9 Basic Refrigeration and Air-Conditioning System Components

LEARNING OUTCOMES

9.1 Compressors

9.1-1 Explain the operation of fully hermetic and semi-hermetic compressors.

9.1-2 Compare the operation and construction of reciprocating, rotary, and scroll compressors.

9.1-3 Explain the ideal compressor operating conditions and requirements.

9.1-4 Describe the use and operation of various compressor protection devices.

9.2 Metering Devices

9.2-1 Describe the function of metering devices and categorize them as modulating or fixed.

9.2-2 Describe the design and function of capillary tube metering devices.

9.2-3 Describe the design and function of metering orifice devices.

9.2-4 Explain the operation of thermostatic expansion valves (TXVs).

9.3 Evaporators

9.3-1 Compare and contrast different types of evaporators.

9.4 Condensers

9.4-1 Identify characteristics of condensers used in residential systems.

9.5 Other Basic System Components

9.5-1 Explain the design and function of liquid line filter-driers, sight glasses, and service valves.

TECHNICAL TERMS

air-cooled condenser
air-cooled evaporator
air defrosting
baffles
capillary tube
eddy currents
fin-and-tube evaporator
gravitational circulation
heat exchanger
hermetic compressor
metering orifice
microchannel
moisture indicator
orifice
plate evaporator
reciprocating compressor
rotary compressor
scroll compressor
semi-hermetic compressor
sight glass
thermal overload
thermostatic expansion valve (TXV)

Ritchie Engineering Co., Inc. – YELLOW JACKET Products Division

Introduction

Refrigeration and air-conditioning systems contain the same core components. Some of the core components were introduced in Chapter 8, *Basic Compression Refrigeration and Air-Conditioning Systems*. This chapter will dive deeper into the various types of components used in refrigeration and air-conditioning systems and how they operate.

9.1 Compressors

Compressors are driven by an electric motor, which may be mounted outside the compressor unit or inside its housing. Compressors that are driven by an external motor are called open-drive compressors, and compressors that include an integrated drive motor in a sealed unit are called hermetic compressors. Open-drive compressors are primarily used in large commercial and industrial refrigeration applications. Open-drive compressors will be discussed in later chapters.

9.1.1 Hermetic Compressors

In a ***hermetic compressor***, the motor is sealed inside the same dome or housing as the compressor, so a shaft seal is not needed. The motor is directly connected to the compressor, often through a shared shaft. Some are enclosed in a bolted assembly. These types of compressors are often called semi-hermetic, field-serviceable, or accessible. Fully hermetic compressors are sealed in a welded casing. Both semi-hermetic and fully hermetic compressors may be equipped with service valves. These types of compressors may be connected to different types of evaporators and used for many different applications.

Fully Hermetic Compressors

Fully welded hermetic compressors cannot be serviced without cutting open the shell. This is a specialized skill, so these compressors cannot be serviced in the field and are considered "throw-away" compressors. These units are built in sizes from 1/6 hp up to 20 hp. Internal design varies with size and manufacturer.

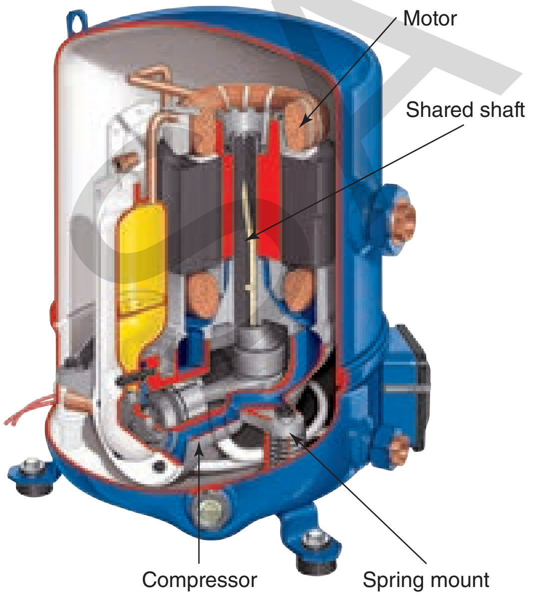
In a fully hermetic compressor, the motor and compressor shaft are in a vertical position. Some hermetic units are made with the motor at the top, **Figure 9-1**. Others have the motor at the bottom and the compressor at the top.

Smaller units usually have one cylinder. Larger units (1/2 hp and up) have two or more cylinders. The motors used in small units are typically single-phase. Three-phase motors are generally used in larger units. The compressor and motor of a hermetic unit are usually spring-mounted inside the hermetic dome, although some units use external mounting springs. The spring mounting prevents most of the compressor vibration from being felt outside of the dome.

In hermetic compressors, the motor's rotor is mounted directly on the compressor shaft. In hermetic reciprocating compressors, the rotor often has a built-in counterweight, which balances the weight of the crank, connecting rod, and piston. Hermetic motors are lubricated by the oil carried in the refrigerant. They do not use brushes or open points inside the dome. Arcing would cause pollution in both the oil and the refrigerant, which would lead to an electrical burnout. The electrical connections and starting relay are located outside the dome.

The discharge (exhaust) and suction lines inside the dome are flexible. Service connectors are provided on the dome for connecting the exterior lines to the lines inside the dome. Electrical connections to the motor pass through the dome by means of an insulated leakproof seal.

A hermetic compressor is lubricated by oil in the refrigerant that flows through the unit. The refrigerant vapor enters the dome through a suction connector, cooling the motor and picking up some oil (less than 1%) before it is pulled into the suction chamber for compression. The oil that is carried by the refrigerant helps to lubricate and seal the valves and other elements in the vapor's path.



Danfoss-Maneurop Ltd.

Figure 9-1. This hermetic reciprocating compressor is a universal compressor for both commercial refrigeration and air-conditioning applications. Note the vertical arrangement of the motor and compressor, which are connected by a shared shaft.

Semi-Hermetic Compressors

A ***semi-hermetic compressor*** combines a motor and a compressor inside a multipart shell that is bolted together. The shell can be unbolted to open the unit for repair. For this reason, they are sometimes called *serviceable hermetic compressors*. Gaskets are used between the bolted sections to seal the unit and prevent leaks. Semi-hermetic compressors are often air-cooled and have cooling fins on the exterior housing to increase surface area and improve heat dissipation. The motor and compressor are usually arranged horizontally. See **Figure 9-2**.

Safety Note

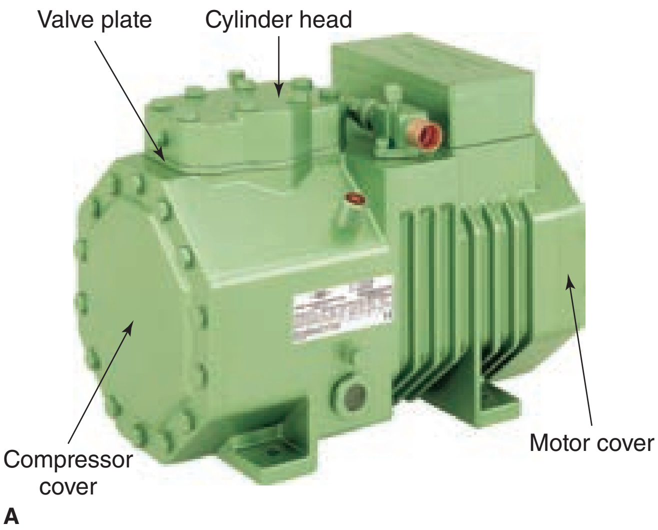
Avoiding Burns

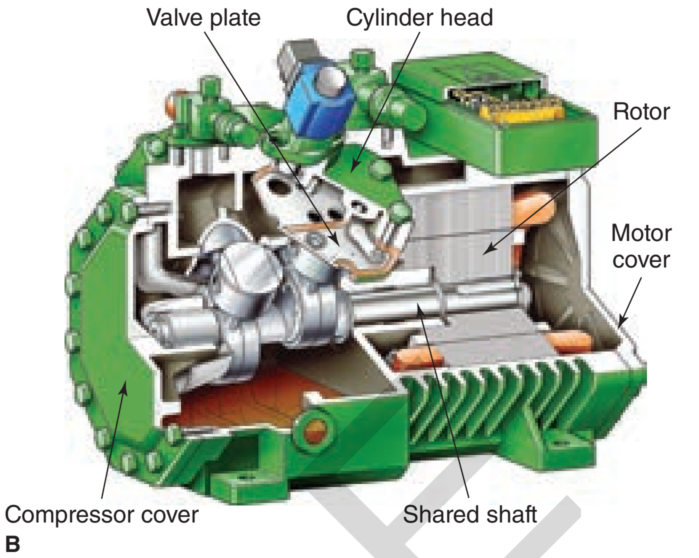
Avoid touching the compressor discharge line. During and after operation, it is very hot and may cause burns.

9.1.2 Types of Compressors

In addition to the open-drive and hermetic classifications already mentioned, compressors can be further classified based on their method of compression. There are three basic types of compressors used in the residential refrigeration and air conditioning industry:

- Reciprocating (piston-cylinder).
- Rotary.
- Scroll.





