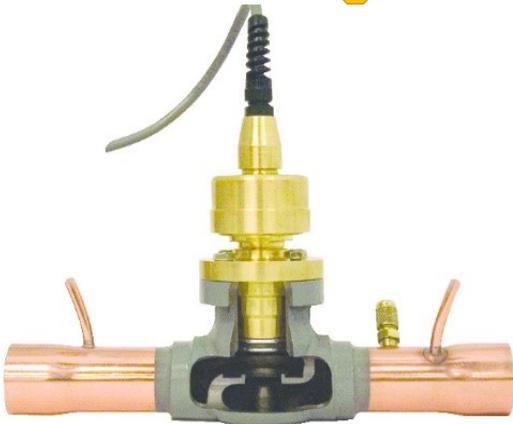
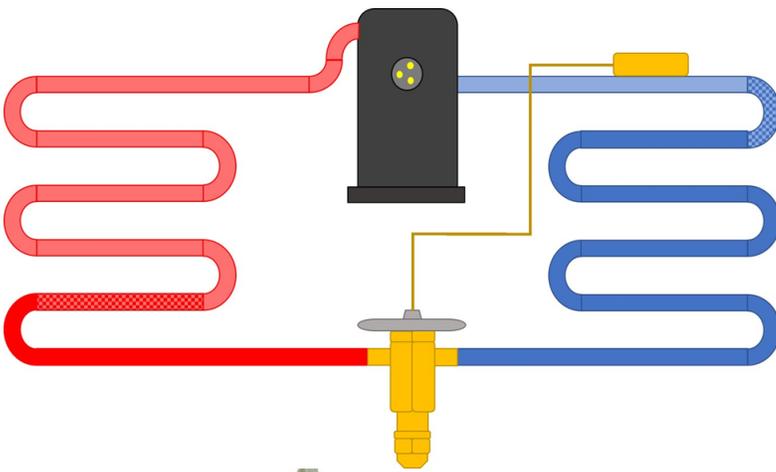


Quick Guide

A Supplement to the EPA Section 608 Certification Exam Preparatory Manual

Refrigeration Cycle • Refrigerants • Components



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Quick Guide

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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

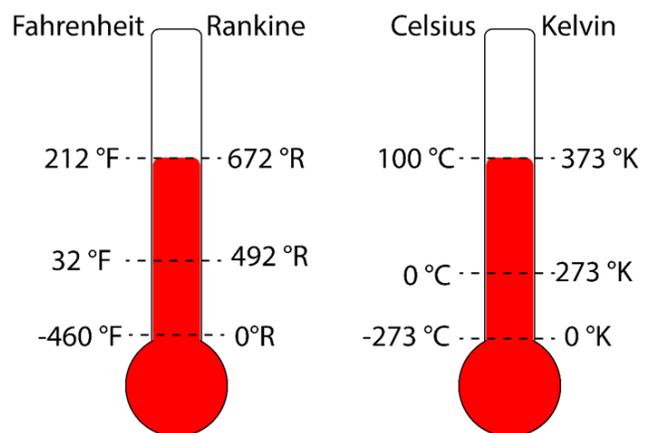
Temperature is a term used to describe the speed of the molecules or level of heat intensity of a substance. As the temperature of a substance increases, the molecules in the substance vibrate with more force. As the temperature of a substance drops, the intensity of molecular motion within the substance 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.

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:



VAPOR LINE: 55 LIQUID LINE: 90

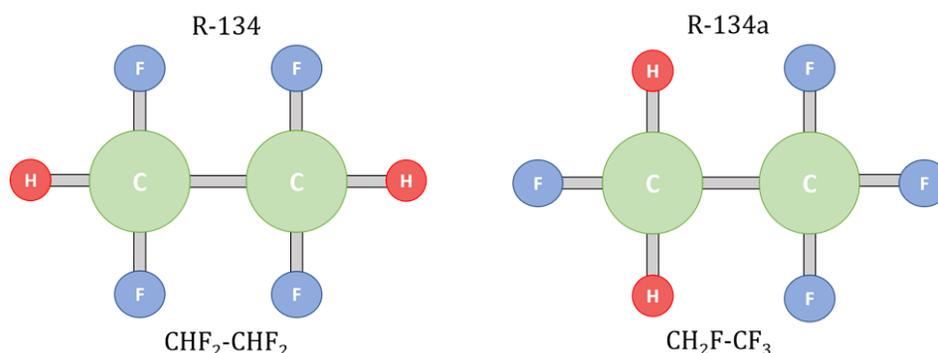


VAPOR LINE: 58 LIQUID LINE: 100



VAPOR LINE: 52 LIQUID LINE: 105

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.



