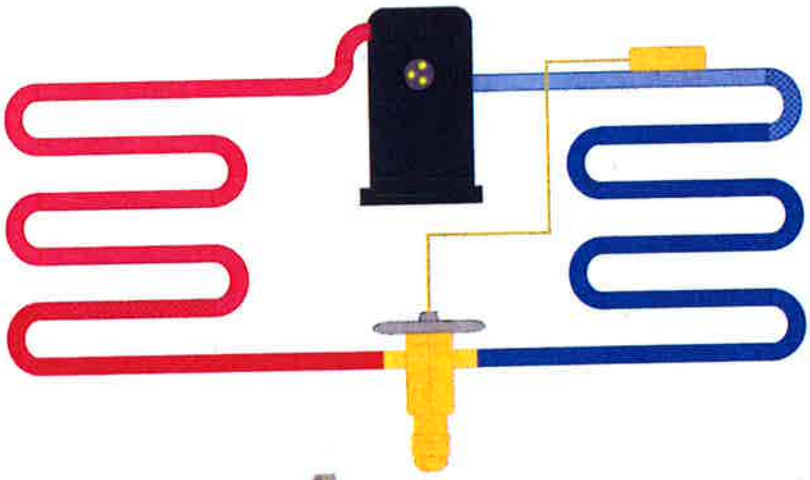
Quick Guide

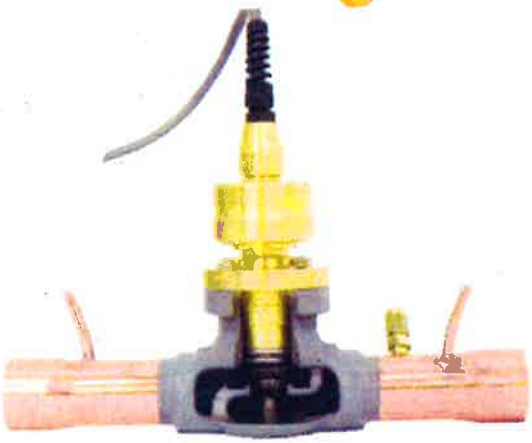
esco institute

A Supplement to the EPA Section 608 Certification Exam Preparatory Manual

Refrigeration Cycle • Refrigerants • Components









Quick Guide

Refrigeration Cycle • Refrigerants • Components



esco institute

Table of Contents

Section 1: The Refrigeration Cycle

Learning Outcomes 1
Temperature 1
Measuring Temperature 1
Ambient Temperature 1
Dew Point Temperature 2
Dry-Bulb and Wet-Bulb Temperature 2
Temperature Conversion 2
Pressure 2
Boyle's Law 2
Charles' Law 2
Dalton's Law 3
Atmospheric Pressure 3
Gauge Pressure 3
Absolute Pressure 3
Vacuum 3
Pressure Conversion 4
Temperature/Pressure Relationship 4
Heat 5
Specific Heat 5
States of Matter 5
Change of State 5
Superheat and Subcooling 6
Thermodynamics 6
The First Law of Thermodynamics 6
The Second Law of Thermodynamics 6
Heat Transfer 6
The Refrigeration Cycle 7
Calculating Superheat and Subcooling 8
Review Questions 9

Section 2: Refrigerants and Oils

Learning Outcomes 10
Refrigerants 10
Refrigerant Properties and Characteristics 10
Chlorofluorocarbons (CFCs) 12
Hydrochlorofluorocarbons (HCFCs) 12
Hydrofluorocarbons (HFCs) 13
Hydrofluoroolefins (HFOs) 13
Hydrocarbons (HCs) 13
Refrigerant Blends 13
Temperature Applications 14
Refrigerant Safety 14
Refrigerant Oils 14
Mineral Oil 14
Alkylbenzene Oil (AB) 14
Polyol Ester Oil (POE) 14
Polyvinyl Ether (PVE) 15
Polyalkylene Glycol (PAG) 15
Working with Refrigerant Oil 15
System Retrofitting 15
Retrofitting Procedures 16
Compressor Oil Change 17
Review Questions 18

Section 3: System Components

Learning Outcomes 19
Refrigeration Circuit Components 19
Liquid Line Filter-Driers 19
Evaporator 19
Evaporator Design 20
Evaporator Installation 20
Condenser 21
Condenser Design 22
Condenser Installation 22
Compressor 23
Compressor Designs 24
Reciprocating Compressor 24
Scroll Compressor 25
Compression Ratio 26
Testing a Compressor 26
Metering Device 27
Fixed Orifice Metering Device 27
Adjustable Metering Devices 27
Thermostatic Expansion Valve (TEV) 27
Sensing Bulb Placement 29
Review Questions 30

Answers to Review Questions 31

This publication is intended to provide industry personnel with a review/refresher of fundamental concepts needed to be successful on the EPA Section 608 examination and should not be used as a formal refrigeration training course.

Learning Outcomes:

After completing this section, the reader should be able to:

- define pressure and how it is measured.
- define temperature and how it is measured.
- understand temperature, pressure, and related gas laws.
- explain state changes as they relate to temperature and pressure (boiling and condensing).
- understand P/T charts for common refrigerants: R-22, R-410A, R-134a.
- understand sensible and latent heat and their measurements.
- discuss heat transfer methods.
- define superheat and subcooling as they relate to the refrigeration cycle.
- perform superheat and subcooling calculations.
- explain dew point and bubble point as they relate to blended refrigerants.
- understand the vapor compression refrigeration cycle.
- explain the differences between the low-pressure and the high-pressure sides of the refrigeration cycle.
- discuss heat transfer as it occurs during the refrigeration cycle.

Temperature

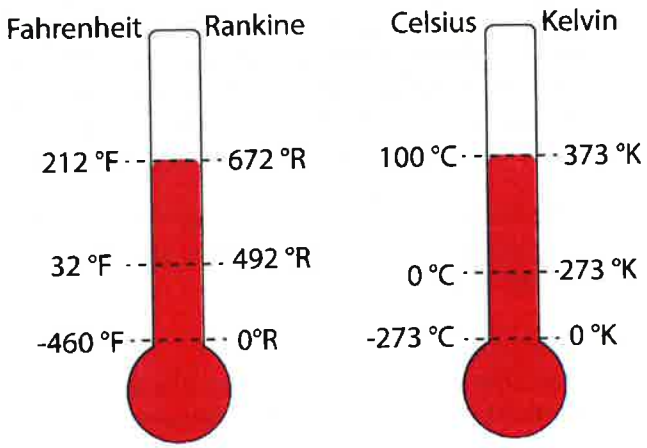
Temperature is a term used to describe the speed of the molecules or level of heat intensity of a substance. As the temperature of a substance increases, the molecules in the substance vibrate with more force. As the temperature of a substance drops, the intensity of molecular motion within the substance decreases. The lowest possible temperature, -460°F, is called absolute zero. At absolute zero, all molecular motion within a substance ceases and all heat has been removed.

Temperature is an indication of how hot something is but not how much heat it contains. For example, if two containers, one containing one gallon of water and the other containing ten gallons of water, are placed over identical heat sources, the temperature in the one-gallon container will rise faster than the temperature in the ten-gallon container. Ten times the heat energy must be added to the larger container in order to heat the water in both containers to an equal temperature.

Measuring Temperature

Temperature is measured with a thermometer. Thermometers may be graduated in one of four different scales: Fahrenheit and Rankine which are used in the United States, or Celsius (Centigrade) and Kelvin which are used in the metric system. On the Fahrenheit scale, water freezes at 32°F and boils at 212°F. On the Celsius scale, water freezes at 0°C and boils at 100°C.

For scientific calculations, absolute temperature scales must be used. Absolute temperature scales are those of which the lowest reading on them is zero. On the Rankine scale, for example, absolute zero is 0°R. On this scale, the freezing point of water is 492°R and the boiling point of water is 672°R. On the Kelvin scale, absolute zero is 0°K. The freezing point of water is 273°K and the boiling point of water is 373°K. The Kelvin scale is also called Celsius Absolute (CA).



Ambient Temperature

Ambient temperature is the temperature of the air surrounding an object. The components of a residential split air conditioning system are located both inside and outside the home. The temperature of inside components can be controlled, but ambient temperature outside the home can vary greatly, affecting the efficiency of the system significantly.

Dew Point Temperature

The temperature at which condensation forms is called the dew point temperature. Air can be dehumidified (moisture removed) by passing it over a surface, such as an evaporator coil, that is at a temperature below the dew point temperature. Moisture forms on the cold surface of the evaporator coil and can then be removed from the system through the condensate drain line.

Dry-Bulb and Wet-Bulb Temperatures

Dry-bulb temperature refers to the actual air temperature of a substance, typically an air stream, and is measured with a dry-bulb (ordinary) thermometer. Wet-bulb temperature takes into account the amount of moisture in the air and is measured with a special thermometer that keeps the bulb of the thermometer wet. This is accomplished by placing a cotton, sock-like, wick over the end of the thermometer bulb. The wick is wetted with distilled water. Evaporation of the distilled water causes the wet-bulb thermometer bulb to cool. This is because, as water evaporates, it absorbs heat from its surroundings. Since the wick surrounds the thermometer bulb, the bulb will get cooler. When this happens, it is easy to see that a wet-bulb thermometer will, in most cases, provide a lower temperature reading than a dry-bulb thermometer.

Less moisture in the air means that more evaporation occurs from the wick and therefore more cooling occurs, resulting in a lower wet-bulb temperature reading. The difference between the dry-bulb and wet-bulb temperatures of the ambient air is called the wet-bulb depression. As the air's moisture content increases, there is less evaporation from the wick and less wet-bulb depression. When the wet-bulb and dry-bulb temperature are the same, there is no wet-bulb depression, and the relative humidity is 100 percent. Relative humidity is the amount of moisture in the air compared to the amount it can hold under the present environmental conditions. **Note:** The air must be moving across the cotton wick. The wet-bulb thermometer is usually made where it can be spun in a circular motion.

Temperature Conversion

Fahrenheit = (C × 1.8) + 32	**Example:** 100°C = (100 × 1.8) + 32 = (180) + 32 = 212°F
Fahrenheit = (R 460)	**Example:** 492°R = (492 - 460) = 32°F
Celsius = (F - 32) ÷ 1.8	**Example:** 212°F = (212 - 32) ÷ 1.8 = (180) ÷ 1.8 = 100°C
Celsius = (K - 273)	**Example:** 373°K = (373 - 273) = 100°C
Rankine = (F + 460)	**Example:** 212°F = (212 + 460) = 672°R
Rankine = (K × 1.8)	**Example:** 373°K = (373 × 1.8) = 672°R
Kelvin = (C + 273)	**Example:** 100°C = (100 + 273) = 373°K
Kelvin = (R ÷ 1.8)	**Example:** 672°R = (672 ÷ 1.8) = 373°K

Pressure

Pressure is defined as force per unit area. In the United States, pressure is most commonly expressed in pounds per square inch (psi). The metric (SI) system uses a pressure unit called the pascal (Pa). Pressure is an extremely important concept in the HVACR industry as the operation of these systems depends heavily on pressure differences throughout the system. The pressure acting on a substance affects its physical properties, especially its boiling point. HVACR technicians need a thorough understanding of the behavior of gases in order to accurately read pressure gauges and diagnose system problems. The gas laws that deal with pressure, as well as volume and temperature, that will be covered are Boyle's Law, Charles' Law, and Dalton's Law.

In the formulas that follow, P1, V1, and T1 represent the initial pressure, volume, and temperature of the gas, while P2, V2, and T2 represent the final pressure, volume, and temperature values. All of the values in the following formulas must be expressed as absolute values.

Boyle's Law

Boyle's law states that the pressure of a gas varies inversely to its volume, provided that the temperature remains constant. At a constant temperature, decreasing the volume will increase the pressure and increasing the volume will decrease the pressure.

Boyle's law can be stated mathematically as:

$$P1 \times V1 = P2 \times V2$$

Charles' Law

Charles' law states that the volume of a gas is proportional to the absolute temperature of a gas at constant pressure. Doubling the temperature of gas doubles its volume, as long as the pressure and quantity of the gas remain constant.

Charles' law can be mathematically stated as:

$$\frac{V1}{T1} = \frac{V2}{T2} \quad \text{OR} \quad V1 \times T2 = V2 \times T1$$

Dalton's Law

Dalton's law states that the total pressure of a confined mixture of gases is the sum of the pressures of each gas in the mixture. It can be mathematically stated as:

$$\text{Total Pressure } (P_T) = P1 + P2 + P3....$$

Dalton's law assumes that the initial and final volumes of the gases in the mixture do not change. For example, Dalton's law will hold true if one cubic foot of gas A is mixed with one cubic foot of gas B in a **one** cubic foot container. Dalton's law will **not** hold true if one cubic foot of gas A is mixed with one cubic foot of gas B in a **two** cubic foot container.

Atmospheric Pressure

The earth's atmosphere is the layer of gases that completely surround our planet's surface and consists of approximately 78% nitrogen and 21% oxygen. The remaining 1% is composed of other gases. Even though gas molecules are very small, they still have weight. The atmosphere exerts a pressure of 14.7 pounds per square inch at sea level (psia). At higher altitudes, atmospheric pressure is significantly less. The most common way of measuring atmospheric pressure is with a mercury barometer. Normal atmospheric pressure at sea level (14.7 psia) will support a column of mercury 29.92 inches high.