Bitzer

Figure 9-2. Semi-hermetic reciprocating compressors. A—The cylinder head, compressor cover, and motor cover can be unbolted to service the compressor. B—This cutaway shows the arrangement of parts inside a semi-hermetic reciprocating compressor.

Additional types of compressors, including screw compressors and centrifugal compressors, are used in larger commercial refrigeration and air-conditioning systems. These compressor types are discussed in later chapters.

The type of compressor used for a given application depends on the physical size of the unit, cooling capacity required, cost, serviceability, and noise requirements. **Figure 9-3** compares the wide range of compressors available for many different refrigeration applications.

The size of a compressor intended for residential or domestic use must be small because of the limited space available for most applications. It must be quiet and not require servicing for many years. Small hermetic reciprocating or scroll compressors best meet these requirements and are typically preferred for residential or domestic applications.

Large building air conditioning has very different requirements for a compressor. Serviceability is a primary

Refrigeration and Air Conditioning Compressor Applications

Compressor Type	Capacity Range HP (W)	Capacity Range Tons (W)	Application
Centrifugal	33–12,000 hp (24.6 kW–8942 kW)	6.96–2544 Ton (24.6 kW–8942 kW)	Commercial air conditioning
Reciprocating (open-drive)	0.17–200 hp (126 W–149 kW)	0.03–42 Ton (126 W–149 kW)	Commercial air conditioning Commercial refrigeration Industrial refrigeration
Reciprocating (semi-hermetic)	0.5–150 hp (373 W–111.9 kW)	0.10–31.8 Ton (373 W–111.9 kW)	Commercial air conditioning Commercial refrigeration
Reciprocating (fully hermetic)	0.17–25 hp (126 W–18.6 kW)	0.04–5.3 Ton (126 W–18.6 kW)	Domestic refrigeration Residential air conditioning Commercial air conditioning Commercial refrigeration
Rotary	3–50 hp (2.2 kW–37.3 kW)	0.64–10.6 Ton (2.2 kW–37.3 kW)	Domestic refrigeration
Screw	3–5000 hp (2.2 kW–3730 kW)	0.64–1000 Ton (2.2 kW–3730 kW)	Commercial air conditioning Commercial refrigeration Industrial refrigeration
Scroll	3–2000 hp (2.2 kW–1492 kW)	0.64–424 Ton (2.2 kW–1492 kW)	Residential air conditioning Commercial air conditioning Commercial refrigeration

Goodheart-Willcox Publisher

Figure 9-3. Table showing typical compressor applications and capacities. Be aware that the capacities and applications will vary somewhat, depending on the manufacturer's design.

concern, so easy access to the compressor must be provided. Such systems often have a designated mechanical room, so limited space is seldom a concern. In large building air-conditioning systems, compressor size is primarily determined by the amount of cooling capacity required.

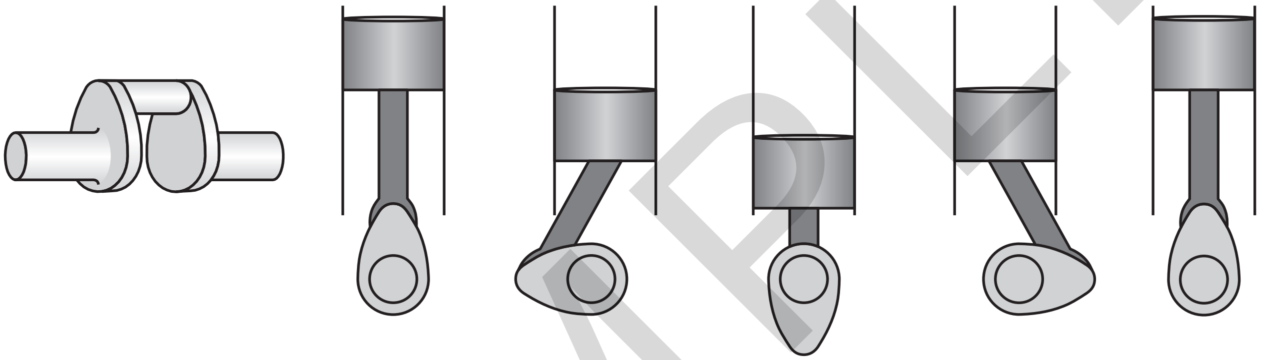
Reciprocating Compressors

The majority of residential, commercial, and industrial HVACR systems use reciprocating compressors. A ***reciprocating compressor*** is a compressor that functions by changing the rotational movement of a crankshaft into the reciprocating motion of the pistons within cylinders. These compressors are classified in a number of ways:

- By cylinder arrangement.
- By number of cylinders.
- By type of crankshaft.
- By construction (open-drive, semi-hermetic, or hermetic).

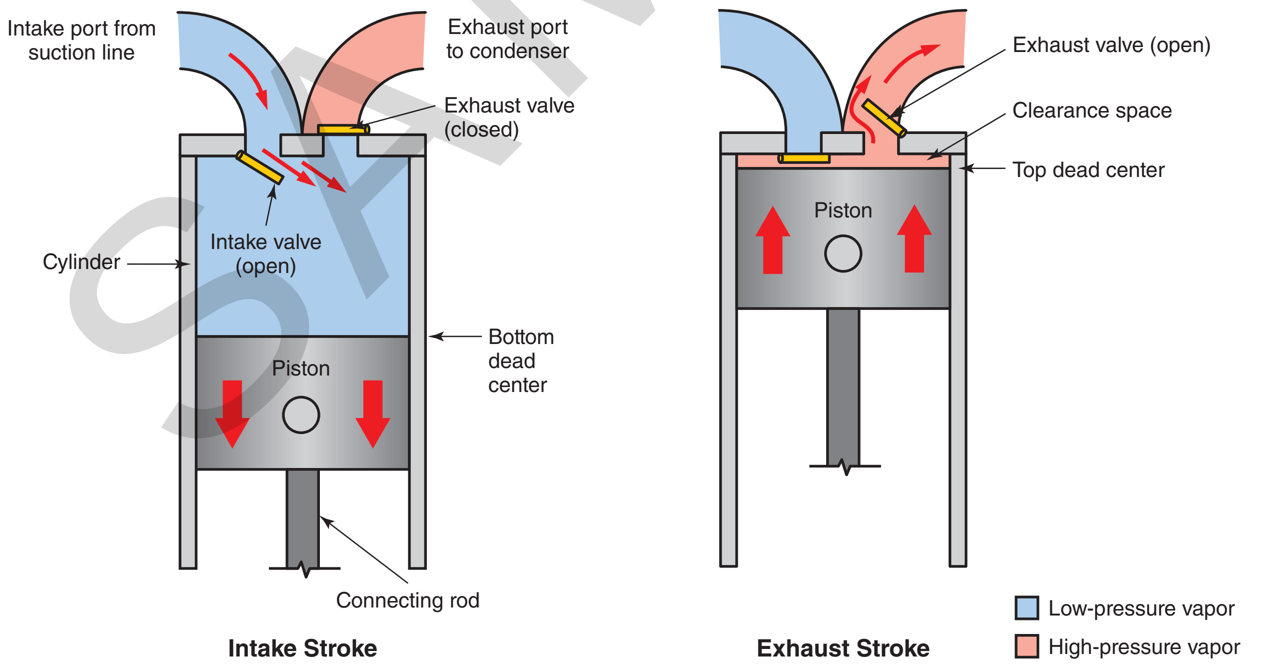
The construction of a reciprocating piston compressor resembles that of the automobile engine. Like an automobile engine, a reciprocating compressor has a crankshaft, connecting rods, pistons, cylinders, and intake and exhaust valves. Reciprocating compressors are usually driven by an electric motor. The motor's rotary motion is changed to *reciprocating* motion (back-and-forth action in a straight line) through the action of a crankshaft and connecting rods. The reciprocating motion moves pistons up and down in cylinders to draw in and compress the refrigerant, **Figure 9-4**.

Figure 9-5 shows the basic operation of a reciprocating compressor. During the intake stroke, the piston moves downward in the cylinder. The vacuum created as the



Goodheart-Willcox Publisher

Figure 9-4. A crank throw-type crankshaft and connecting rod completing one revolution.



Goodheart-Willcox Publisher

Figure 9-5. Basic operation of a reciprocating compressor. During the intake stroke, the piston moves down in the cylinder, creating suction and drawing refrigerant through the intake valve. During the exhaust stroke, the piston moves up in the cylinder, sealing the intake valve and compressing the refrigerant. When the refrigerant reaches a sufficient pressure, it forces open the exhaust valve and exits into the discharge line.

piston moves downward draws refrigerant vapor from the suction line through the intake valve and into the cylinder. During the exhaust stroke, the piston moves upward. As it moves up, it compresses the vaporized refrigerant into a much smaller space. When a sufficient pressure is reached, the compressed vapor is pushed through the exhaust valve into the condenser.

Rotary Compressors

A ***rotary compressor*** is a compressor in which vapor compression takes place in spaces between the cylinder wall and sides of an off-center rotor that spins inside the cylinder. A check valve is usually placed in the discharge. It prevents backflow of refrigerant during the Off cycle. A check valve should be placed in the oil lines for the same reason.

