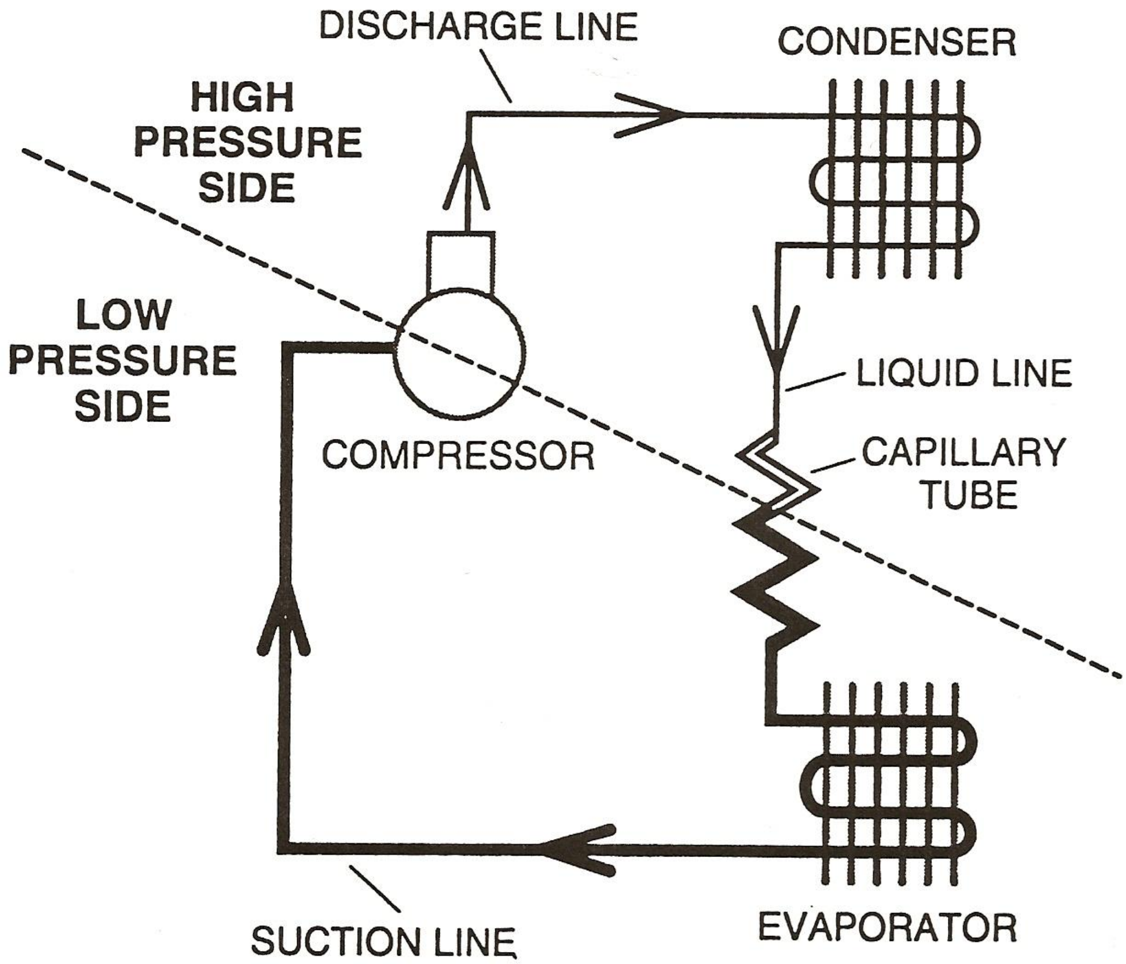
Which leaves the two coils to accomplish what is referred to in simple terms as change-of-state. Not change of state like going from one place to another like from Pennsylvania to New York, or from Colorado to Wyoming, or from California to Arizona, but a change *in* state.

In the evaporator the change is from a liquid state to a vapor state.

And in the condenser the change is from a vapor state to a liquid state.

And, we know what happens to the heat that comes in contact with the evaporator coil, then what happens to that heat when the condenser coil is in an environment that is cooler that it itself is.

All of which brings us to the next concept….maintaining a pressure differential in a refrigeration system. It simply can't work without it. When you're servicing a refrigeration system, you're always considering the high-pressure side and the low-pressure side of the system.  For the purpose of illustration, you could draw a diagonal line through an illustration of a fundamental refrigeration system to illustrate the high and low pressure segments, as in the drawing on the next page.




So, are we saying it's as simple as this….?

If there was some heat just hanging around near the evaporator coil and we started the refrigeration system…the heat would move through the air (Warmer To Cooler and Radiation), then contact the outer surface of the tubing and move through it (Conduction) and be absorbed into the refrigerant (Evaporating)…and then the heat-laden refrigerant would travel through the compressor and into the condenser where it would reject the heat (Convection and Condensing), right through the tubing (Conduction again) and out into the outside air because it's cooler than the coil (Warmer To  Cooler and Radiation again)?

Ummm…yes, we're saying it's that simple, providing there is a pressure differential that exists between the two sides of the system. And, as we mentioned, the two components that raise and lower the pressure in a system are the compressor and the metering device.

Troubleshooting Hint: In a situation in which the necessary pressure differential isn't achieved by a refrigeration system, there won't be enough heat transfer accomplished, and the system won't be able to cool properly.

## COMPRESSORS

Vapor refrigeration system compressors can be identified as being in one of two basic categories:

1. Hermetic
2. Semi-Hermetic

As far as compressor types within the two categories:

1. Piston (Reciprocating)
2. Rotary
3. Scroll
4. Screw
5. Centrifugal

Whatever the design or category of compressor, the fundamental idea to understand is that they are designed to:

Accept a low pressure vapor on the suction side, and:

Deliver a high pressure vapor from its discharge side.