Gauge Pressure



In air conditioning and refrigeration systems, we are concerned with the pressures that are present within the system itself, not the pressures outside of the system. Since atmospheric pressure does not affect the pressure inside of a sealed system, another measurement must be used. The pressure reading most often used in the HVACR industry is gauge pressure. Gauges used to measure system pressures (hence the term gauge pressure) are designed and calibrated to negate the effects of atmospheric pressure on a system. A gauge exposed to atmospheric pressure (at sea level), will register 0 psig (pounds per square inch gauge). Compound gauges used to measure low-side pressures in air conditioning systems can measure pressures both above and below 0 psig. Compound gauge readings below atmospheric pressure are indicated in inches of mercury (in. Hg). It may be necessary to adjust compound gauges to compensate for changes in atmospheric pressure/altitude. **Note:** A compound gauge is not accurate when measuring a vacuum for system dehydration; a micron gauge should be used.

Absolute Pressure

The absolute pressure scale allows the measurement of both vacuum and pressure to be made using the same units. Absolute pressure measurements are indicated as pounds per square inch absolute (psia). 0 psia is the lowest possible absolute pressure. Because atmospheric pressure is 14.7 psia at sea level, gauge pressure can be converted to absolute pressure by adding 14.7 to the gauge pressure measurement. So, a reading of 0 psig is the same as 14.7 psia.

Vacuum



A thorough understanding of vacuum principles is a necessity for the HVACR technician. Pressures below atmospheric are usually read in inches of mercury (in. Hg) or millimeters of mercury (mm Hg). An increase in pressure increases the boiling point of a liquid and the opposite is also true. A lower pressure results in a lower boiling point. Any pressure below atmospheric is considered a partial vacuum. A perfect vacuum is the absence of all atmospheric pressure.

A micron gauge is used for measuring deep vacuums. A micron is 1/1000 of a millimeter and one inch of mercury vacuum is equal to 25,400 microns. **Note:** A compound gauge is not accurate for measuring a vacuum for system dehydration.

Pressure Conversion

1 pound per square inch = 27.7 inches of water column (in. WC)
1 inch of water column = 1.87 millimeter of mercury
25,400 microns = 1 inch of mercury
50 pascal = 0.20 inch of water (in. WC)
1 pound per square inch (psi) = 6.89 kPa

For pressures less than one psi, the following can be used:
Inches of water column (in. WC)
Millimeters of mercury (mm Hg)
Inch of mercury (in. Hg)
Microns

Temperature/Pressure Relationship

In the HVACR industry, we control pressures within a system to achieve desired temperatures. There is a relationship that exists between the condensing and evaporating temperatures and pressures for the refrigerants that are used in air conditioning and refrigeration systems. This relationship is referred to as a temperature/pressure relationship and applies to refrigerants that exist as a mixture of liquid and vapor. This mixed state is commonly known as saturation. As the pressure of a saturated refrigerant changes, so does its boiling or condensing temperature. This temperature is referred to as the saturation temperature.

A pressure/temperature chart is one of the most important tools used by an HVACR technician. Operating temperatures of the indoor and outdoor coils can be found using a P/T chart. From the chart, it is evident that as pressure goes up, the temperature goes up, and as pressure goes down, so does the temperature.

In the chart to the right, the numbers on the left-hand side are temperatures. The numbers that are listed under the individual refrigerants are pressures. Numbers that are red are vacuum pressures, expressed in inches of mercury (in. Hg). The P/T chart can be used to find either the pressure or temperature.

For example, an R-410A system with an evaporator pressure of 130 psig would have a saturation temperature of 45°F. To determine this, first locate R-410A at the top of the chart, then look for 130 psig in the R-410A column. Then, look to the left to identify the corresponding saturation temperature. This would mean that the refrigerant in the evaporator will boil from a liquid to a vapor at 45°F.

Blended refrigerants, such as R-407C and R-417A, have two columns listed under them. They use dew point (vapor) and bubble point (liquid) to make calculations. So, if the condensing temperature of a blended refrigerant is needed, the technician will use the liquid pressure column. Similarly, if evaporating temperature of a blended refrigerant is needed, the technician will use the vapor pressure column. Blended refrigerants typically have two separate columns because the

Temp °F	R22	R410A	R134A	R407C	
				Liquid	Vapor
0	24.0	48.6	6.5	29.9	19.6
5	28.2	55.2	9.1	34.7	23.6
10	32.8	62.3	11.9	39.9	28.0
15	37.7	70.0	15.0	45.6	32.8
20	43.0	78.3	18.4	51.6	38.0
25	48.8	87.3	22.1	58.2	43.6
30	54.9	96.8	26.0	65.2	49.6
35	61.5	107	30.3	72.6	56.1
40	68.5	118	35.0	80.7	63.1
45	76.0	130	40.0	89.2	70.6
50	84.0	142	45.4	98.3	78.7
55	92.6	155	51.1	108	87.3
60	102	170	57.3	118	96.9
65	111	185	63.9	129	106
70	121	201	71.0	141	117
75	132	217	78.6	153	128
80	144	235	85.6	166	140
85	156	254	95.1	180	153
90	168	274	104.2	195	166
95	182	295	113.8	210	181
100	196	317	124.1	226	196
105	211	340	134.9	243	211
110	226	365	146.3	261	229



Temp °F	R22	R410A	R134A	R407C	
				Liquid	Vapor
0	24.0	48.6	6.5	29.9	19.6
5	28.2	55.2	9.1	34.7	23.6
10	32.8	62.3	11.9	39.9	28.0
15	37.7	70.0	15.0	45.6	32.8
20	43.0	78.3	18.4	51.6	38.0
25	48.8	87.3	22.1	58.2	43.6
30	54.9	96.8	26.0	65.2	49.6
35	61.5	107	30.3	72.6	56.1
40	68.5	118	35.0	80.7	63.1
45	76.0	130	40.0	89.2	70.6
50	84.0	142	45.4	98.3	78.7
55	92.6	155	51.1	108	87.3
60	102	170	57.3	118	96.9
65	111	185	63.9	129	106
70	121	201	71.0	141	117
75	132	217	78.6	153	128
80	144	235	85.6	166	140
85	156	254	95.1	180	153
90	168	274	104.2	195	166
95	182	295	113.8	210	181

refrigerants that make up the blend change state at different temperatures when exposed to a certain pressure. So, blended refrigerants change state over a temperature range, which is referred to as temperature glide.

There are numerous P/T chart apps that can be downloaded onto a smart device. Some of these apps will even assist in evaluating a unit's charge if you enter the system temperatures and pressures.

Heat

Heat is a form of energy and should not be confused with temperature. Temperature is described as the level of heat intensity, while heat refers to the quantity of heat energy contained in a substance. Heat is expressed in units called the British Thermal Unit, or Btu. A Btu is the amount of heat energy required to raise the temperature of one pound of water one degree Fahrenheit.

Two common forms of heat are sensible heat and latent heat. Sensible heat is heat that is added to or removed from a substance that causes a change in temperature of the substance. A change in sensible heat can be felt with your hand or measured with a thermometer. Latent heat is heat added to or removed from a substance causing a change in state but not temperature. For example, as water is heated to 212°F, a sensible heat transfer is taking place. Once the temperature of the water has reached 212°F, the water will begin to turn to steam. As the water is vaporizing, latent heat is being added. This is because the water is changing state, but the temperature is remaining constant at 212°F. Latent heat is sometimes called hidden heat because it cannot be felt by hand or measured with a thermometer.

Air conditioning and refrigeration systems are designed to transfer heat from one place to another. These systems move heat from an area where it is not wanted to an area where it is less objectionable. For example, a refrigerator transfers heat from the inside of the cabinet to the outside, while an air conditioning system moves heat from inside a structure to the outside. Air conditioning transfers heat by using the latent heat process.

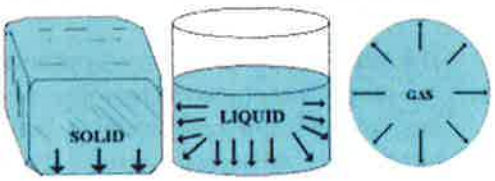
Specific Heat

Specific heat is defined as the amount of heat (measured in Btu) required to raise the temperature of one pound of a substance one degree Fahrenheit. The specific heat of a substance does not apply when the substance undergoes a change in state. Different substances can have very distinctive specific heats. Metals tend to have very low specific heat values, meaning that they heat up and cool down rapidly. Water has a very high specific heat, nine times that of iron, and 32 times that of gold. The specific heat of some common substances are shown in the table.

Water 1.0	Gold 0.032
Air 0.24	Silver 0.056
Ice 0.5	Copper .093
Water Vapor 0.49	Iron .11
Alcohol 0.58	Mercury 0.033

States of Matter

Matter most commonly exists as a solid, liquid, or gas, depending on pressure, temperature, and heat content. The molecules in all substances are constantly in motion, except when the substance is exposed to absolute zero conditions. Even when matter is in its solid state, its molecules are moving. In the liquid state, molecules move faster. If liquid matter is heated further, its molecules move so fast that they are now free to travel in all directions as a gas.



Change of State

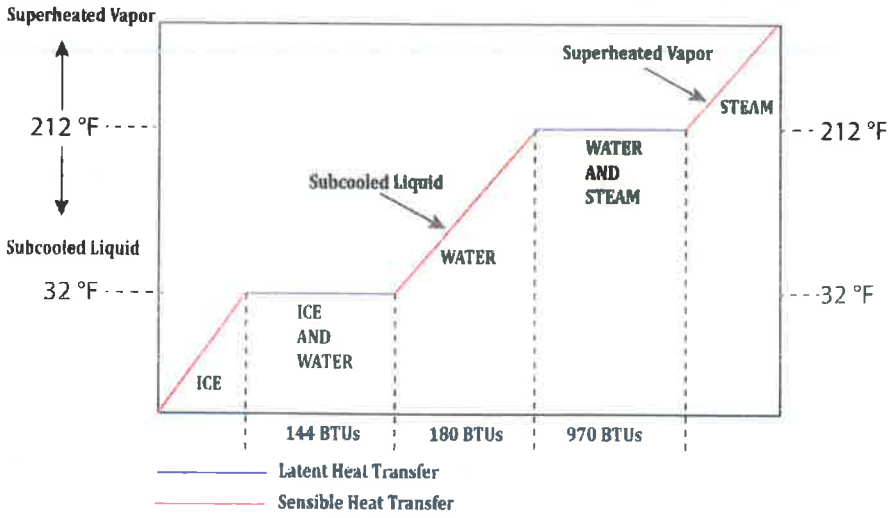
As a substance is heated or cooled, it may undergo a change of state. The substance most commonly used to exemplify this is water. At temperatures below 32°F, water exists in its solid form, ice. Between 32°F and 212°F water is a liquid, and at 212°F it becomes steam (at atmospheric pressure). The term used to describe any substance at its "change-of-state" point at a given pressure is saturation point. Water, for example, at atmospheric conditions, will be saturated at 212°F, because any additional heat added to the water will cause it to change state. Similarly, ice at 32°F is said to be saturated because any additional heat added to it will cause the ice to melt.

Atmospheric pressure has a direct influence on the saturation point (boiling point) of liquids. For example, water at sea level boils at 212°F; however, on a 15,000-foot high mountaintop, it boils at 184°F. Reduced atmospheric pressure at higher altitudes allows water to boil at a lower temperature.

The saturation point of a substance can be changed by changing the pressure acting on the substance. For example, placing a cap on the radiator of your automobile's cooling system raises the saturation point of the water/antifreeze mixture approximately

2.5°F for each pound of pressure increase. When a material is undergoing a change of state, its temperature remains constant. In other words, when water boils, its temperature remains at 212°F until all of the water becomes steam. Adding heat will only make the water boil faster. During this process it is possible to have 100% liquid, 100% steam, or a mixture of liquid and steam.

This principle also applies when matter changes from gas to liquid (condensing) or liquid to solid (freezing). At 32°F, it is possible to have only ice, only liquid, or a mixture of ice and liquid. Since different materials have different molecular structures, the temperature at which a change of state occurs can vary. For example, the saturation point of water is 212°F at atmospheric pressure, but the saturation point of R-410A is -57°F at atmospheric pressure.



Superheat and Subcooling

Superheated vapor is a gas that has been heated to a temperature above its saturation point (boiling point). When a substance is superheated, this means that sensible heat has been added after the substance has changed state. For example, if steam is heated to 213°F at atmospheric pressure, it is superheated 1°F. Any substance whose temperature is below its saturation point is considered subcooled. Water that is 210°F at atmospheric pressure is subcooled 2°F. In other words, subcooling is the number of degrees below the boiling point of a given substance.

Thermodynamics

Thermodynamics deals with the transfer of energy from one place to another and from one form to another. For example, an air conditioner transfers the heat from inside a home, where it is not wanted, to the outdoors where it makes little or no difference. While there are four (4) laws of thermodynamics, only the first and second will be discussed here.

The First Law of Thermodynamics

The laws of thermodynamics give us a basic understanding of heat. The first law of thermodynamics, also called the law of energy conservation, states that energy cannot be created or destroyed; it can only be converted from one form to another. This law applies to heat and to all forms of energy: electrical, mechanical, solar, chemical, and nuclear.

The Second Law of Thermodynamics

The second law of thermodynamics states that heat always travels from a warmer substance to a cooler one. The speed at which heat travels from one object to another depends upon the temperature difference between the two objects. A greater temperature difference causes a faster heat transfer. The transfer of heat will stop when both objects reach the same temperature. When two substances are at the same temperature, they are said to be in thermal equilibrium with each other.