Rotary compressors are commonly used to power small, refrigerated appliances such as window air conditioners, packaged terminal air conditioners, and heat pumps up to five tons. Rotary compressors have high volumetric efficiency. There are two basic types of rotary compressors: rotating-vane and stationary-blade.

Rotating-Vane Rotary Compressors. A rotating-vane rotary compressor uses an off-center rotor to turn vanes (blades) that create pockets between the rotor and cylinder wall. The vanes in some compressors are spring-loaded so they can adjust position and continually push out against the cylinder walls as the shaft rotates. In other designs, the vanes are pulled outward from their grooves solely by the centrifugal force of the spinning shaft. **Figure 9-6** shows the operating principles of a typical two-blade rotating-vane compressor.

The low-pressure vapor from the suction line is drawn into the opening between the vanes as the vanes revolve. The trapped vapor in the space ahead of the lead vane is compressed until it can be pushed into the exhaust line to the condenser.

Stationary-Blade (Divider-Block) Rotary Compressors. The blade on a stationary-blade rotary compressor is mounted in the housing assembly rather than on the shaft. The blade in this type of compressor is spring-loaded and presses against the rotor as it rotates. In both rotary compressor types, the blades provide a continuous seal for the refrigerant vapor. In a rotating vane compressor, the rotor stays in a stationary position as it spins the vanes. In a stationary-blade compressor, the blade stays stationary, while the rotor moves in an orbit around the inside of the cylinder. **Figure 9-7** shows a stationary-blade (often called a divider-block) rotary compressor.

An eccentric shaft rotates a rotor in a cylinder. This rotor constantly rolls against the outer wall of the cylinder. As the rotor (or roller) revolves, the blade traps quantities of vapor between the cylinder and rotor. The vapor is compressed into a smaller and smaller space as the rotor revolves. As the volume decreases, both the pressure and temperature increase. Finally the pressure opens the exhaust valve, and vapor is forced through the exhaust port. It enters the high-pressure side of the system (condenser).

The compression action on one quantity of vapor takes place at the same time another quantity of vapor is filling the cylinder on the intake stroke. All of the parts are fitted to extremely close tolerances and clearances and the surfaces are extremely smooth. Therefore, no gaskets are needed in the compressor assembly.

Blade (Vane) Construction. Rotating-vane compressors use two or more blades. These blades may be made of cast iron, steel, aluminum, or carbon. The blades are pushed outward from the bottom of their grooves by springs or by centrifugal force. This keeps the blades in contact with the cylinder walls, where they form a seal.

Cylinder Construction. The cylinders in rotary compressors are usually made of cast iron. All cylinders have intake and exhaust ports. The intake ports are generally much larger than the exhaust ports. Some models have oil passages for lubrication. Cylinders are usually mounted on an end plate, which is part of the main compressor crankcase. Refrigerant passages continue into the end plate.

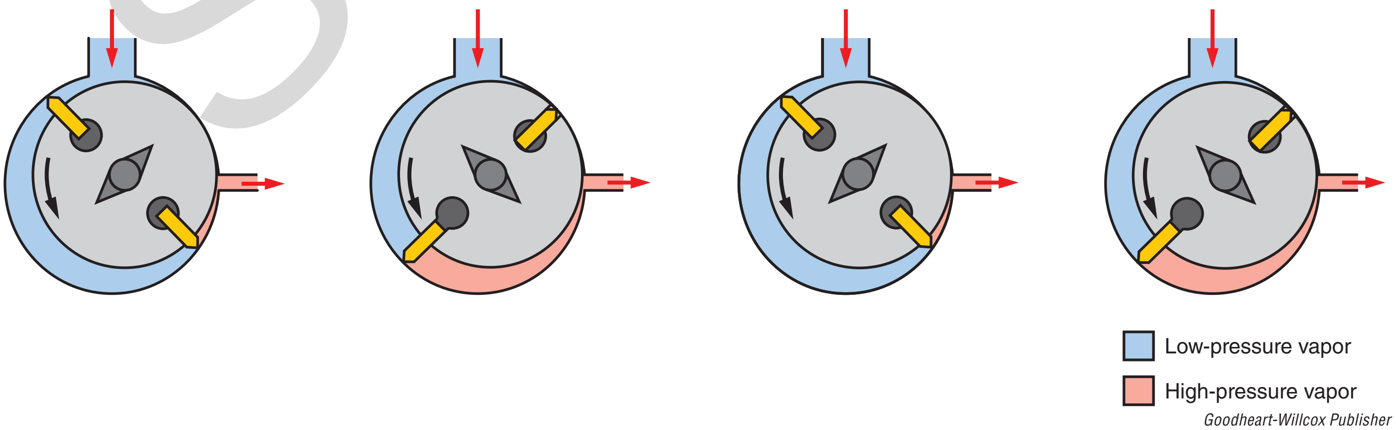


Figure 9-6. Basic operation of a rotating-vane rotary compressor. Black arrows indicate the direction of rotation of the rotor. Red arrows indicate the flow of refrigerant vapor.

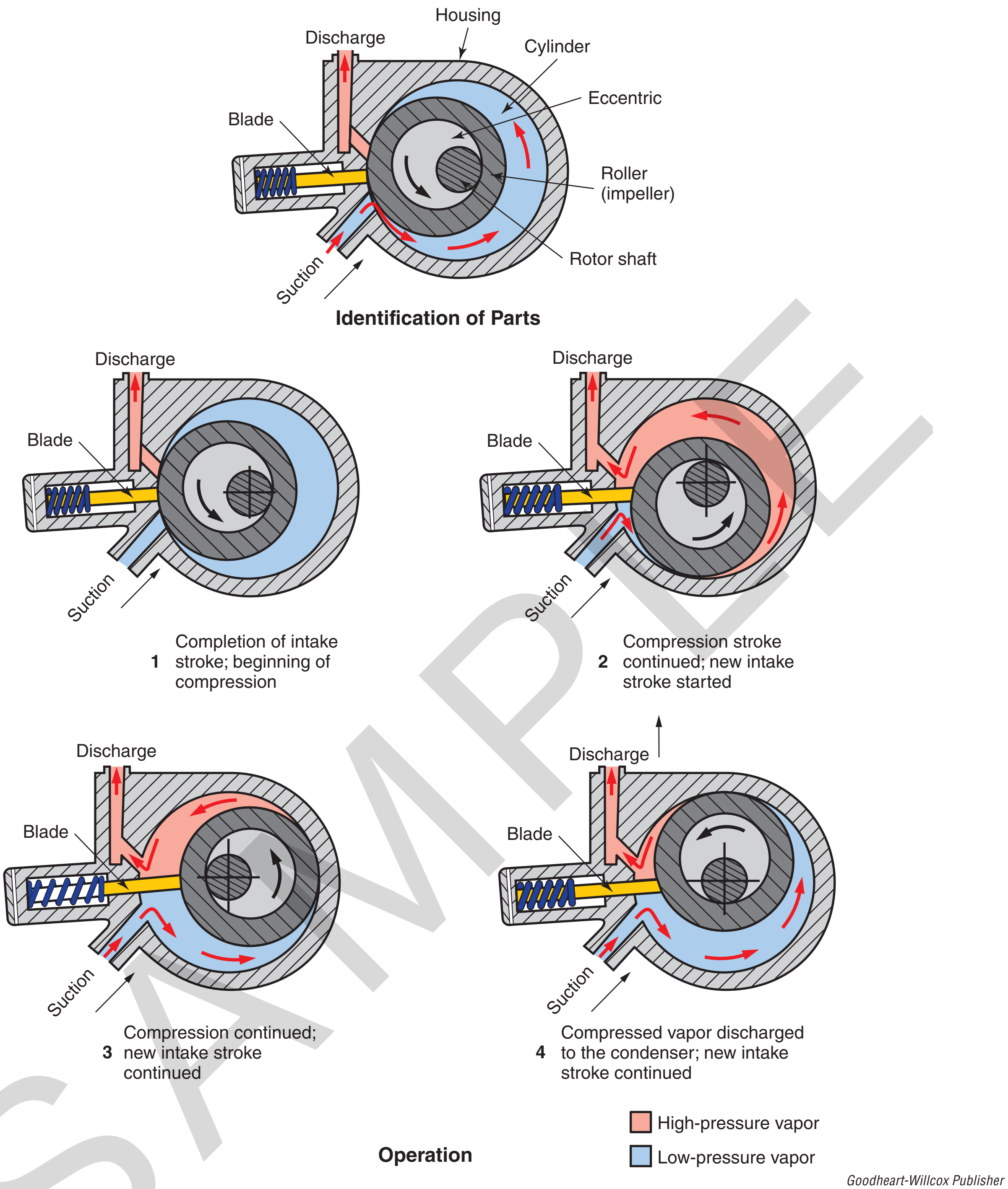


Figure 9-7. In a stationary-blade (or divider-block) rotary compressor, a single stationary spring-loaded blade remains in constant contact with a rotating impeller.

The exhaust reed valve is mounted on the exhaust port outlet of the compressor. It is mounted as close to the compression chamber as possible. Check valves are usually used in the suction line. They prevent the high-pressure vapor and compressor oil from flowing back into the evaporator. Four or more bolts hold the cylinder to the main part of the compressor. One or more steel dowel pins help align the cylinder on the back plate. Another accurately finished plate seals the other end of the cylinder.