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

Condensing Unit No. 36790-CC
Model # GMS-13-3610-CC
Serial # S0927040249
Test Pressure Low Side: 150 PSIG
Test Pressure High Side: 400 PSIG
Refrigerant R-22

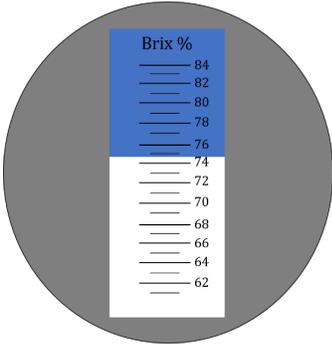
Cased Evaporator Coil
Model # GMS-13-3610-CC
Serial # S0927040249
Design Pressure 150 PSIG
Refrigerant R-22

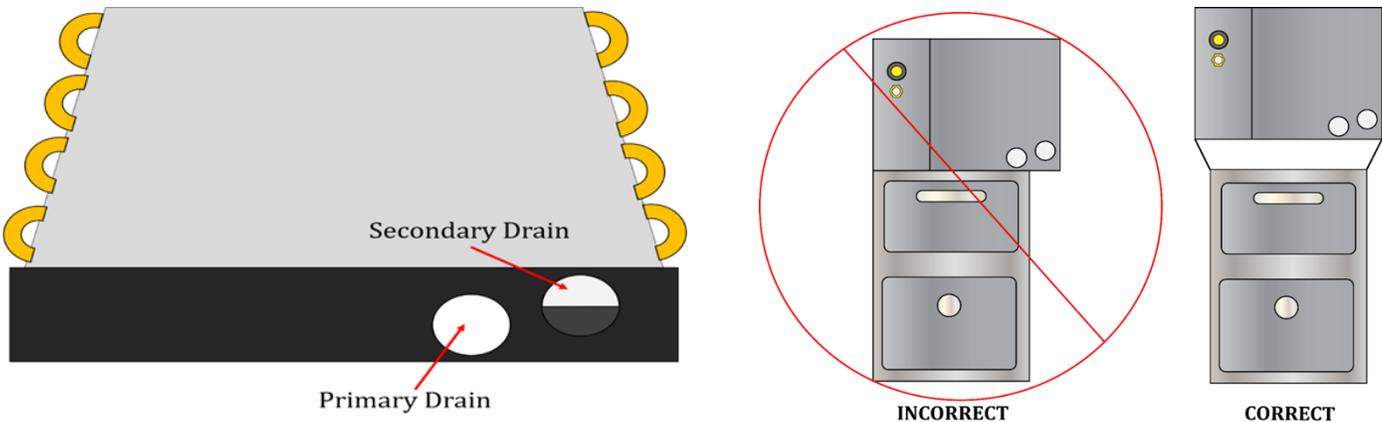
Next, the system should be pulled into a deep vacuum of at least 500 microns. Once the appropriate vacuum level has been reached, the system should be valved off and observed to see if the system pressure rises. If the vacuum level does not rise considerably, the system can be charged with the new refrigerant. 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.



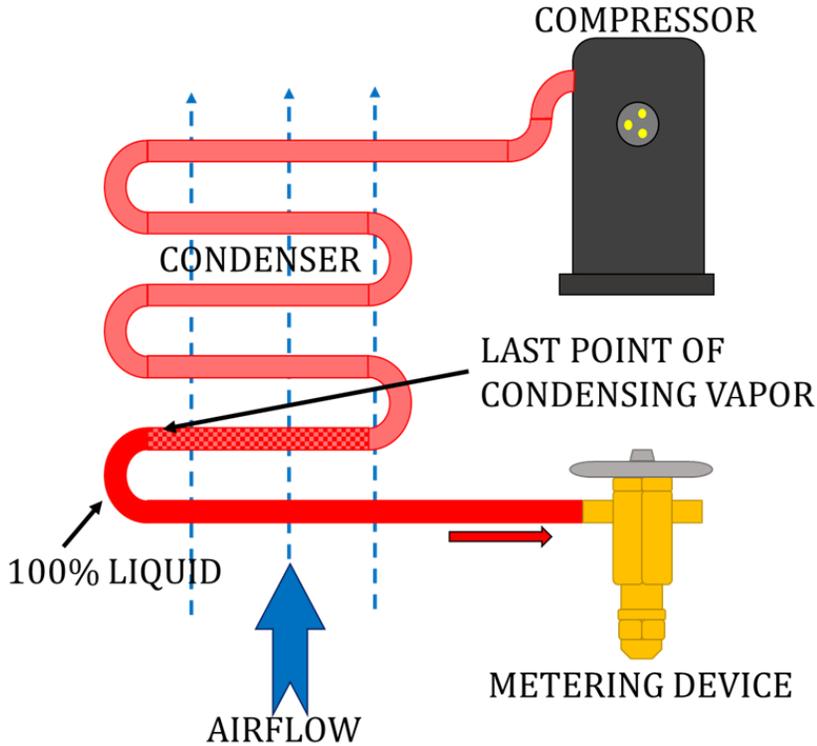


When installed with a gas furnace, the evaporator is typically located on the discharge, or supply side of the furnace. On an air handler installation, the coil is typically located on the negative pressure, or return side of the system. On either installation, the air should be filtered before passing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



Microchannel coil



Aluminum Spine Fins

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.