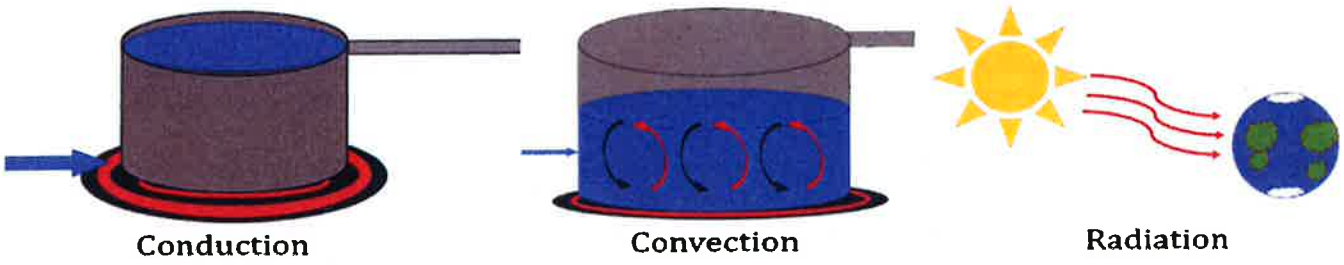
Heat Transfer

Since refrigeration involves the exchange of heat, it is important to understand how heat travels. There are three ways in which heat travels from one object to another: radiation, conduction, and convection.

Conduction is the transfer of heat either through an object or by direct contact between two objects. When one end of a metal bar is heated, the heat travels by conduction to the cooler end of the bar.

Convection is the transfer of heat through fluids in either a liquid or vapor state. Convection creates currents as the warmer (expanding) fluid rises above the colder (contracting) fluid. Convection currents can be natural or forced. Natural convection occurs as warm air naturally rises above cooler air. Forced convection, when a fan or blower is used, allows the use of a smaller heat exchanger.

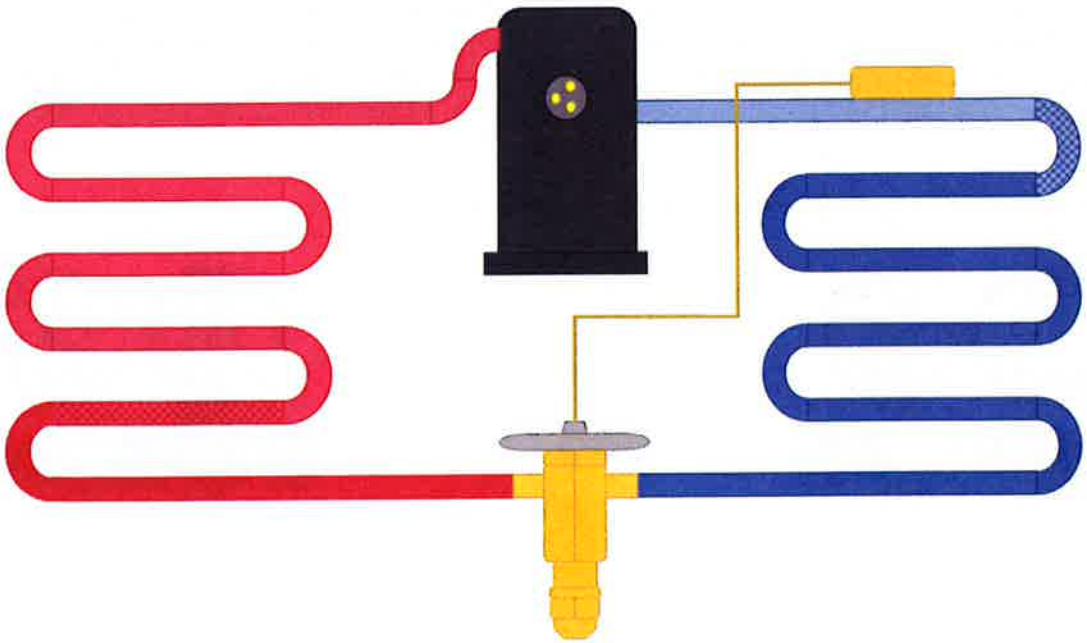
Radiation is the transfer of heat by waves such as light waves or radio waves. Radiant heat waves are absorbed by solid objects, not by the space they travel through. For example, heat from the sun travels through space and then is absorbed by the earth and its atmosphere.



The Refrigeration Cycle

Refrigeration and air conditioning systems are designed to transfer heat by circulating refrigerant through a piping arrangement and a number of heat transfer surfaces. In the basic refrigeration cycle, refrigerant absorbs unwanted heat from one location and moves it to a remote location. The refrigerant absorbs heat through evaporation, then releases it through condensation.

Vapor-compression systems are relatively simple, but mastery of them requires a basic understanding of heat transfer theory and the components that make up the system. A malfunction in one component can effect the operation of others in the system. As refrigerant flows through the system, it undergoes the processes of expansion, vaporization, compression, and condensation. Liquid refrigerant under high pressure is fed to a metering device. The metering device causes a drop in pressure as the refrigerant flows to the evaporator. This reduced pressure lowers the temperature of the refrigerant and causes it to vaporize as it absorbs heat from the space being conditioned. The refrigerant vapor then passes through the suction line and into the compressor, where the pressure and temperature of the refrigerant increases. The compressed refrigerant is then pumped out to the condenser, where it begins to cool. When the refrigerant is cool enough, it condenses and becomes liquid. It then travels through the liquid line to the metering device, and the refrigeration cycle is repeated.



A closed-loop (sealed) refrigeration system can be divided into two sides: the high-pressure side (red) and the low-pressure side (blue). Whatever is done on one side of the system must be undone on the other side. Heat that is absorbed on the low-pressure side must be expelled on the high-pressure side. Refrigerant that is boiled (vaporized) on the low-pressure side must be condensed to a liquid on the high-pressure side. The repeating cycle continues until the space being conditioned reaches the desired temperature.

Refrigeration systems are classified by the temperatures they are intended to maintain. The three most common refrigeration system classifications are high-temperature, medium-temperature, and low-temperature. Most refrigeration systems fall into one of these three ranges. High-temperature refrigeration maintains a space temperature between 47°F and 80°F. This is most often used to maintain human comfort or to preserve perishable food items or organic materials. Medium-temperature refrigeration maintains a box temperature between 28°F and 40°F. The fresh food storage compartment of a domestic refrigerator is an example of a medium-temperature application. Medium temperature is above freezing for most products. Low-temperature refrigeration maintains a temperature below 32°F. Most applications start at 0°F, and may maintain temperatures as low as -20°F.

Another, less common, temperature range is the ultra-low temperature range. Ultra-low temperature refrigeration systems typically operate in the -40°F range and are popular in the food industry. Quick freezing of food products, for example, is accomplished in the ultra-low temperature range. Below the ultra-low temperature range is the cryogenic range. Cryogenic temperatures are between -250°F and absolute zero, or -459.7°F. Gases such as oxygen, nitrogen, and helium can be liquefied at these low temperatures. A cascade design, which uses the evaporator of one system to cool the condenser of another system, can be used to achieve these low temperatures. Many stages may be required in a cascade system to reach these ultra-low temperatures.

Calculating Superheat and Subcooling

When evaluating the performance or charge of a system, one task often performed by the HVACR service technician is calculating evaporator superheat, system superheat, and condenser subcooling. A refrigerant absorbs heat in the evaporator and rejects it in the condenser. Superheat is the amount of heat absorbed above the boiling point, after all liquid has boiled to a vapor. All systems should have some superheat to ensure that liquid refrigerant does not leave the evaporator and make its way to the compressor. Subcooling is the amount of heat removed below the refrigerant boiling point.

To calculate evaporator superheat, the system low-side pressure and the suction line temperature at the outlet of the evaporator are needed. For example: An R-410A system is operating with a low-side pressure of 118 psig and suction line temperature at the outlet of the evaporator is 55°F. Using a P/T chart, we can see that at 118 psig, R-410A has a saturation temperature of 40°F. The vapor leaving the evaporator is 55°F, 15°F above the boiling (saturation) temperature. So, the evaporator superheat is 15°F.

To calculate subcooling, the system high-side pressure and the liquid line temperature at the outlet of the condenser are needed. For example: An R-410A system is operating with a high-side pressure of 418 psig and the liquid leaving the condenser is measured at 110°F. Using a P/T chart, we can see that at 418 psig, R-410A has a saturation temperature of 120°F. The liquid line temperature leaving the condenser is at 110°F, 10°F below the condensing (saturation) temperature. So, the condenser subcooling is 10°F.

Calculate the superheat and subcooling for the following R-410A systems:



VAPOR LINE: 73 LIQUID LINE: 103



VAPOR LINE: 60 LIQUID LINE: 94

Section 1 Review Questions

Name: _____ Date: _____

1. What unit of measurement is used for pressures below atmospheric?
2. Atmospheric pressure is _____ at sea level.
3. Refrigeration is the movement of _____ from an area where it is not wanted to an area where it is less objectionable.
4. As a substance is heated or cooled, it may undergo a _____.
5. Superheated vapor is a gas that has been heated to a temperature _____ its saturation point.
6. A measurement of the molecular activity or heat intensity of a substance is called _____.
7. Steam at a temperature of 222°F would contain _____°F of superheat.
8. _____ is the number of degrees a liquid is below its boiling point.
9. The temperature at which condensation forms is called the _____.
10. A _____ should be used to measure a deep vacuum.

Refer to the P/T chart to answer the following questions:

11. R-22 at a pressure of 84 psig would have a saturation temperature of _____°F.
12. R-410A at a pressure of 130 psig would have a saturation temperature of _____°F.
13. Which refrigerant would have a saturation temperature of 35°C at a pressure of 182 psig?
14. R-407C at a vapor pressure of 0.6 inches of mercury would have a saturation temperature of _____°F.
15. R-417A with a liquid pressure of 170 psig would have a saturation temperature of _____°F.

Calculate the superheat and subcooling for the following R-22 systems:

A.



VAPOR LINE: 55 LIQUID LINE: 90

B.



VAPOR LINE: 58 LIQUID LINE: 100

C.



VAPOR LINE: 52 LIQUID LINE: 105

Learning Outcomes:

After completing this section, the reader should be able to:

- understand the uses and properties of refrigerants.
- explain the differences between CFCs, HCFCs, HFCs, and HFOs.
- discuss safe refrigerant handling, use, and transportation.
- discuss temperature applications and the common refrigerants used for each.
- understand the most common refrigerants, oils, and their uses.
- explain properties of each refrigerant oil.
- discuss refrigerant oil handling, acid testing, and safety.
- understand refrigeration system retrofitting and the reasons for it.
- discuss general procedures and guidelines of a retrofit.
- discuss a refrigerant oil change as it pertains to a system retrofit.
- understand how to test the oil after an oil change and acceptable residual percentages.

Refrigerants

A refrigerant is a substance (fluid) used to transfer heat in a refrigeration circuit. It can be easily boiled to a vapor and condensed to a liquid as it is circulated through the system components. Refrigerants are chosen for specific applications based on their thermodynamic properties, component compatibility, safety ratings, and operating characteristics.

The most common refrigerants are carbon-based and contain hydrogen (H). They are typically derived from methane or ethane. These refrigerants include:

- Chlorofluorocarbon (CFC)
- Hydrochlorofluorocarbon (HCFC)
- Hydrofluorocarbon (HFC)
- Hydrofluoroolefin (HFO)
- Hydrocarbon (HC)

Due to their impact on the environment, most refrigerants are regulated by either the Environmental Protection Agency (EPA), state laws, or both. It is a technician's responsibility to obtain the appropriate license(s), where necessary, and to stay up to date with the most current refrigerant regulations.

Refrigerants are evaluated using their ozone depletion potential (ODP) and their global warming potential (GWP). Chlorinated refrigerants (CFCs and HCFCs) can deplete the ozone in the earth's stratosphere, causing numerous health and environmental hazards. Ozone-depleting refrigerants are being, or have been, phased out. Refrigerant emissions also contribute to global warming or climate change. Refrigerants with a high GWP, greater than 1500, are being phased down, limiting their applications and use.

Ref No	Type	Ozone Depletion Potential (ODP)	Global Warming Potential (GWP)	Common Use	EPA Pressure Range	ASHRAE Class
R-11	CFC	1 Base	4000	Air Conditioning Chillers (Phased Out)	Low	A1
R-12	CFC	1	10900	Automotive, Domestic, Commercial (Phased Out)	Medium	A1
R-22	HCFC	0.055	1810	Air Conditioning	High	A1
R-123	HCFC	0.012	76	Commercial Chillers	Low	B1
R-134a	HFC	0	1430	Automotive, Domestic, Commercial	Medium	A1
R-404A	HFC	0	3820	Medium and Low-Temperature Commercial and Industrial	High	A1
R-407C	HFC	0	1770	Air Conditioning R-22 Retrofit	High	A1
R-410A	HFC	0	2090	Air Conditioning	High	A1
R-422B	HFC	0	3143	Retrofit for Medium & Low Temp., R-22, R-407, R-502 & Other HCFC Blends	High	A1
R-290	HC	0	3	Commercial & Industrial Process Refrigeration	High	A3
R-600	HC	0	3	Domestic, Commercial & Industrial Process Refrigeration	Medium	A3
R-1234yf	HFO	0	4	Automotive	Medium	A2L
R-1234ze	HFO	0	6	New Chillers, Heat Pumps, and Vending	Medium	A2L
R-1233zd	HFO	0	1	New Chillers & Foam Blowing	Low	A1
R454B	HFC/HFO	0	466	Positive Displacement, DX Air Conditioning, Heat Pumps and Chillers	High	A2L

Refrigerant Properties and Characteristics

All refrigerants have different properties and operating characteristics that make them suitable for various applications. An ideal refrigerant for a system would be non-corrosive to the system components, have operating pressures within the system's design capacity, have a boiling point that is lower than the temperature application it is being used for, provide oil return to the compressor, and have a critical temperature that is higher than the system's design condensing temperature. The critical temperature of a refrigerant is the temperature at which the refrigerant vapor can no longer be condensed to a liquid, no matter

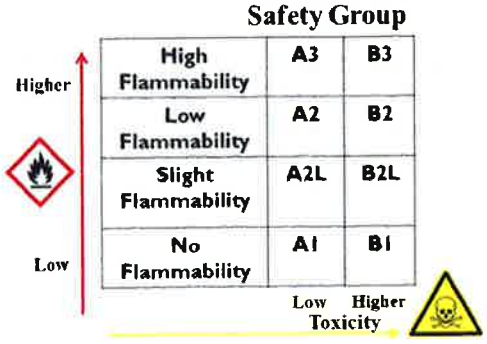
how much pressure is applied. Refrigerants have a very specific pressure/temperature (P/T) relationship which can be seen using a P/T chart. This chart, also referred to as a saturation chart, can be used to evaluate a refrigeration system's performance.