Scroll Compressors

A ***scroll compressor*** produces vapor compression between the walls of a fixed scroll and an orbiting scroll. Its main compression parts consist of these two intertwined scrolls. One scroll is fixed to the housing and remains stationary, while the orbiting scroll revolves in an eccentric path around the center of the stationary scroll, **Figure 9-8**.

The space between the scrolls forms a series of pockets. As the orbiting scroll moves, the sizes of the existing

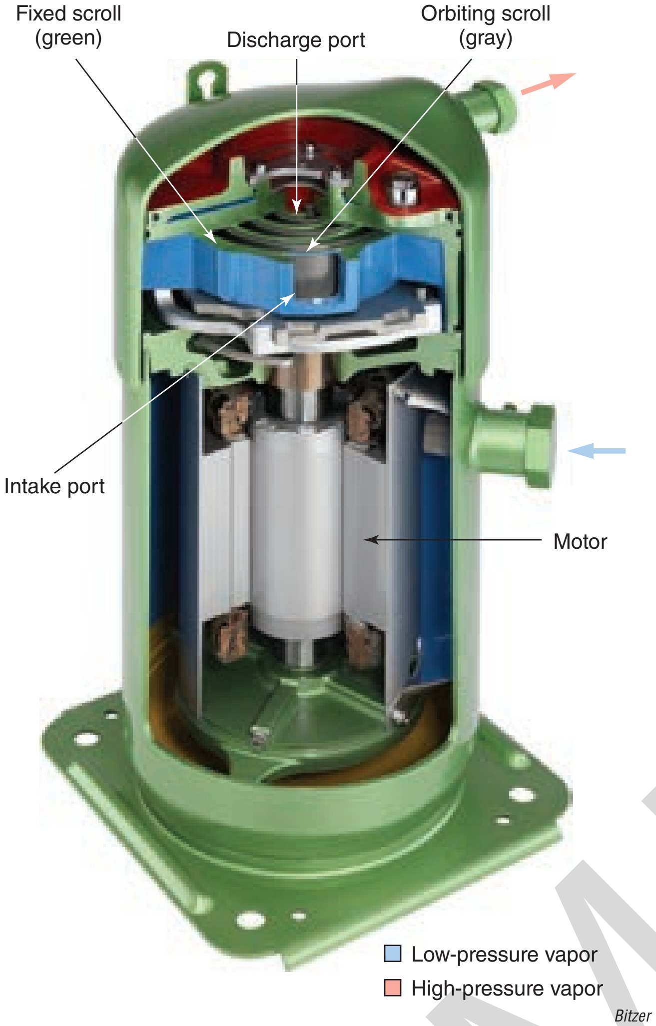


Figure 9-8. Cutaway of a scroll compressor showing its main parts.

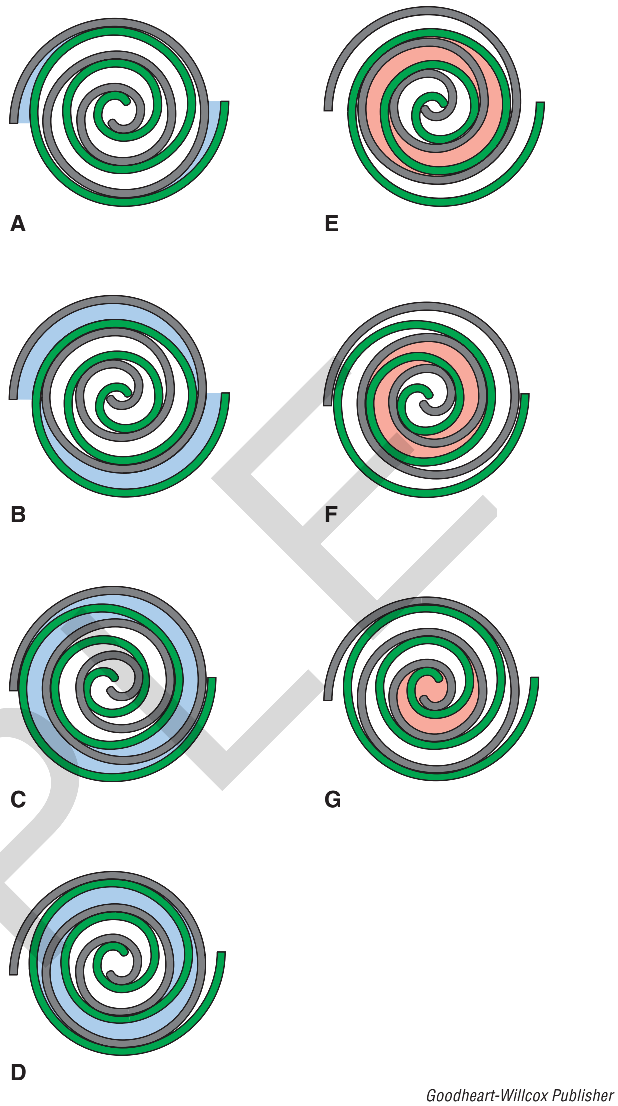


Figure 9-9. Diagram showing the scroll compressor process. A—Vapor enters the outer pockets between the scrolls. B—The full amount of vapor fills the inlet space for the first set of pockets. C—As the gray scroll orbits, it seals the pockets. D, E, F—The pockets get progressively smaller and pressure increases. G—The lead pockets are forced to the center of the scrolls, where the compressed vapor escapes through the discharge port. Note that new vapor pockets form continuously during the cycle.

pockets are reduced as they are pushed toward the center of the two scrolls. This reduces the volume of the vapor in the pockets, **Figure 9-9**.

As two high-pressure pockets are discharging, new low-pressure pockets are formed at the outer edges of the scrolls. When a pocket reaches the center of the scroll, the vapor inside the pocket is at a high pressure. It is discharged out of the center port, **Figure 9-10**.

The suction from the outer portion of the scroll and the discharge from the inner portion are continuous. Between the two scrolls, there are four sealed vapor pockets at various stages of compression at any given time. This continuous process gives the compressor very smooth action.

Some scroll compressors have the ability to modulate their capacity during operation. Depending on the compressor model, this can be done by opening a bypass port partway between the outer edge and the center of the fixed scroll. This bypass port redirects some of the partially compressed vapor back to the compressor inlet, reducing the overall capacity of the compressor. Other models are equipped with a variable speed motor that can be operated at different speeds to modulate capacity. Another method of modulating capacity is to briefly move the fixed scroll and the orbiting scroll apart, creating gaps between the vapor pockets that briefly allow the pressure differences between the pockets to equalize.

Scroll compressors are commonly used in residential air conditioning and heat pump applications. Benefits of scroll compressors include fewer moving parts, less internal friction, a smooth compression cycle resulting in less torque variation, low noise levels, and low vibration levels.

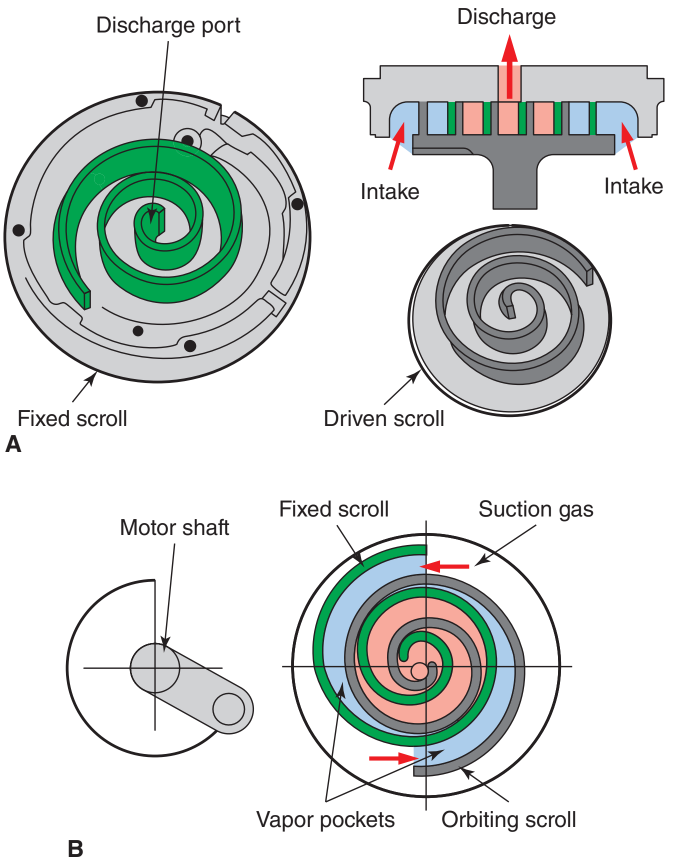


Image courtesy of Trane, a brand of Ingersoll Rand

Figure 9-10. Scroll compressor design. A—The upper scroll is stationary and the lower scroll is driven. Vapor enters the compressor through side gaps between the upper and lower scrolls. The discharge port is built into the upper scroll. B—Note how the rotation of the motor shaft causes the orbiting scroll to orbit (not rotate) about the shaft center.