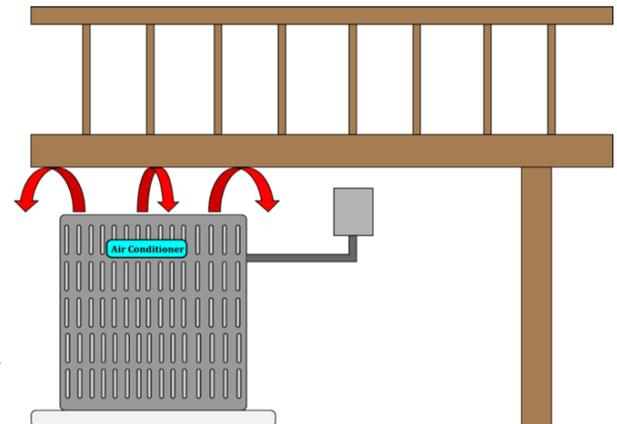
Top air discharge condenser



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

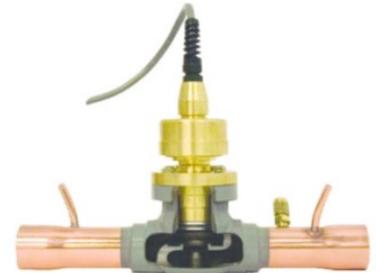
Metering Device

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 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.

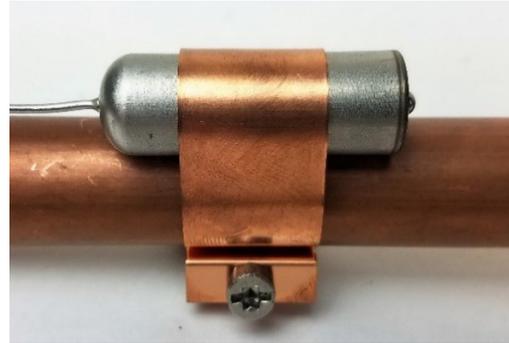
A TEV is designed to maintain a constant evaporator superheat. It has a remote sensing bulb that is mounted on the suction line at the outlet of the evaporator. The TEV is the most common type of adjustable metering device found in comfort cooling systems and, as such, will be the primary focus of this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

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.

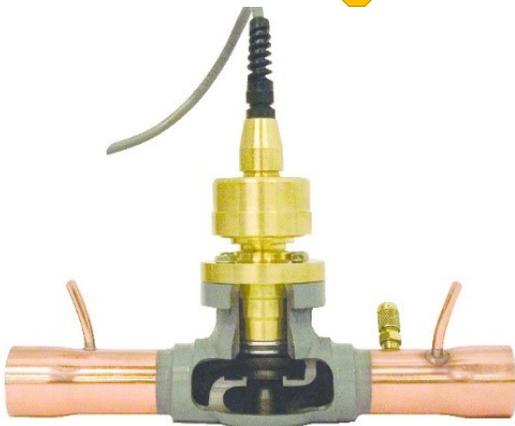
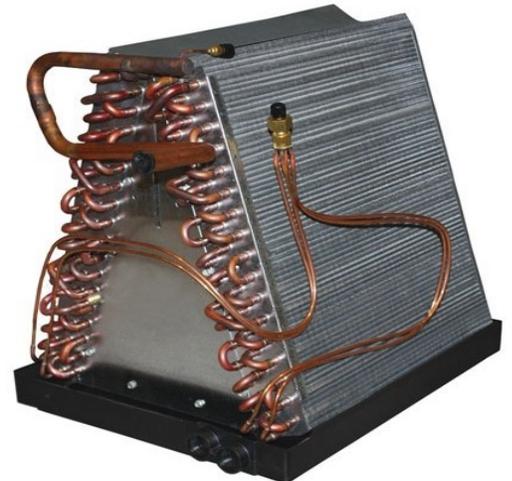
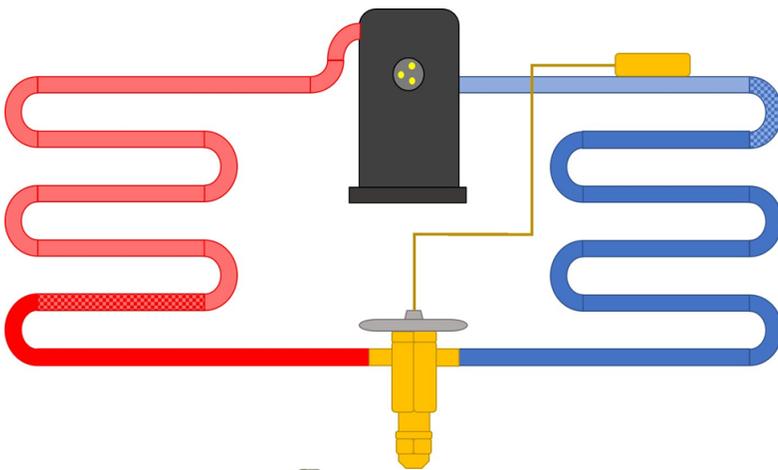


Thermostatic expansion valve sensing bulb placement and mounting

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