Temp °F	R22	R410A	R134A	R407C	
				Liquid	Vapor
0	24.0	48.6	6.5	29.9	19.6
5	28.2	55.2	9.1	34.7	23.6
10	32.8	62.3	11.9	39.9	28.0
15	37.7	70.0	15.0	45.6	32.8
20	43.0	78.3	18.4	51.6	38.0
25	48.8	87.3	22.1	58.2	43.6
30	54.9	96.8	26.0	65.2	49.6
35	61.5	107	30.3	72.6	56.1
40	68.5	118	35.0	80.7	63.1
45	76.0	130	40.0	89.2	70.6
50	84.0	142	45.4	98.3	78.7
55	92.6	155	51.1	108	87.3
60	102	170	57.3	118	96.9
65	111	185	63.9	129	106
70	121	201	71.0	141	117
75	132	217	78.6	153	128
80	144	235	85.6	166	140
85	156	254	95.1	180	153
90	168	274	104.2	195	166
95	182	295	113.8	210	181
100	196	317	124.1	226	196
105	211	340	134.9	243	211
110	226	365	146.3	261	229

Other refrigerant characteristics that must be taken into consideration are toxicity, flammability, and environmental impact. ASHRAE Standard 34 is used to classify a refrigerant based on its toxicity and flammability. Toxicity is represented with a letter, with A being the lowest. Flammability is represented with a number, with 1 being non-flammable. The higher the flammability, the higher the number a refrigerant is assigned. An A1 refrigerant would have low toxicity and low flammability. The lower flammability designation (2) has been divided into two categories, 2 and 2L. The 2L refrigerants are mildly flammable with a maximum burning velocity of less than 10 cm/s.

ASHRAE Grouped Refrigerants

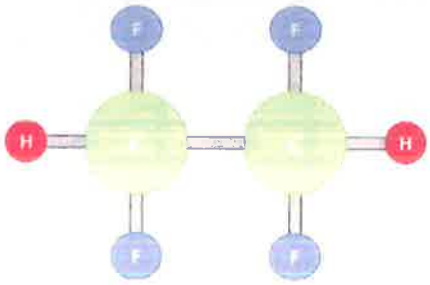
- Refrigerant Classification
- A (Safest)
- B, toxicity level to humans
- L Flammability
  - 1 (no flammability)
  - 2 (low flammability)
  - 3 (high flammability)



The 2L refrigerants have a burning velocity of 10 cm/s or slower

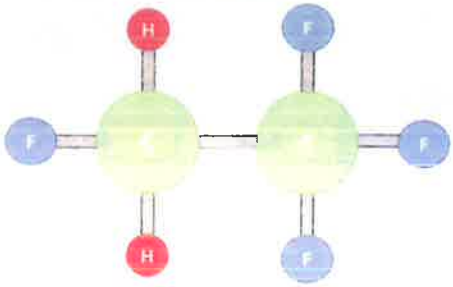
Refrigerants that have a lowercase letter (a, b, c) designation indicate an isomer. Isomers are chemical compounds that have the same formula and molecular weight but different molecular arrangements and properties. For example, R-134 and R-134a have the same chemical formula, but the different molecular arrangement gives them different chemical properties.

R-134



CHF_2-CHF_2

R-134a



CH_2F-CF_3

An uppercase letter (A, B, C) designation is used when refrigerant blends are composed of the same refrigerants, but with different percentages of each. For example, R-407A, R-407B, and R-407C all contain R-125, R-134a, and R-32. Each letter designation of R 407 indicates that a different percentage of each refrigerant is used in the blend.

407 Blend	R-125	R-134a	R-32
R-407A	40%	40%	20%
R-407B	70%	20%	10%
R-407C	25%	52%	23%

Chlorofluorocarbons (CFCs)

CFCs contain chlorine, fluorine, and carbon and have the highest ozone depletion potential of all refrigerants. The production of CFCs was completely phased-out in 1995. Some common CFC refrigerants were R-11, R-12, and R-113. R-12 was a very popular refrigerant used for many years in automobiles, refrigerators, and commercial refrigeration applications. After its phase out, R-12 was replaced with HFC-134a.

R-Number	Chemical Name	Boiling Point	Cylinder Color
R-11	Trichlorofluoromethane	74.9°F	Orange
R-12	Dichlorodifluoromethane	-21.7°F	White
R-113	Trichlorotrifluoroethane	118°F	Purple
R-114	Dichlorotetrafluoroethane	38.4°F	Navy Blue
R-500	R-12/152a blend	-28.5	Yellow
R-502	R-22/115 blend	-49.5	Violet

Hydrochlorofluorocarbons (HCFCs)

HCFCs contain hydrogen, chlorine, fluorine, and carbon. These refrigerants have a lower ozone depletion potential than CFCs and their production will be completely phased-out by January 1, 2020. R-22, the most common HCFC refrigerant, has been used in residential air conditioners and heat pumps for decades. It has also been used in medium-temperature refrigeration systems. There are numerous *replacement* refrigerants for R-22, but not one of them is a drop-in replacement. Prior to charging a replacement refrigerant into a system, the original R-22 charge must be recovered, filter driers must be changed, and a deep vacuum will need to be pulled on the system. Depending on the replacement refrigerant, a system oil change may also be required.

R-Number	Chemical Name	Boiling Point	Cylinder Color
R-22	Difluoromonochloromethane	-41°F	Light Green
R-123	Dichlorotrifluoroethane	82°F	Light Blue Grey

Hydrofluorocarbons (HFCs)

HFCs contain hydrogen, fluorine, and carbon and do not deplete the ozone as they have no chlorine. However, many of the most common HFCs have high global warming potentials (GWP) of over 1,500. HFCs are used in a wide variety of cooling systems; from refrigerators and freezers to automotive and residential air conditioning units. HFC-134a has been used as a replacement refrigerant for most CFC-12 applications including medium-temperature coolers and automobiles. HFC-407C is used as a retrofit refrigerant for HCFC-22 in comfort cooling applications. HFC-404A is mainly used in low-temperature refrigeration applications. Due to the high GWP of HFC-404A (3920), it has been scheduled for a phase down in many parts of the country. HFC-410A is primarily used in residential and light commercial air conditioning and heat pump systems.

R-Number	Chemical Name	Boiling Point	Cylinder Color
R-134a	Tetrafluoroethane	-15.3°F	Light Blue
R-404A	R-125/143a/134a blend	-46.2°F	Orange
R-407C	R-32/125/134a blend	-43.6°F	Chocolate
R-410A	R-32/125 blend	-55.3°F	Rose

Hydrofluoroolefins (HFOs)

HFOs are chemically similar to HFCs; they contain hydrogen, fluorine, and carbon. The only difference is that they are unsaturated, meaning that they have at least one double carbon bond. These molecules are named olefins or alkenes. Unlike HFCs, these refrigerants have a very low global warming potential (GWP) and most are mildly flammable (A2L). HFOs also have an ozone depletion potential (ODP) of 0. They are being used in a number of different temperature applications, such as automotive air conditioners and commercial refrigeration systems and are being tested for expanded use.

R-Number	Chemical Name	Boiling Point	Cylinder Color
R-1234yf	Tetrafluoropropene	-22°F	Red stripe
R-1234ze	Tetrafluoroprop-1-ene	49.6°F	Red stripe
R-1233zd	Trifluoropropene	66°F	Green

Hydrocarbons (HCs)

HC refrigerants contain hydrogen and carbon and are classified by ASHRAE in the A3 safety group, which are highly flammable. Pure HC refrigerants have no chlorine or fluorine, have an ozone depletion potential (ODP) of 0, and a very low global warming potential (GWP). These refrigerants are often referred to as natural refrigerants. HC-600a is currently being used in some domestic refrigerators and freezers. HC-290 is being used in some small package refrigeration units. HC refrigerants are very energy efficient, reducing energy consumption when compared to HFC refrigerants. However, due to their highly-flammable nature, their use is limited to systems with very small charges, typically 5.3 ounces or less.

R-Number	Chemical Name	Boiling Point
R-290	Propane	-44°F
R-600	Butane	31°F
R-600a	Isobutane	11°F

Refrigerant Blends

A blended refrigerant is a mixture of two or more refrigerants that is classified as azeotropic, near-azeotropic, or zeotropic. Blends are created in the factory by engineers, not in the field by technicians. An azeotropic refrigerant blend behaves like a single-component refrigerant. It follows a single pressure/temperature chart and does not separate, or fractionate, with a change in pressure, temperature, or both. Azeotropic refrigerant blends are numbered in the 500 series (R-500, R-502, etc.).

A zeotropic refrigerant blend is a mixture of two or more refrigerants that can separate, or fractionate, into their original components. The components of these blends have a range of different boiling points, known as temperature glide. The larger the range of boiling points, the higher the temperature glide will be. Zeotropic refrigerants will have two pressure/temperature charts, one for the vapor phase (dew point), and one for the liquid phase (bubble point). To avoid fractionation, zeotropic refrigerant blends must be charged as a liquid.

Near-azeotropic refrigerant mixtures (NARMS) are zeotropic blends that have properties that are very close to those of azeotropes. They have a small temperature glide, less than 5°F, and a very low fractionation potential. NARMs and zeotropic refrigerant blends are numbered in the 400 series (R-404A, R-410A, etc.).

Temperature Applications

One of the design conditions that will determine which refrigerant will be used, is temperature application. Each application has a temperature range and refrigerants that perform best in that range. The three main temperature applications are: low-temperature, medium-temperature, and high-temperature. Low and medium temperature are used in the refrigeration industry. The high-temperature application can refer to either refrigeration or comfort cooling. The chart shows the most common temperature ranges and refrigerants. It should be noted that temperature ranges and refrigerant types can vary from one publication to the next.

Temperature Application	Space Temperature Range	Common Refrigerants
Low	0°F – (-20°F)	R-404A, R-507, R-448A
Medium	28°F – 45°F	R-134a, R-22, R-448A, R-450A
High	47°F – 75°F	R-22, R-134a, R-410A, R-407C

Refrigerant Safety

When working with or transporting refrigerant, care must be taken to avoid serious injury and/or death. Refrigerants are heavier than air and can displace oxygen, leading to suffocation or asphyxiation. Some refrigerants can be very toxic. In the event of a large refrigerant leak, the area should be vacated and ventilated. Liquid refrigerant splashed onto the skin or into the eyes can cause serious burns or blindness. Proper gloves and safety goggles should always be worn.

Refrigerant cylinders are pressurized and can explode when exposed to high temperatures. Cylinders should be stored at temperatures lower than 125°F and transported in the upright position. Refillable cylinders (recovery tanks) should not be filled beyond 80% of their maximum capacity, allowing room for refrigerant expansion and to prevent the tank from rupturing. Some refrigerants can be highly flammable. Always follow the manufacturer's recommendations when working with flammable refrigerants.

Refrigerant Oils

Refrigeration system compressors require oil for lubrication. A small amount of this oil is circulated through the system with the refrigerant during operation. Refrigerant oils are soluble in liquid refrigerant and, at normal room temperatures, will mix completely. Oil and refrigerant vapor do not mix as well and, as such, the velocity of the refrigerant vapor must be high enough to ensure that the oil returns to the compressor. Compressor manufacturers will specify what type of oil is to be used for a specific application. The type of oil used must also be compatible (miscible) with the refrigerant in the system. The most common oils are mineral, alkylbenzene (AB), polyolester (POE), polyvinyl ether (PVE), and polyalkylene glycol (PAG). Each of these oils have different thermal properties, viscosities, and are hygroscopic, meaning that they readily absorb moisture. Refrigerant oils should not be mixed; the resulting mixture may not lubricate the compressor properly or be miscible with the system refrigerant.

Mineral Oil

Mineral oil is a by-product of the processing of crude oil to produce gasoline or other petroleum-based products. Mineral oil can be classified into the three groups: naphthenic, paraffinic, and aromatic. Naphthene-based mineral oils are the most common and are suitable for refrigeration systems using CFC and some HCFC refrigerants. Mineral oil contains wax in its composition and is mildly hygroscopic.

Alkylbenzene Oil (AB)

Alkylbenzene oil is a synthetic oil suitable for refrigeration systems using CFC or HCFC refrigerants. It is compatible with mineral oil and has better refrigerant miscibility with R-22 in low-temperature applications. Alkylbenzene oil does not contain wax in its composition and works best with HCFC-blend refrigerants and retrofit applications. Alkylbenzene oil is hygroscopic and its exposure to the atmosphere should be limited.