9.1.3 Compressor Operating Conditions

Compressors are mechanical devices that generate friction and heat from their moving parts. Therefore, all compressors require lubrication and cooling to operate efficiently and without sustaining damage. Refrigerant oil is used to lubricate the mechanical parts of the compressor, while refrigerant vapor is often used to cool the internal motor windings of hermetic and semi-hermetic compressors. The oil must be free from contamination, and the refrigerant must be in vapor form, not liquid. Contaminants in the refrigerant oil can damage the surfaces of pistons, scrolls, and screws in a compressor. Liquid refrigerant is noncompressible. If it enters the suction side of the compressor, it will result in *liquid slugging*. This can damage compressor valves, pistons, scrolls, and vanes.

All compressors also use safety devices to ensure that they do not run during periods of excessive heat or pressure. Safety devices, such as internal overloads, external overloads, and pressure switches, are used to stop compressor operation in the event of high pressure or high temperature.

The shutdown of a compressor by safety devices is intended to prevent a potential compressor failure. If a compressor does not have sufficient lubrication or cooling, the internal parts will eventually overheat. If the compressor is permitted to run when starved of oil or refrigerant vapor, there will be unlubricated metal-to-metal contact with the pistons, scrolls, vanes, and valves. This unlubricated metal-to-metal contact could eventually create small metal chips in the refrigerant loop that further damage various internal components. Insufficient cooling can also cause motor windings to overheat. Overheating of motor windings may result in burnt-out or shorted windings and eventual motor failure within the compressor.

9.1.4 Compressor Protection Devices

There are several variables that should be monitored to ensure that a compressor is operating safely. Compressor protection devices installed into an HVACR system can monitor these variables and react before unsafe conditions can cause damage to a compressor. Important variables that a device may monitor include the following:

- Current draw on the compressor's motor.
- Head pressure.
- Temperature of the compressor dome.
- Temperature of the discharge line.

Overcurrent Protection

Motors and other current-drawing electrical devices require overcurrent protection. High current can damage conductor insulation and lead to a short circuit or a ground fault (short to ground). Since compressors generally use motors to produce the torque needed for operation, most compressors require some form of overcurrent protection. This is generally provided by circuit breakers or fuses. If something occurs that causes a motor to draw an abnormally high current level, a circuit breaker or fuse opens the circuit to stop the flow of electricity and prevent potential damage.

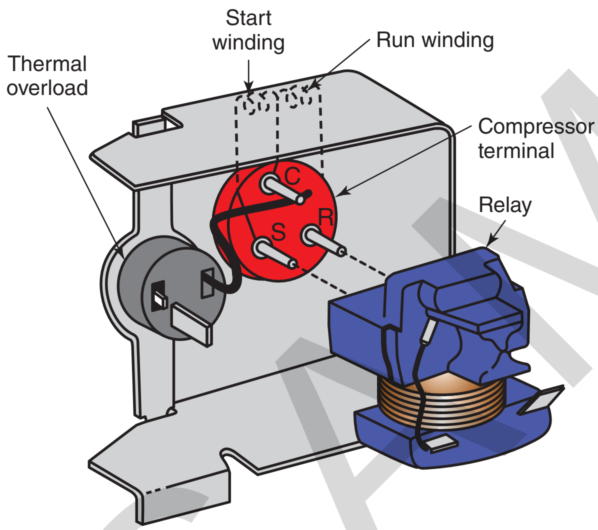
Compressor Overload Devices

Compressors may overheat due to internal problems, such as a lack of oil or shorted motor windings. They may also overheat due to system issues, such as head pressure that is too high due to a blocked or dirty condenser. To prevent compressor damage from overheating, a ***thermal overload*** opens the power circuit to turn off the compressor, **Figure 9-11**.

A thermal overload is a type of compressor protection device that is mounted to the compressor shell near the compressor motor terminals. Many use a bimetal disc that opens and closes a set of electrical contacts based on temperature. They open when exposed to too much heat and then reset when the heat falls to an acceptable level. A thermal overload is wired in series with the common terminal of the compressor, **Figure 9-12**.

Sealed Unit Parts Co., Inc.

Figure 9-11. This thermal overload is mounted to the shell of a compressor. It is connected in series with the compressor's common wire and opens the circuit when it senses dangerously high temperature.



Frigidaire

Figure 9-12. Compressor overload mounted to the shell of the compressor.

Pro Tip

Recurrent Trip Problem

A thermal overload reacts to the heat surrounding a compressor, not just the internal heat generated by the compressor. If a compressor is mounted in a closed-off area subject to high ambient conditions, it may trip regularly due to poor air circulation around the compressor. Always make sure that there is proper cooling airflow around a compressor when its thermal overload has tripped.

Some compressors also have internal overloads located within the compressor. These are usually wired into the motor windings at the manufacturer. They are designed to open when excessive current is sensed or under extreme temperatures. Most internal overloads will reset after the conditions return to normal. Some compressors also contain a reset button mounted to the shell of the compressor. The reset button requires the HVACR technician to manually reset the overload when it has tripped.

Pro Tip

Compressor Protection Devices

Compressor protection devices are designed to protect the compressor from an internal failure or inefficient operation. They should be viewed as a sign to the HVACR technician that something is wrong in the system, not just in the compressor. Never just replace an overload device or reset a tripped protection device. Always troubleshoot to determine the root cause that is forcing the protection device to trip off the system.

9.2 Metering Devices

Mechanical refrigeration and air-conditioning systems depend on a change of pressure as liquid refrigerant flows into the evaporator. Many different types of mechanical and electromechanical devices can be used to create this pressure difference in a system. These devices are referred to as *metering devices* and are installed between the liquid line and the evaporator.

A metering device provides a small opening, or ***orifice***, through which only a certain amount of refrigerant can flow at one time. As the system operates, a limited amount of the refrigerant is allowed to pass through the metering device into the evaporator. Since only a small amount of refrigerant is entering the evaporator, the refrigerant has room to expand and is at a low pressure. However, since only a small amount of refrigerant passes through the metering device, the refrigerant in the liquid line remains under high pressure. The metering device must allow just the right amount of refrigerant to pass to sustain this pressure difference.

There are many different types of metering devices. One of the simplest types of metering devices is the capillary tube. One of the more complex controls is the electronic expansion valve, which is controlled by a microprocessor. The most common types of metering devices are:

- Capillary tube (cap tube).
- Metering (fixed) orifice.
- Thermostatic expansion valve (TXV).
- Automatic expansion valve (AXV).
- Electronic expansion valve (EEV).
- Low-side float (LSF).
- High-side float (HSF).

Pro Tip

TXV and TEV, AXV and AEV, and EEV and EXV

Although the abbreviation TXV is used to refer to thermostatic expansion valves throughout this book, in the field you will find the abbreviation TEV may be used instead. Both abbreviations refer to the same type of valve. Similarly, the abbreviation AXV is used in this book to identify automatic expansion valves. In the field, you may encounter the abbreviation AEV used to describe the same type of valve. The same also applies to electronic expansion valves, which are indicated by the abbreviation EEV in this book. In the field, electronic expansion valves may also be identified by the abbreviation EXV.

Most metering devices fall under one of two categories: fixed or modulating. Fixed metering devices are the simplest type of metering devices. They have a fixed diameter passage through which the refrigerant must pass to enter the evaporator. These simple metering devices have few or no moving parts to fail. The two main types of fixed metering devices are capillary tubes and metering orifices. Capillary tubes are used extensively in refrigerators and window ac units. Metering orifices are frequently used in heat pumps and split air-conditioning systems. The rate of flow through fixed metering devices is relatively constant when the compressor is running.

Metering devices that can change their orifice size to account for changes in cooling loads are referred to as modulating metering devices. All types of expansion and float valves fall into this category. Because of their ability to change refrigerant flow based on load, these types of valves operate more efficiently than fixed metering devices. They are also better suited for use in an application that is subject to frequent or extreme changes in the cooling load.

9.2.1 Capillary Tubes

A ***capillary tube*** is a metering device consisting of a length of seamless tubing with a small and precisely formed inside diameter. This tube acts as a constant throttle on the refrigerant flow. Pressure decreases as the small diameter restricts the flow of liquid refrigerant through the tube. As the pressure drops, a small amount of the liquid starts to evaporate in the tube. The vapor that is produced by the drop in pressure is known as *flash gas*, and its formation provides a sudden drop in temperature in approximately the last quarter of the tube length. The refrigerant is cooled to evaporator temperature, and its pressure is reduced to evaporator pressure.

The performance of a capillary tube depends on the following variables:

- Tube length.
- Inside diameter.
- Number of turns.

The amount of restriction and resulting pressure drop is designed by the system manufacturer to provide the maximum cooling effect for the system. The length, inside diameter, and number of turns in the capillary tube determine how much the pressure drops between the condenser and evaporator. The longer the capillary tube, the greater the pressure drop. The smaller the diameter, the greater the pressure drop. Turns create friction as the refrigerant flows and create additional pressure drops. The more turns, the greater the pressure drop.