Polyol Ester Oil (POE)

Polyol Ester oil is a synthetic oil suitable for most refrigeration systems using HFC and HFO refrigerants. POE oil is very hygroscopic and should not be exposed to the atmosphere. It can pull moisture through a plastic container and should therefore be stored in

metal or glass containers. Moisture can rapidly cause POE oil to breakdown into sludge. POE oil is also susceptible to hydrolysis. Hydrolysis is the decomposition, due to the presence of water, of the POE oil into esters, organic acid, and/or alcohol. This can cause clogs to develop in refrigeration system components. POE oil can cause a rash or irritation if it comes into contact with skin.

Polyvinyl Ether (PVE)

Polyvinyl Ether oil is a non-POE, synthetic oil that is being used as an alternative to POE oil in systems using HFC refrigerants. It is more hygroscopic than POE oil and less than PAG oil. PVE oil does not undergo hydrolysis, making it less likely to clog system components when moisture is present.

Polyalkylene Glycol (PAG)

Polyalkylene Glycol is a synthetic oil primarily used in automotive air conditioning systems using R-134a and R-1234yf. It is extremely hygroscopic, more than either POE or PVE oils, and is not miscible with chlorine. PAG oils are available with different viscosities for different types of systems. PAG oil can cause a rash or irritation if it comes into contact with skin.

Working with Refrigerant Oil

All refrigerant oils are hygroscopic, meaning that they absorb moisture. Care should be taken to limit their exposure to the atmosphere, no more than 15 minutes is recommended. In some cases, as with POE, the moisture can not be removed from the oil with a deep vacuum or filter drier. The oil must be flushed from the system and replaced if it becomes saturated with moisture. Some of the more highly hygroscopic oils can pull moisture through plastic containers and must be stored in glass or metal containers. Refrigerant oils can be a skin irritant and should be handled appropriately. Gloves and goggles are recommended. If oil gets on the skin, the affected area should be washed thoroughly with soap and water.

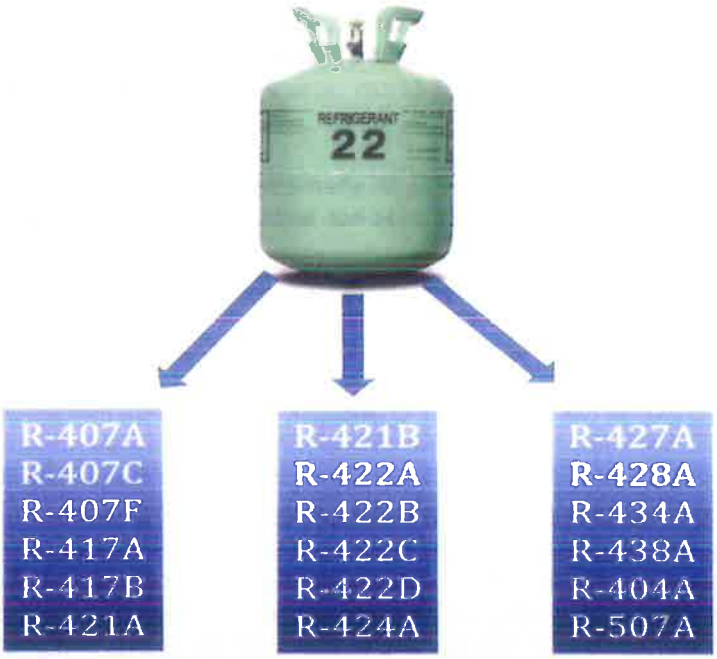
Systems that have been subjected to moisture, air, or other contaminates, may experience a chemical reaction that produces acid when exposed to excessive heat. A compressor burnout may also cause the formation of acid. An acid test should be done on any system suspected of being acidic. If a system is found to contain acid, the refrigerant should be recovered into a separate recovery tank, the oil drained, and the system components flushed with an approved line flush. New suction and liquid-line filter driers should also be installed. Once cleaned, new oil and refrigerant can be added to the system.

Oil Type		Composition	Moisture Control	Refrigerant Type(s)	Application(s)
Mineral	MO	Natural	Hygroscopic	CFCs, HCs, HCFCs	Refrigeration and Comfort Cooling
Alkylbenzene	AB	Synthetic	More Hygroscopic	CFCs, HCFCs, HCs	Low and Medium-Temperature Refrigeration
Polyol Ester	POE	Synthetic	Very Hygroscopic	HFCs, HFOs, HCs	Refrigeration and Comfort Cooling
Polyalkylene Glycol	PAG	Synthetic	Extremely Hygroscopic	HFC, HFO	Automotive only
Polyvinyl Ether	PVE	Synthetic	Very Hygroscopic	HFCs	Refrigeration and Comfort Cooling

System Retrofitting

With the phase out and phase down of many older refrigerants taking place, retrofitting an existing system to a newer refrigerant is becoming more common in the HVACR industry. The move toward greener technologies and environmentally safer refrigerants has caused numerous retrofit and replacement refrigerants to emerge. The type of system and the temperature application will determine which refrigerant should be used during a retrofit. The refrigerant that is chosen will then dictate which lubricant should be used. Before beginning a system retrofit, it should be verified that the refrigerant and oil to be used are approved for the system being converted. The existing charge should be recovered, the filter driers changed, and the system evacuated before charging the system with a new refrigerant. It should also be verified that the existing metering device is compatible with the retrofit refrigerant.

HCFC-22 has the most retrofit refrigerant options for residential or light commercial air conditioning applications. Some will work with the mineral oil already present in the R-22 system, some will require an oil change to POE, and others will work with a mixture of POE and mineral oil. As a reminder, there are no drop-in replacement refrigerants. Refrigerant manufacturers provide literature that detail what oil setup is necessary for their refrigerant in a retrofit application.



Retrofit Procedures

When retrofitting a system, under no circumstances should a technician add a new refrigerant to a system before recovering the old refrigerant. Mixed refrigerants will not follow a pressure/temperature chart, may cause a capacity or efficiency loss, and can lead to equipment failure. Before retrofitting a system, it should be cycled, and its normal operating characteristics recorded. The following are just *some* of the conditions that should be noted:

- vapor line temperature at the condenser
- liquid line temperature at the condenser
- evaporator saturation temperature
- condenser saturation temperature
- compressor discharge temperature
- superheat
- subcooling
- compressor amperage

Some manufacturers may require more information to be recorded prior to converting a system. After the system has been converted, it should be cycled, and the operating characteristics compared to those with the previous refrigerant. These characteristics should be very close in order for the system to perform as designed.

After recording the initial system operating characteristics, the old refrigerant charge should be recovered and weighed. Once the pressure has been reduced to atmospheric (0 psig), the filter drier(s) should be cut out and a new one brazed in place. A nitrogen sweep should be used during the brazing process to prevent oxidation of the copper as seen in the photo.

If the metering device must be replaced, it should be done after the system has been opened. After the system has been sealed, a standing nitrogen pressure test should be done to check for leaks. Refer to the system data plates for the maximum test pressure, the lowest pressure listed on either data plate should be used. Note that in the images the test pressure would be 150 psig. Once the system has been leak-tested and no leaks are found, the nitrogen can be released to the atmosphere.



Cross sections of copper tubing. The tubing on the left (black colored) have been oxidized.

Condensing Unit No. 36790-CC
Model # GMS-13-3610-CC
Serial # SO927040249
Test Pressure Low Side: 150 PSIG
Test Pressure High Side: 400 PSIG
Refrigerant R-22

Cased Evaporator Coil
Model # GMS-13-3610-CC
Serial # SO927040249
Design Pressure 150 PSIG
Refrigerant R-22

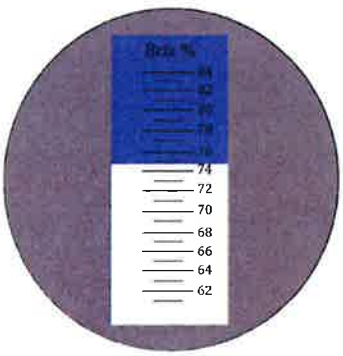
Next, the system should be pulled into a deep vacuum of at least 500 microns. Once the appropriate vacuum level has been reached, the system should be valved off and observed to see if the system pressure rises. If the vacuum level does not rise considerably, the system can be charged with the new refrigerant. Most manufacturers recommend charging 80% - 90% of the original charge into the system by weight before energizing the system. Refrigerant can then be added as needed, in small quantities until the system is operating within the desired range. Always refer to the manufacturer's recommended charging procedures for the appropriate charge weight. A large, visible placard or label should be placed on the unit to show that the system refrigerant charge has been changed.

NOTICE: RETROFITTED TO R-427A
DATE:_____
CHARGE WEIGHT:_____
OIL TYPE:_____

Compressor Oil Change

Some retrofit applications will require the compressor oil to be changed. In most residential and light commercial air conditioning and heat pump systems, the hermetic compressor must be cut out of the system to drain the oil. The oil should be poured out and measured to serve as a guide for how much new oil should be added to the compressor. Some manufacturers provide guidelines for how much oil should be put into the system. The remaining system components may need to be flushed with an approved line flush to rid the system of any residual oil. A small amount of residual oil will remain in the system. The industry's best practice is to keep changing the oil until the concentration of the old oil is less than 5% of the total oil charge. This level often can be reached by performing multiple oil changes. Consult the specific compressor manufacturer for the allowable percentage of mixed oil. Tools, such as a refractometer, can be used to check the composition of the oil. It measures the refractive index (Brix %) of the oil. If the refractive index of the new and existing oil is known, the oil mixture ratio can be calculated. As a reference, clean POE oil has a Brix % of 64.4. Mineral oil can range from 78% - 81%, depending on the type.





Section 2 Review Questions

Name: _____ Date: _____

1. Refrigerants are evaluated using their _____ and their _____.

2. The _____ of a refrigerant is the temperature at which the refrigerant vapor can no longer be condensed to a liquid, no matter how much pressure is applied.

3. ASHRAE Standard 34 is used to classify a refrigerant based on its _____ and _____.

4. _____ contain chlorine, fluorine, and carbon and have the highest ozone depletion potential of all refrigerants.

5. The most common HCFC refrigerant is _____.

6. _____ contain hydrogen, fluorine, and carbon and do not deplete the ozone as they have no chlorine.

7. _____ refrigerants contain hydrogen and carbon and are classified by ASHRAE in the A3 safety group, which are highly flammable.

8. NARMs and zeotropic refrigerant blends are numbered in the _____ series.

9. _____ refrigerant blends are numbered in the 500 series.

10. Refrigerant cylinders should be stored at temperatures lower than _____ and transported in the upright position.

11. Refrigeration system compressors require oil for _____.

12. A refrigerant oil that is _____ readily absorbs moisture.

13. _____ oil is a by-product of the processing of crude oil to produce gasoline or other petroleum-based products.

14. Converting a system from one refrigerant to another is referred to as _____.

15. _____ oil is a synthetic oil suitable for most refrigeration systems using HFC and HFO refrigerants on systems using HFC and HFO refrigerants.

Learning Outcomes:

After completing this section, the reader should be able to:

- understand the function and design of evaporators.
- explain proper installation and maintenance of evaporators.
- describe evaporator condensate removal.
- discuss proper airflow across evaporators.
- describe the function and design of condensers.
- explain proper installation and maintenance of condensers.
- discuss proper airflow across condensers.
- understand the function and design of compressors.
- explain compression ratio calculations and how they relate to the refrigeration cycle.
- discuss compressor troubleshooting, mechanical and electrical.
- describe proper compressor installation and maintenance.
- understand the function and design of metering devices, TXV and fixed-bore.
- discuss the operational differences between fixed-orifice and adjustable metering devices.
- describe proper metering device installation and maintenance.

Refrigeration Circuit Components

There are four major system components in the vapor-compression refrigeration circuit: the evaporator, condenser, compressor, and the metering device. Some systems may have additional components such as a receiver, accumulator, filter-drier, and reversing valve, to name a few. The focus here will be the components used in the comfort cooling (air conditioning) refrigeration circuit.

Liquid Line Filter-Driers

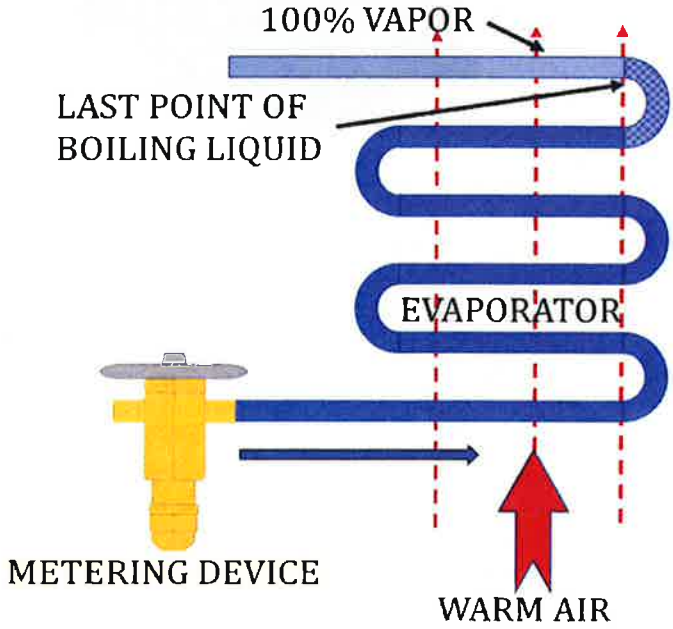
Liquid line filter-driers are used in almost all refrigeration circuits. They are marked with an arrow to indicate the direction in which the refrigerant should flow through them. While some technicians install them on the liquid line near the condenser for convenience, they last longer when installed indoors near the metering device.



Heat pump systems require bi-flow liquid line driers, which allow the refrigerant to flow through them in either direction. Suction line driers can be used on systems that require cleanout after a compressor burnout. They are not meant to be left on the system permanently and should be removed if they become clogged.

Evaporator

The evaporator is a heat transfer component located on the low-pressure side of the system. Low-pressure/low-temperature liquid refrigerant is fed into the evaporator by a metering device. The refrigerant is boiled to a vapor by heat from the air passing over it. This heat is absorbed by the refrigerant and ultimately removed from the system by the condenser. The heat absorbed during the change in state, from liquid to vapor, is latent heat. Once all the liquid has boiled to a vapor, the heat absorbed is sensible heat, also called superheat. In a system with the proper refrigerant charge and appropriate airflow, the last point of liquid typically occurs near the end of the evaporator, just before the refrigerant enters the suction line.



Another function of the evaporator in the comfort cooling application is the removal of humidity. The evaporator coil temperature of an air conditioner or heat pump is typically between 40-45°F, which is below the dew point of the air being cooled. As the warm air comes into contact with the cooler surface of the coil,

moisture in the air will condense on the coil's surface. The water, in the form of condensate, is piped from the evaporator to a nearby drain or condensate pump. According to most industry guidelines, the average relative humidity design condition is 50% during the summer, depending on the geographic region.

The industry standard for airflow across the evaporator is 400 cubic feet per minute (CFM), per ton of cooling. In areas with a high latent heat load, or high humidity climates, slightly lower airflow (325-350 CFM) can be used across the evaporator for additional humidity removal. In areas with a high sensible heat load, slightly higher airflow (425-450 CFM) can be used to satisfy the conditioned space requirements. Always refer to the manufacturer's literature for airflow recommendations for the equipment being used. On a system that is properly installed, has the correct charge, and is clean, the temperature split (difference in temperature between the supply and return ducts) should be between 16°F - 22°F, depending on the system's efficiency and the latent load on the system.

Evaporator Design

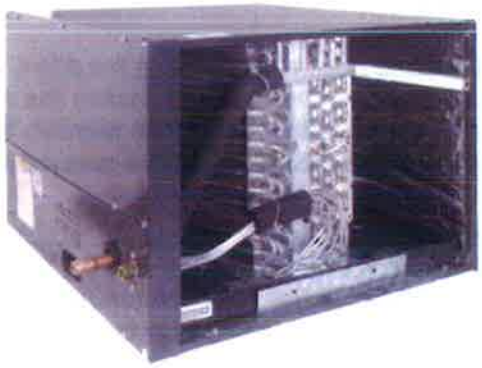
The evaporator design, sometimes referred to as the "A" coil, in most comfort cooling applications is copper tubing with aluminum fins, although some manufacturers have switched to an all-aluminum design. On an aluminum evaporator, the manufacturer typically provides a copper stub to braze the copper lines to. The aluminum fins aid in the transfer of heat and should be kept clean for optimum performance of the coil. Before a chemical coil cleaner is used, it should be verified that it is compatible for use with the coil and that it is safe for use on evaporators.

Most, if not all, evaporators used with comfort cooling systems are multi-circuit evaporators. Multiple refrigerant circuits are used when the coil length becomes too long for a single circuit. Excessive lengths will cause a large pressure drop as the refrigerant travels through circuit. In a multi-circuit design, the refrigerant lines are piped into shorter, parallel "circuits" or paths through the evaporator. A distributor evenly feeds the refrigerant from the metering device to each circuit. At the end of the evaporator, all of the individual circuits are connected to a header or manifold that is connected to the suction line.

Evaporators are manufactured in a variety of configurations to fit almost any installation. The most common airflow patterns are upflow/downflow and horizontal and the coils can be cased, in a prefabricated enclosure or cabinet, or uncased. A drain pan is mounted to the bottom of the coil for the collection and disposal of condensate.



An upflow/downflow copper and aluminum uncased evaporator

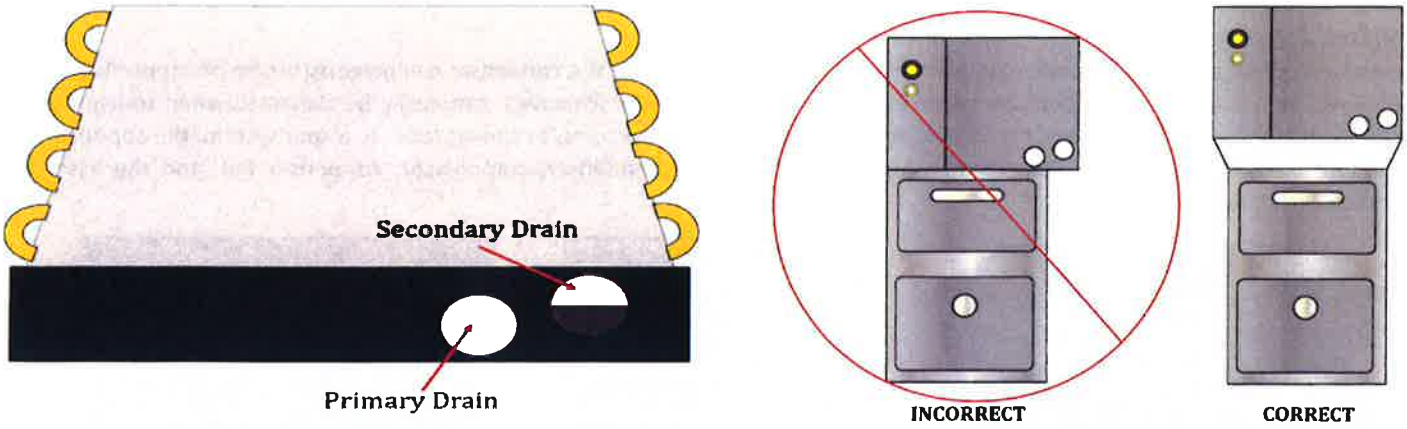


An all-aluminum horizontal cased evaporator

Evaporator Installation

When a coil is chosen for installation, it should be sized to fit the furnace or air handler properly. The evaporator should be mounted level and in a manner that allows the condensate to drain from the drain pan as designed. The drain pan should be piped to a nearby drain and the interconnecting piping should be pitched to allow for proper drainage. Depending on local codes, a trap may be required on the drain piping. The drain piping should also have a fitting to allow for line cleaning. If a convenient drain location is not present, a condensate pump can be used to pump the water to a drain.

Most evaporators have two drain connections, an upper and lower, with the lower connection being the primary drain. The secondary (auxiliary) connection is located higher on the drain pan and, under normal circumstances, will not drain any water. Should the primary drain line become clogged, the secondary, upper opening, will begin to carry the water to the drain. The secondary drain should be piped in a manner that the draining water is noticeable to the customer. The customer should be informed that if the secondary drain line begins to drain water, a call for service should be made to inspect the evaporator drain piping.

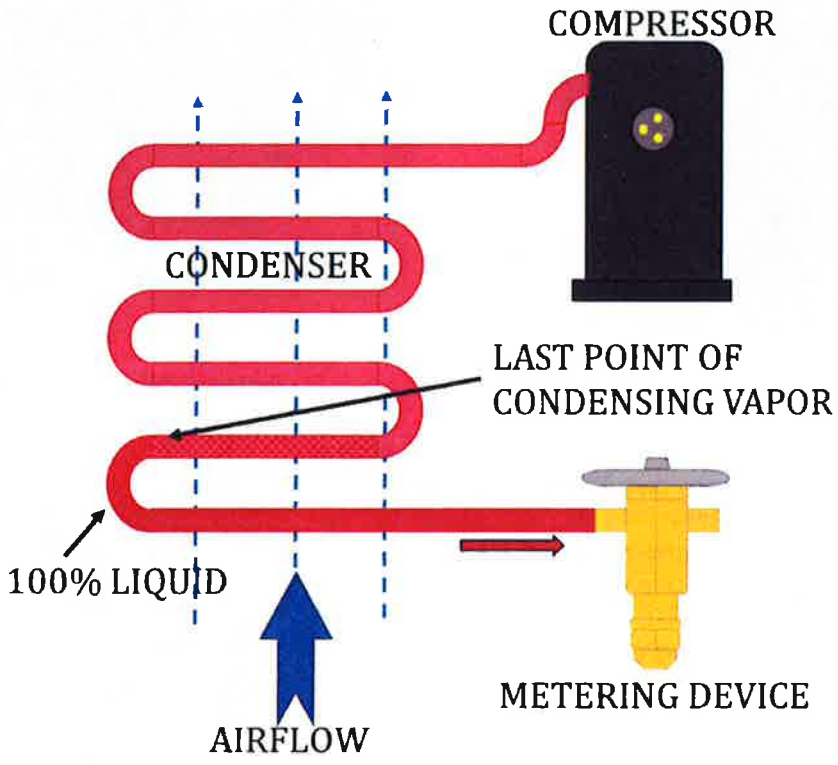


When installed with a gas furnace, the evaporator is typically located on the discharge, or supply side of the furnace. On an air handler installation, the coil is typically located on the negative pressure, or return side of the system. On either installation, the air should be filtered before passing through the coil to help keep the coil clean.

Condenser

The condenser is a heat transfer component located on the high-pressure side of the system. Condensers can be air-cooled or water-cooled. The scope of this text will focus on air-cooled condensers used in comfort cooling systems. High-temperature/high-pressure refrigerant vapor is pumped into the condenser by the compressor. In the condenser, heat absorbed by the refrigerant in the evaporator and compressor is removed from the refrigerant and is rejected to the outdoor air.

Once in the condenser, the refrigerant vapor will first be desuperheated, bringing its temperature down to the saturation temperature. After being desuperheated, the refrigerant vapor will begin to condense into a liquid. Near the end of the condenser, all of the refrigerant has condensed to a liquid and the subcooling process begins. Subcooling is the process of lowering the refrigerant's temperature below its boiling (saturation) temperature. Manufacturers publish charts and/or literature which contain information on acceptable levels of subcooling for various operating conditions.

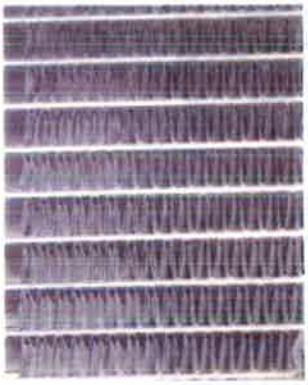


Condenser Design

In comfort cooling package systems, split systems, and mini-split systems, the condenser can be constructed of copper tubing with aluminum fins, spine fins, or aluminum microchannels. The fins, or microchannels, can easily be damaged when transporting or installing the equipment. Damaged fins should be straightened with a fin comb or similar tool. In a split system, the condenser coil is part of the condensing unit. The condensing unit contains the condenser, compressor, condenser fan, and the associated electrical components and controls.



Copper and aluminum condenser



Aluminum Spine Fins



Microchannel coil

Condensing units are designed with either a top or a side air discharge. Package and split systems typically have a top air discharge, while mini-splits are designed with a side air discharge. The coil must be cleaned regularly to ensure proper airflow and heat transfer. There are many coil cleaning chemicals on the market, some of which contain acid. Before applying a cleaner to a coil, it should first be verified that the chemical is compatible with the coil design.



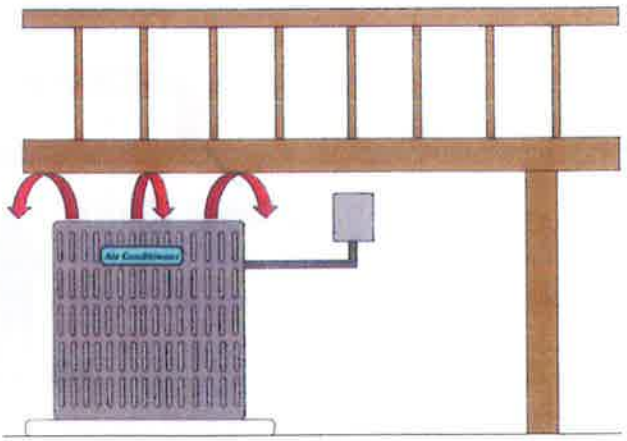
Top air discharge condenser



A dirty condenser coil

Condenser Installation

Split system and mini-split condensing units should be mounted level on a vibration pad with appropriate clearance on all sides for proper airflow. The manufacturer's installation manual should be referenced for recommended clearances. Split system condensing units should be set on vibration pads. Top air discharge units should not be located under a deck or other structure as the hot discharge air can be recycled back through the condenser coil, causing high pressures, high electrical consumption, low efficiency, and overall poor system performance. Most manufacturers recommend 8 feet or more of vertical clearance and at least 18 inches on each side for proper operation. Providing adequate space on the sides of the condensing unit also makes future equipment servicing easier.



An improperly installed condensing unit under a deck



Mini-split condensers



Package unit installed on a curb

Condensers should be located away from water runoff or low-lying areas where water can pool and flood the unit. Package systems should be installed on a curb or other recommended mounting hardware and properly sealed.