A capillary tube is usually attached between the evaporator and the liquid line. In some applications, a capillary tube serves the function of both the metering device and the liquid line. In such a case, it is connected between the evaporator and the condenser. If the distance between the evaporator and the liquid line or condenser is shorter than the required length of the capillary tube, a portion of the capillary tube can be coiled so that it fits. A fine filter or a filter-drier is usually installed between the liquid line or condenser and the capillary tube. The filter-drier helps prevent contaminants from entering and clogging the capillary tube, **Figure 9-13**.

A capillary tube can be installed so that a portion of it is in contact with the suction line. This allows the two tubes to act as a heat exchanger, in which the capillary tube transfers some of its heat to the cooler suction line through conduction. This heat transfer superheats the refrigerant in the suction line and subcools the refrigerant in the liquid line, which improves system efficiency.

Capillary tubes do not have check valves or directional control valves. Since the refrigerant is free to flow in either direction, the high-side and low-side pressures equalize when the compressor switches off. In a capillary tube system, since the compressor starts with equal pressures on the high and low sides, a high-torque motor is not required.

Because system pressures equalize when the compressor shuts off, a capillary tube system must not have an overcharge of refrigerant. Extra refrigerant tends to fill the evaporator too full. This causes the motor to work harder during start-up and also increases the risk that liquid refrigerant could be drawn into the compressor. Severe frosting of the suction line during compressor start-up indicates an overcharge.

Capillary Tube Capacities

Capillary tubes must be appropriately sized for their applications. The required length and diameter of the capillary tube are determined by the capacity of the compressor, the type of refrigerant being used, and the desired target temperature of the system.

The proper capillary tube size also depends on the type of condenser used in the application. Static condensers are condensers that do not have a fan. They depend on convection to cool the condenser. Static condensers are most often found in older domestic refrigerators. In general, systems with static condensers require a 10% longer capillary

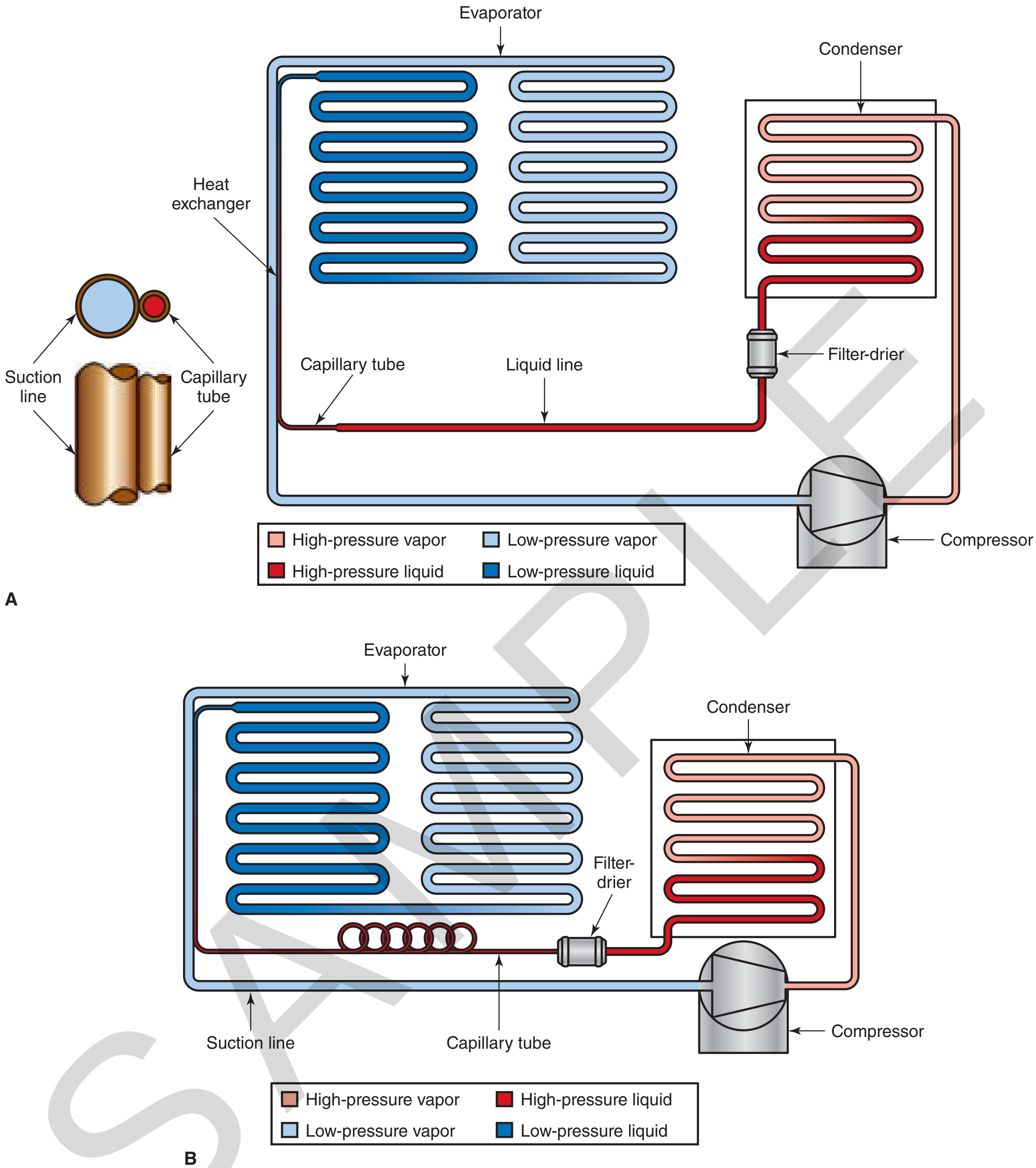
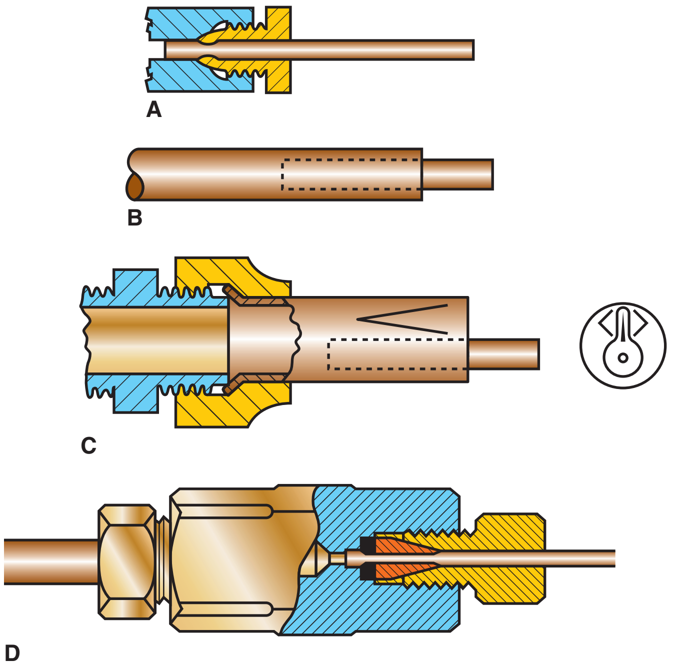


Figure 9-13. Two simple schematics of refrigeration systems that use capillary tubes. In both, a filter-drier is located ahead of the capillary tube. Also in both, part of the capillary tube is fastened to the suction line to function as a heat exchanger. A—The capillary tube is connected to the liquid line. B—In this system, the capillary tube serves as the liquid line. Part of the capillary tube is coiled due to its length.

tube than those with fan-cooled condensers because static condensers cannot remove heat as efficiently. Because different refrigerants have different pressure-temperature characteristics, the type of refrigerant used in a system also affects capillary tube sizing.

Capillary Tube Fittings

A capillary tube can be attached between the evaporator and the liquid line, condenser, or filter-drier with either brazed connections or fittings. If fittings are used, they must be leak proof and able to withstand vibration. **Figure 9-14** illustrates ways to make these connections.



A-1 Components Corporation

Figure 9-14. Some typical capillary tube connections. A—The capillary tube is connected to the liquid line with a special compression fitting. B—The capillary tube is brazed to the liquid line. C—The capillary tube is brazed to a short section of larger tubing, which is then connected to the liquid line with a standard flare fitting. D—This liquid line standard flare fitting is connected to a special capillary tube fitting.

Applications

Capillary-tube metering devices are usually used on small, fractional-horsepower, hermetic compressor systems that are charged with refrigerant by the manufacturer. These types of systems are commonly found in domestic refrigerators and freezers. The small hermetic compressors typically used in these appliances do not have the torque required to start up when the high side of the system is under pressure. The capillary tube allows the high-side pressure and low-side pressure of a system to equalize when the compressor is off, reducing the torque required to start the compressor.

The main advantage of the capillary tube is that it has no moving parts to wear out or stick. The most common cause of capillary tube failure is a bent, crimped, or plugged tube. Bending or crimping is usually the result of someone cleaning the condenser and accidentally hitting the capillary tube. Capillary tubes may become plugged due to wax buildup from overheated oil in the system or from compressor failures. When a capillary tube is replaced, it is a good practice to also install a new liquid line filter-drier. It is also important to replace the capillary tube with another capillary tube with the same length and inside diameter. The amount of refrigerant charge is critical in capillary tube systems. Overcharging or undercharging results in poor system performance.