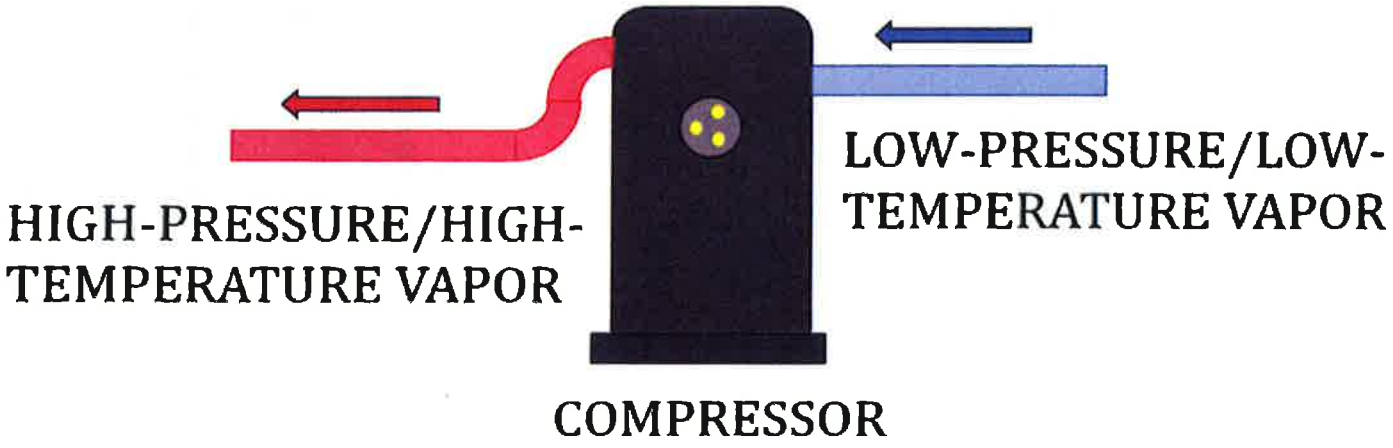
Compressor

The compressor circulates the refrigerant through a refrigeration circuit. It takes in a low-pressure/low-temperature vapor and pumps out a high-pressure/high-temperature vapor. Under normal operating conditions, liquid refrigerant does not enter the compressor. The compressor is a vapor pump and can be damaged by liquid. It is the compressor, together with the metering device, that creates the pressure difference between the high-pressure and low-pressure sides of the system.

All compressors require lubrication (oil) to operate properly. There are several different compressor designs, each of which lubricates its internal components in a different manner. The most common oils are:

- Mineral oil
- Polyol Ester oil (POE)
- Alkylbenzene oil (AB)
- Polyalkylene Glycol oil (PAG)
- Polyvinyl Ether oil (PVE)
-

Compressor manufacturers will specify what type of oil is to be used for a specific application. While most of the oil stays in the compressor oil sump to provide lubrication, a small amount of this oil is circulated through the system with the refrigerant during operation. The refrigerant piping must be sized and installed in a manner that facilitates the return of this oil to the compressor during operation. If oil were to become trapped out in the system, such as in the evaporator, the compressor will slowly be drained of all its oil. Without proper lubrication, the compressor will most likely suffer a catastrophic failure.





Cutaway of a hermetic scroll compressor



A semi-hermetic reciprocating compressor

Compressor Designs

Compressors can be designed as hermetic, semi-hermetic, or open. Hermetic compressors are welded shut at the factory and are not field-serviceable. Semi-hermetic compressors are bolted together and allow access to some of the internal components. On an open compressor, the motor is mounted externally and is connected to the compressor by a shaft. Some of the most common compressors are:

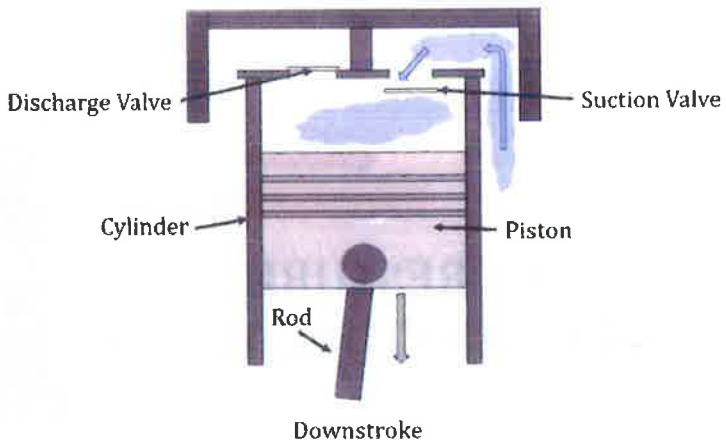
- reciprocating,
- rotary,
- screw,
- scroll,
- centrifugal.

Compressors can be designed with up to five speeds for multi-stage systems, or as a variable-speed in the highest-efficiency systems. Most variable-speed models are inverter driven. The focus of this text will be those compressors most commonly found in residential and light commercial air conditioning and heat pump systems. These compressors are direct drive, hermetic, reciprocating and scroll compressors.

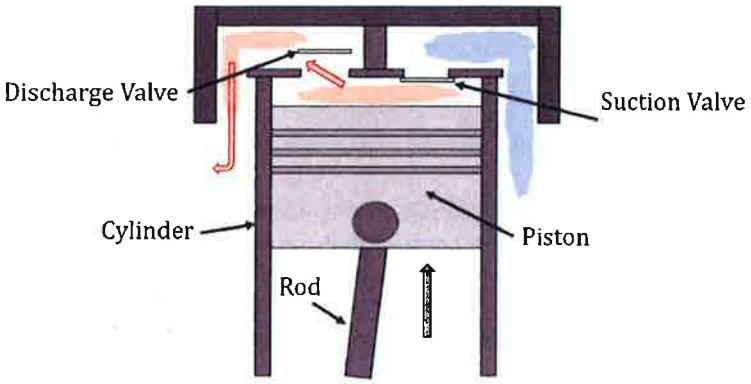
Reciprocating Compressor

Hermetic reciprocating compressors were the mainstay of comfort cooling systems for many years. The motor and the compressor are both contained inside of the welded shell and are not intended to be serviced. In most residential and light commercial applications, the motor is a permanent split capacitor (PSC) motor. A PSC motor utilizes a run capacitor, which stays in the electrical circuit during the run cycle. There are typically three electrical terminals, common (C), start (S), and run (R). A thermal overload is usually wired into the motor windings inside of the compressor shell.

The reciprocating compressor is made up of a crankshaft, connecting rods, pistons, cylinders, valves, and compressor head. Mounted to the crankshaft, the piston moves up and down inside of the cylinder. The length of the piston's path inside the cylinder is called a stroke. As the piston moves up and down in the cylinder, valves in the compressor open and close to pump refrigerant vapor through the system. During the downstroke, the suction valve opens, due to the low pressure in the cylinder, and refrigerant vapor fills the cylinder. When the piston begins its upstroke, the refrigerant vapor is compressed in the cylinder. As the piston moves up into the cylinder, high-pressure refrigerant forces the discharge valve up (open) and the compressed refrigerant vapor is pushed out. If the discharge pressure were to rise above the compressor design pressure, an internal pressure relief valve (IPR) would open, allowing the system pressures to equalize.



When the piston reaches the very top of its upstroke, it stops short of hitting the compressor's valve plate, which holds the valves in place. Should the cylinder hit the valve plate, damage to the cylinder, valves, and compressor head would result. The space between the top of the piston and the valve plate is called the compressor's clearance volume. A small amount of refrigerant remains in the cylinder and is not forced into the discharge line. This leftover refrigerant becomes part of the next compression stroke. The smaller the clearance volume, the more efficient the compressor will pump.



Upstroke

Most hermetic reciprocating compressor motors are cooled by the low-temperature refrigerant vapor that enters them. Running a suction gas-cooled compressor that is undercharged, or that has lost its charge, will result in the compressor overheating and possible damage. The compressor motor may also overheat if the suction vapor temperature is too high.

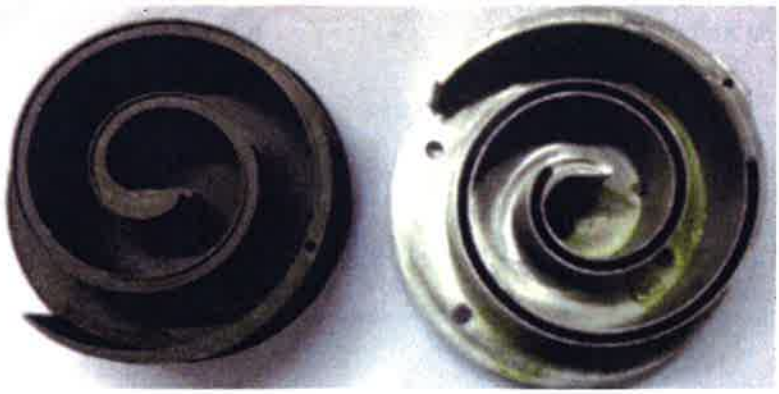
Reciprocating compressors are considered standard-efficiency and are typically designed for single and two-stage systems. Multi-stage or variable-capacity systems would typically use scroll compressors, which have higher efficiencies.

Scroll Compressor

The scroll compressor performs the same function as a reciprocating compressor, it circulates refrigerant through the system. However, it has fewer moving parts, draws less current, is more efficient, and is quieter than a reciprocating compressor. Scroll compressors do not have a clearance volume like reciprocating compressors, which makes them a more efficient design. Most air conditioning and heat pump equipment manufactured today use hermetic scroll compressors.

Hermetic scroll compressors are cooled by the suction gas that passes through the compressor. They are designed with two spiral-shaped scroll plates that fit inside of one another. One of the plates remains stationary, while the other moves in an orbital path. As the orbiting scroll oscillates, refrigerant vapor is drawn in, compressed, and then discharged. During the discharge phase, the refrigerant is compressed to a zero volume. Since there is no clearance volume, as in the case of the reciprocating compressor, scroll compressors are much more efficient and desirable.

Orbiting Scroll **Stationary Scroll**



Due to the manner in which the scroll plates fit together, they can handle a small amount of liquid. The orbiting scroll plate can move in a sideways, or radial, motion to allow space for the liquid. The liquid will be quickly vaporized and discharged as a gas. The compressor may stop pumping briefly and a gurgling noise may be heard until the liquid is vaporized and discharged. While the scroll compressor can handle small amounts of liquid, it should be avoided whenever possible, as this will reduce the pumping efficiency of the compressor.

Compression Ratio

Compression ratio is a term used to describe the relationship between the high-pressure side and the low-pressure side of the system during operation and is expressed as a ratio. It is calculated by dividing the absolute discharge pressure by the absolute suction pressure. Absolute pressures are used to keep the numbers positive as some systems may operate with the low-side pressure in a vacuum. To convert gauge pressure to absolute pressure, 14.7 is added to the gauge pressure reading. For example, if the high-pressure gauge is showing 350 psig, the absolute pressure would be 364.7 psig (350 + 14.7). A compression ratio of 5 to 1 (5:1) would indicate that the discharge pressure is 5 times higher than the suction pressure.

Lower compression ratios typically indicate lower power consumption and higher efficiency. Higher compression ratios typically indicate higher power consumption and lower efficiency. An increase in discharge pressure or a decrease in suction pressure would result in a higher compression ratio. A decrease in discharge pressure or an increase in suction pressure would result in a lower compression ratio. The typical compression ratio range for a comfort cooling system is about 2.75-3.25 to 1 (2.75-3.25:1), depending on the system efficiency rating. The following are examples for typical air conditioning systems.

R-410A

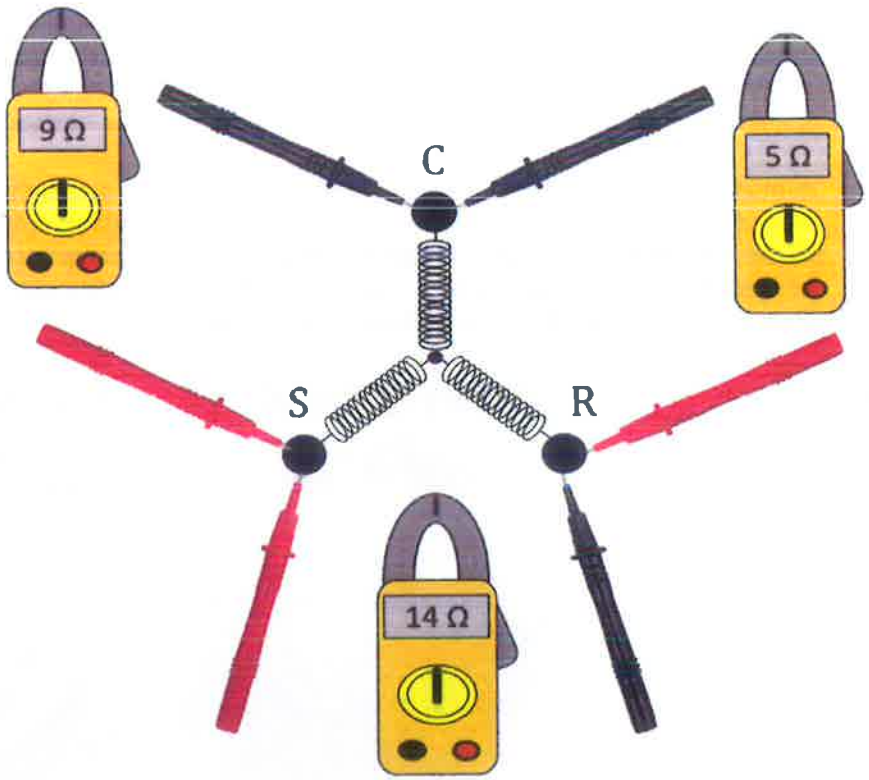
High-pressure (discharge): 350 psig — 350 + 14.7 = 364.7
Low-pressure (suction): 120 psig — 120 + 14.7 = 134.7
364.7 ÷ 134.7 = 2.70 to 1 (2.70:1)

R-22

High-pressure (discharge): 250 psig — 250 + 14.7 = 264.7
Low-pressure (suction): 68 psig — 68 + 14.7 = 82.7
264.7 ÷ 82.7 = 3.20 to 1 (3.20:1)

Testing a Compressor

When testing a compressor's motor windings, two useful test instruments are the digital multimeter and a megohmmeter. A resistance test should be performed on each of the compressor's two windings, Start (S), and Run (R). Each of the windings must have a measurable resistance. A reading of infinity or OL would indicate an open or burned winding. A reading of 0 Ω would indicate a shorted winding. Single-phase compressors have three terminals that are called the common terminal, the run terminal, and the start terminal. The start winding is located between the Common and Start terminals, while the run winding is located between the Common and Run terminals. On a single-phase compressor, the resistance reading between the Common and Start terminals added to the resistance reading between the Common and Run terminals should equal the resistance reading obtained between the Start terminal and the Run terminal, (C and S) + (C and R) = (S and R). On a three-phase compressor, the resistance of each winding should be the same ±10%, (C and S) = (C and R) = (S and R).