Capillary tubes are inexpensive and work well on small hermetic systems. However, they do not control evaporator performance as precisely as expansion valves. Expansion valves alter refrigerant flow based on changes to system pressure and temperature. Capillary tubes have a fixed diameter and length, so the rate of flow remains fairly constant.

9.2.2 Metering Orifices

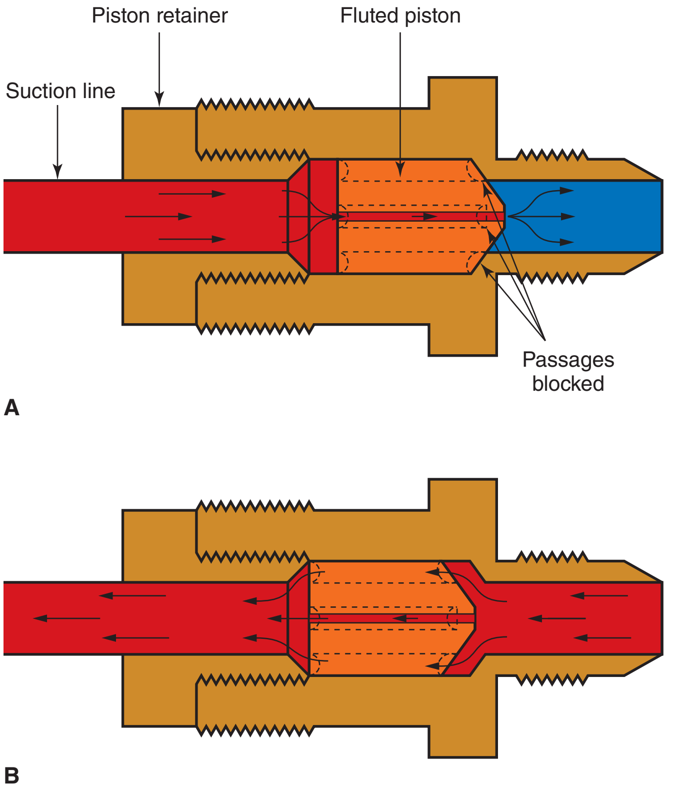
A ***metering orifice*** is a fixed-orifice metering device that consists of a fitting with a small hole, called an orifice, between the fitting's inlet and outlet. The orifice limits the amount of refrigerant that can pass through the fitting. This creates a pressure drop between the fitting's inlet and outlet. A metering orifice is installed between the condenser and evaporator and provides the pressure drop between the high side and low side of the system. It can be removed and cleaned for service.

The orifice must be correctly sized to produce the proper pressure drop for a given system. The refrigerant charge is also critical in a system with a metering orifice. These are frequently used in packaged air-conditioning units or split systems where the condenser, evaporator, refrigerant charge, and compressor sizes are determined by the system manufacturer.

The orifice size may need to be changed for units with long suction line sets to account for the extra refrigerant charge. Manufacturers often supply several metering orifices for air conditioners that may require on-site changes to the suction line length. This allows the technician to select and install the correct size based on the system's final design.

One type of metering orifice commonly used in heat pump applications has a sliding fluted piston with a small hole in it. The high pressure from the condenser pushes the piston against its seat, causing the device to operate like a normal metering orifice. When the refrigerant flow reverses for the heating mode, pressure is applied to the other side of the piston, causing it to slide to the center of the housing. This lifts the piston from its seat and allows refrigerant to flow through the flutes in the piston, which greatly increases refrigerant flow through the device, **Figure 9-15**.

Heat pumps often use two piston-type metering orifices installed between indoor and outdoor coils. One metering orifice meters refrigerant flow during the cooling mode and allows free flow during the heating mode. The other metering orifice meters refrigerant flow during the heating mode and allows free flow during the cooling mode. In other heat pump systems, a single piston-type metering orifice is used at the outdoor coil, and a TXV and check valve bypass line are used at the indoor coil.



Goodheart-Willcox Publisher

Figure 9-15. A piston-type metering orifice. A—In one mode, refrigerant flow pushes the piston into contact with its seat. The only path for refrigerant is through the bore in the center of the piston. B—During the other mode, refrigerant flow pushes the piston off its seat. Refrigerant can then flow through the flutes around the outside of the piston as well as through the bore in the center of the piston, eliminating any pressure drop.

Pro Tip

Metering Orifice Devices

Metering orifices are sometimes called fixed-orifice metering devices, flowraters, flow restrictors, accurators, pistons, or orifices. Be aware of the different names used across industry.

Thinking Green

Fixed Metering Devices

Because they are unable to adjust the refrigerant flow rate, fixed metering devices are less efficient than thermostatic expansion valves under varying load conditions. In many cases, the efficiency of older comfort cooling systems equipped with fixed metering devices can be dramatically improved by installing a thermostatic expansion valve.

9.2.3 Thermostatic Expansion Valves (TXVs)

A ***thermostatic expansion valve (TXV)*** is a type of expansion valve metering device that adjusts the refrigerant flow rate based on a superheat pressure signal from a sensing bulb at the evaporator's outlet. It is capable of adjusting the refrigerant flow rate to compensate for varying loads. TXVs are commonly used in large commercial refrigerators and many air-conditioning systems.

A thermostatic expansion valve has a sensing bulb mounted on the outlet of the evaporator. The *sensing bulb* is a sealed bulb connected to the thermostatic expansion valve by a capillary tube. The sensing bulb is filled with a volatile fluid, and pressure inside the bulb changes with the temperature at the evaporator outlet. The refrigerant flow rate through a thermostatic expansion valve is controlled by the combination of the system's low-side pressure and the pressure signal from the sensing bulb. The valve provides a high flow rate as the evaporator empties (warms) and reduces the flow as the evaporator fills with refrigerant (cools), **Figure 9-16**.

Thermostatic Expansion Valve Operation

A thermostatic expansion valve is operated by a pressure difference between the sensing bulb pressure and low-side (evaporator) pressure. See **Figure 9-17**. If the pressure in the sensing bulb (P_1) is greater than the combined pressure from the evaporator (P_2) and the spring (P_3), the valve is forced open. If the combined pressure from the spring (P_3) and evaporator (P_2) are greater than the sensing bulb pressure (P_1), the valve closes.

With the compressor running, there is a temperature difference in the refrigerant between the evaporator inlet (T_3) and outlet (T_2). This temperature difference is called superheat, and it represents the sensible heat (measurable temperature) absorbed by refrigerant vapor passing through the evaporator outlet. A TXV is designed to maintain a set and steady superheat value. The refrigerant temperature at the outlet (T_2) is usually about 10°F (5.6°C) warmer than the refrigerant temperature at the evaporator inlet (T_3).

The refrigerant temperature at the evaporator outlet (T_2) is sensed by the TXV's sensing bulb. The temperature sensed by the sensing bulb (T_1) determines the pressure in the sensing bulb (P_1). A change in the sensing bulb temperature (T_1) will cause a corresponding change in the sensing bulb pressure (P_1).

When a TXV system is operating normally, the thermostatic expansion valve is partially open and the sensing bulb pressure (P_1) exactly balances the pressure combination of the spring (P_3) and evaporator (P_2). This state is known as equilibrium. The thermostatic expansion valve will hold this position until the evaporator either warms or cools and pressures change.