A megohmmeter is used to check a compressor for grounded windings. One lead from the meter is attached to a terminal and the other to ground. The meter will apply high voltage, usually 500 VDC, to the winding through one meter lead. The other meter lead will measure how much of that voltage is bleeding to ground. A good compressor should read more than 100 megohms of resistance to ground.

Metering Device

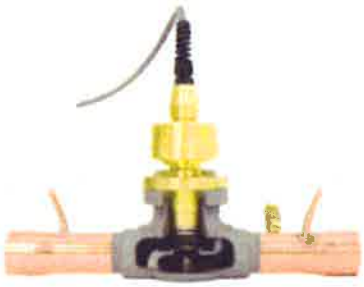
The metering device is the component that regulates (and restricts) the amount of refrigerant entering the evaporator. It separates the low-pressure side of the system from the high-pressure side of the system. It can have a fixed opening, such as a piston or capillary tube, or can be adjustable such as a thermostatic expansion valve (TEV), automatic expansion valve (AEV), or an electronic expansion valve (EEV). The metering device is fed high-pressure, subcooled, liquid refrigerant and it feeds low-pressure, low-temperature liquid to the evaporator. A small percentage of the liquid refrigerant leaving the metering device will immediately flash to a vapor, called flash gas. This flash gas helps to lower the temperature of the remaining liquid refrigerant.



A piston with a fixed orifice



A thermostatic expansion valve



An electronic expansion valve – Courtesy Sporlan Division, Parker Hanifin Corp.

Fixed Orifice Metering Devices

A metering device with a fixed orifice is designed to operate at a single cooling capacity. For example, a 2-ton fixed metering device (24,000 Btu/hr.) would deliver 2 tons of cooling at design conditions. The metering device capacity should be matched to that of the evaporator, compressor, and condenser. Systems with fixed metering devices will experience high superheat when there is a high heat load. They lack the ability to open up to feed more liquid into the evaporator. Once the system reduces the heat load, the superheat will begin to come back down to normal.

A fixed orifice metering device has no moving parts and is not as susceptible to mechanical failures as an adjustable metering device. However, they can become clogged with debris. A system with a piston can be opened and the clog removed. On a system with a clogged capillary tube, the tube is cut out and replaced.

Adjustable Metering Devices

An adjustable metering device is one that can open or close to regulate refrigerant flow based on load or system conditions. The three most common are the automatic expansion valve (AEV), thermostatic expansion valve (TEV), and the electronic expansion valve (EEV).

An AEV is designed to maintain a constant pressure in the evaporator and is adjustable. It has as an internal spring that opens and closes the valve based on pressure conditions in the evaporator. An EEV is an adjustable metering device that is opened and closed by an electronic stepper motor. The motor can rotate at a fraction of a revolution, or step, allowing for incremental adjustments. The valve is adjusted to maintain the ideal superheat for the system. The stepper motor receives its signal to open or close from a solid-state circuit board, which is monitoring several of the system's operating conditions. EEVs are typically found in high-efficiency comfort cooling units and ductless mini-split systems.

A TEV is designed to maintain a constant evaporator superheat. It has a remote sensing bulb that is mounted on the suction line at the outlet of the evaporator. The TEV is the most common type of adjustable metering device found in comfort cooling systems and, as such, will be the primary focus of this text.

Thermostatic Expansion Valve (TEV)

There are thousands of different thermostatic expansion valve (TEV) designs engineered to suit a variety of applications. Manufacturers publish sizing and capacity charts to properly match a TEV to a specific system and temperature application. The spring inside of the TEV, often referred to as the superheat spring, may be adjusted on some, but not all, valves. A spring adjustment should be made as a last resort and should only be done by experienced field technicians, while carefully following the manufacturer's recommendations. Failure to do so can result in severe equipment damage.

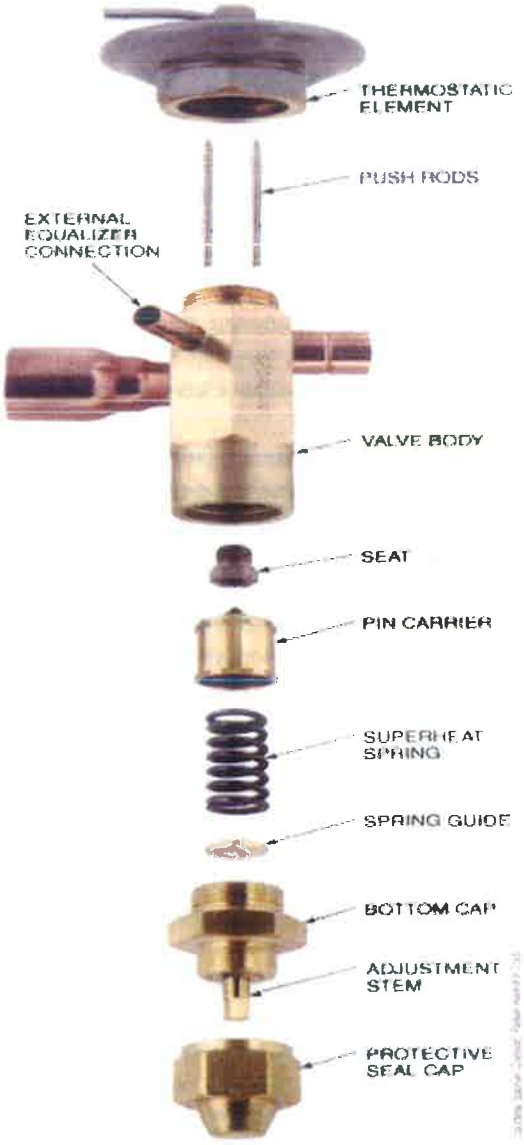


Left – externally equalized TEV, Right – internally-equalized TEV

The thermostatic expansion valve has three pressures that work to open or close the valve. As the valve closes, there is less refrigerant flow into the evaporator. As the valve opens, there is more refrigerant flow. The three pressures are the spring pressure, the bulb pressure, and the evaporator pressure. The spring and evaporator pressures are closing forces, while the bulb pressure is the one and only opening force. Whichever pressure is greater, opening or closing, dictates how the valve responds. Once the pressures are even, in equilibrium, the valve will maintain its position until conditions change.

Thermostatic expansion valves can be classified as either internally equalized or externally equalized. Internally-equalized TEVs sense the evaporator pressure at the inlet of the coil, while externally equalized TEVs sense the evaporator pressure at the outlet of the coil. Most TEVs used on comfort cooling systems are externally equalized. This is because most systems have multi-circuit evaporators and there is a pressure drop across the distributor of these coils. This pressure drop can have a negative effect on the evaporator coil's performance if an internally-equalized valve is used. On single-circuit evaporators, the pressure drop through the evaporator is typically less than 2 psig, so an internally-equalized TEV would be used. You can easily distinguish between internally-equalized and externally-equalized TEVs because internally-equalized TEVs have two connection ports, while externally-equalized TEVs have three.

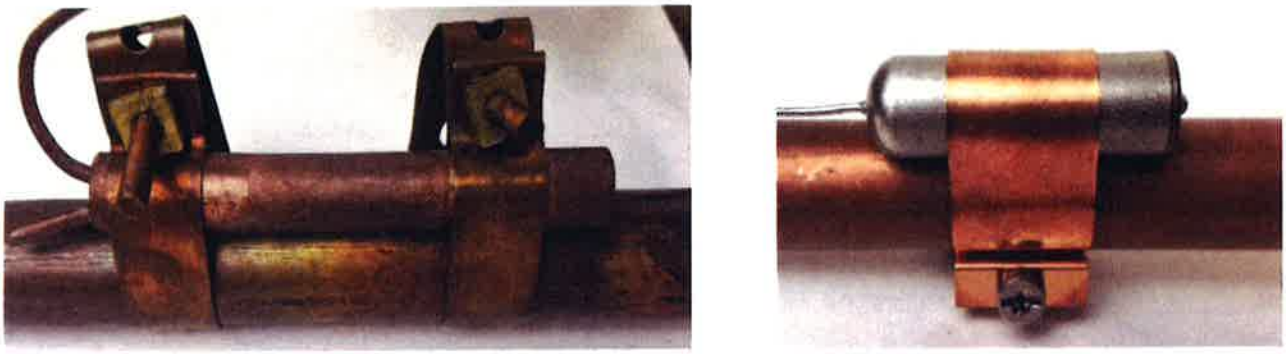
The sensing bulb is connected to the powerhead (thermostatic element) by a capillary tube, or transmission line, and contains a charge of saturated refrigerant, typically the same refrigerant that is used in the system. An increase in the heat load on the system will cause the evaporator superheat to rise, which in turn causes the suction line temperature to rise. The sensing bulb, mounted to the suction line, will react to this rise in temperature. The refrigerant inside the sensing bulb will begin to boil and its pressure will rise. The transmission line allows this pressure to travel from the bulb to the TEV's power head, where it will push down on the diaphragm inside. The diaphragm's movement is transferred to the pin by pushrods, which will push the pin off the seat to open the valve, increasing the flow of refrigerant to the evaporator. This will lower the evaporator's superheat.



Exploded view of a thermostatic expansion valve—Courtesy Sporlan Division, Parker Hannifin

Sensing Bulb Placement

Each manufacturer may have a different requirement for placement of the sensing bulb, but most are similar. The bulb is mounted to the suction line at the evaporator outlet. The recommended location on suction lines that are 7/8" or under is near the top of a horizontal line. The bulb should make good contact with the suction line along its entire length. Ideally, the bulb will be at the same temperature as the suction line. Some manufacturers provide a strap that must be used to aid the heat transfer from the suction line to the bulb. The bulb should be completely insulated to prevent the ambient temperature from affecting its operation.



Thermostatic expansion valve sensing bulb placement and mounting

Section 3 Review Questions

Name: _____ Date: _____

1. The industry standard for airflow across the evaporator is _____ cubic feet per minute (CFM), per ton of cooling.

2. When installed with a gas furnace, the evaporator is typically located on the _____ side of the furnace.

3. Once in the condenser, the refrigerant vapor will first be _____.

4. Most manufacturers recommend the condenser be installed with _____ feet or more of vertical clearance and at least _____ inches on each side for proper operation.

5. The _____ circulates the refrigerant in a refrigeration circuit.

6. _____ compressors are welded shut at the factory and are not field-serviceable.

7. On a reciprocating compressor, the space between the piston and the compressor head at the top of the compression stroke is called the _____.

8. Most hermetic compressor motors are cooled by _____.

9. An increase in discharge pressure or a decrease in suction pressure would result in a _____ compression ratio.

10. A _____ compressor has two spiral plates, one stationary and one that orbits.

11. The two general types of metering devices are the _____ and _____.

12. A _____ metering device is designed to maintain a constant evaporator pressure.

13. A _____ metering device is designed to maintain a constant evaporator superheat.

14. A _____ metering device has no moving parts and works at a fixed capacity under design conditions.

15. The three pressures that work to open or close a thermostatic expansion valve are the _____, _____, and _____.

Answers to Review Questions

Section 1

1. Inches of Mercury (in. Hg)
2. 14.7 psia
3. heat
4. change of state
5. above
6. temperature
7. 10
8. Subcooling
9. dew point temperature
10. micron gauge
11. 50
12. 45
13. R-22
14. –35
15. 95

Calculate Superheat Exercises

A.

Vapor Line = 55°F
R-22 @ 76 psig = 45°F
Superheat = 10°F

R-22 @ 195 psig = 100°F
Liquid Line = 90°F
Subcooling = 10°F

B.

Vapor Line = 58°F
R-22 @ 80 psig = 48°F
Superheat = 10°F

R-22 @ 245 psig = 117°F
Liquid Line = 100°F
Subcooling = 17°F

C.

Vapor Line = 52°F
R-22 @ 68 psig = 40°F
Superheat = 12°F

R-22 @ 260 psig = 120°F
Liquid Line = 105°F
Subcooling = 15°F

Section 2

1. ozone depletion potential (ODP); global warming potential (GWP)
2. critical temperature
3. toxicity; flammability
4. Chlorofluorocarbons (CFCs)
5. R-22
6. Hydrofluorocarbons (HFCs)
7. Hydrocarbon (HC)
8. 400
9. Azeotropic
10. 125°
11. lubrication
12. hygroscopic
13. Mineral
14. retrofitting
15. Polyol Ester

Section 3

1. 400
2. discharge (supply)
3. desuperheated
4. 8; 18
5. compressor
6. Hermetic
7. clearance volume
8. suction gas (refrigerant vapor).
9. higher
10. scroll
11. fixed; adjustable
12. automatic expansion valve (AEV)
13. thermostatic expansion valve (TEV)
14. piston (fixed orifice)
15. bulb, spring, evaporator