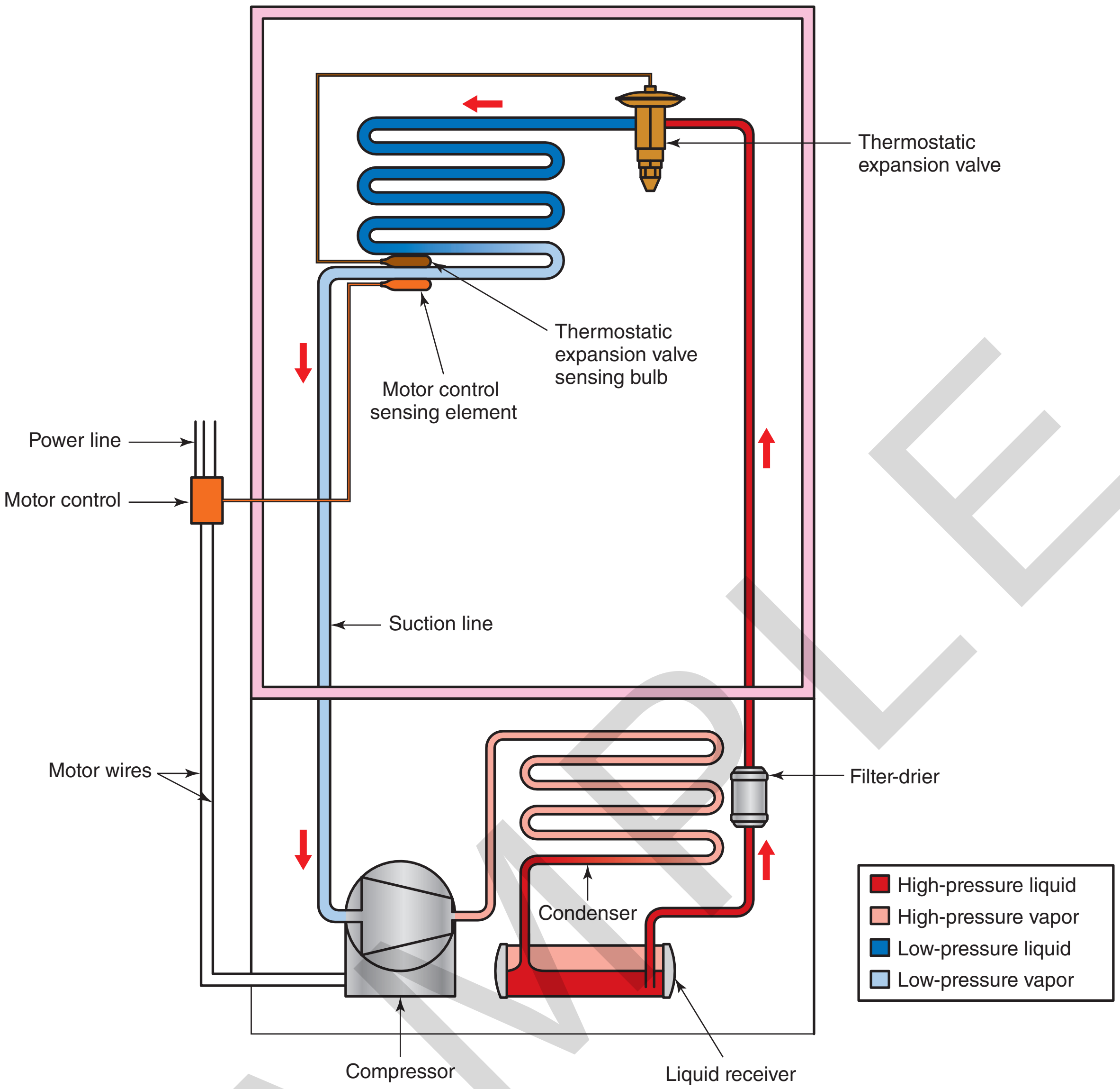


Figure 9-16. A thermostatic expansion valve (TXV) used in a simple refrigeration system. Note that the thermostatic expansion valve's sensing bulb and a motor control sensing element are both installed on the evaporator outlet.

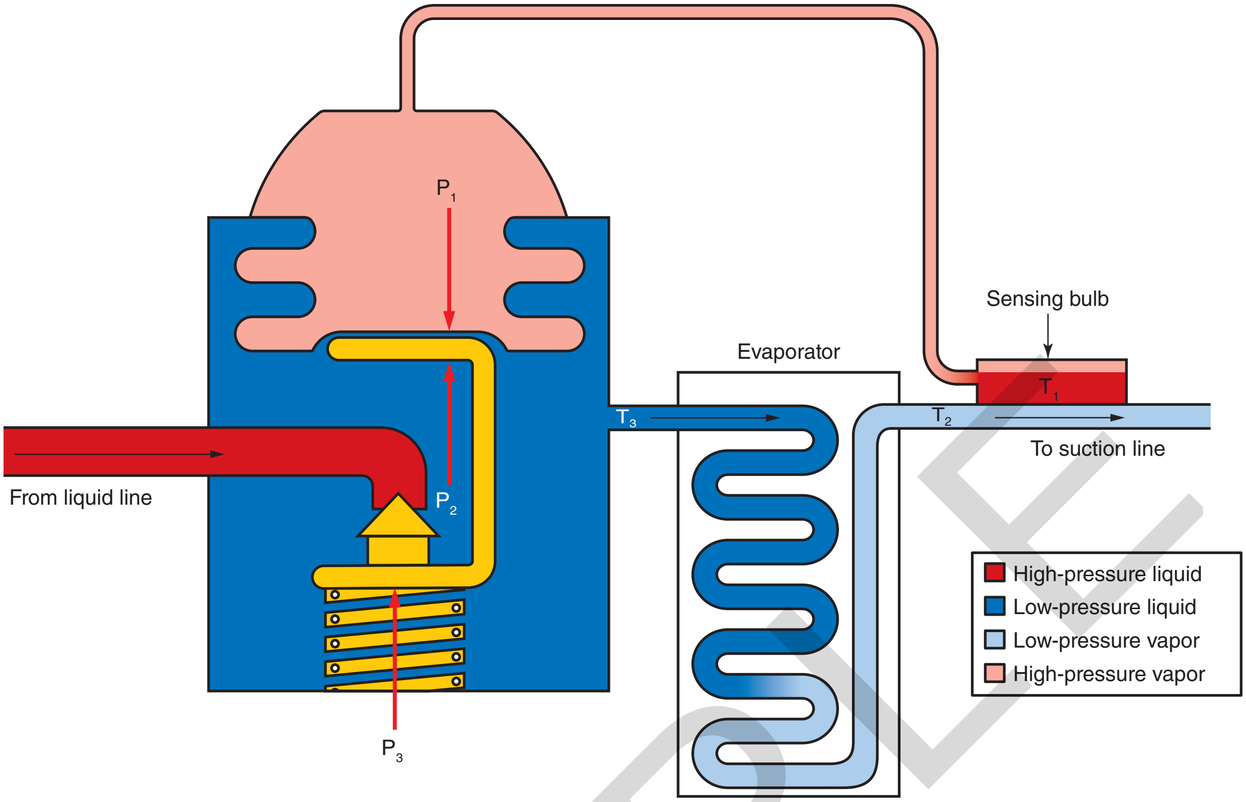
When the suction line temperature drops to the motor control's cut-off temperature, the motor control shuts down the compressor. With the compressor stopped, the sensing bulb pressure (P_1) and the low-side pressure (P_2) equalize. Since the sensing bulb pressure (P_1) and low-side pressure (P_2) cancel each other out, the spring pressure (P_3) is enough to force the valve firmly into its seat. Refrigerant flow stops. The valve will stay closed until the sensing bulb pressure (P_1) once again overcomes the low-side pressure (P_2) and spring pressure (P_3). This can only happen after the compressor is restarted and begins pumping down pressure in the evaporator (P_2).

In some TXV systems, high-side and low-side pressures do not balance during the Off cycle. Therefore, it is necessary to have a compressor that can start under load. On the other hand, some special TXVs are equipped with bleed ports or valves that do equalize pressure, allowing a lower-torque compressor motor to be used.

If a thermostatic expansion valve is adjusted correctly, it will close and remain closed whenever the compressor is idle. It will remain closed unless the evaporator is under reduced pressure, and the temperature is above normal. This prevents flooding of the low side with liquid refrigerant. A thermostatic expansion valve does not regulate the low-side pressure. It controls superheat by filling the evaporator with precise amounts of refrigerant. The pumping action of the compressor establishes low-side pressure.

9.3 Evaporators

Evaporators and condensers are the most common heat exchangers in HVACR systems. They can be categorized multiple ways and applied to systems to meet specific purposes. Many are built similarly (fins and tubes) and with the same types of materials (copper and aluminum) and even look similar to each other, **Figure 9-18**.



Goodheart-Willcox Publisher

Figure 9-17. A thermostatic expansion valve is operated by differences between the sensing bulb pressure and evaporator (low-side) pressure. P_1—Sensing bulb pressure acts to open the valve. P_2—Evaporator pressure acts to close the valve. P_3—Spring pressure acts to close the valve. The valve opens when P_1 is greater than combined force of P_2 and P_3. The valve closes when combined P_2 and P_3 forces are greater than P_1.

Lordan A.C.S. Ltd

Figure 9-18. A variety of evaporators and condensers for different applications.

There are two basic types of evaporators, as categorized by the medium they are designed to cool:

- Air-cooled evaporators are used to directly cool the air within a cabinet or other conditioned space.
- Liquid-cooled evaporators are used to cool a body of liquid that is then used to cool other substances. Liquid-cooling evaporators are more commonly used on commercial systems and will be discussed in later chapters.

Pro Tip

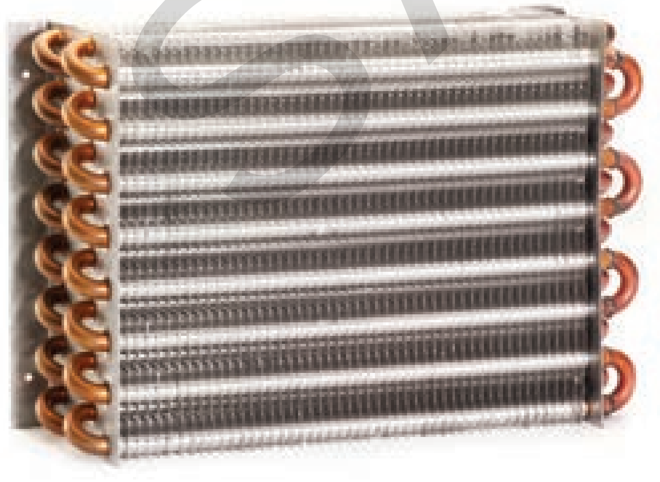
Heat Exchangers

A ***heat exchanger*** is any device in which heat is exchanged between two mediums. There are numerous types of heat exchangers in HVACR systems. Evaporators and condensers are common examples. They exchange heat between the air and the refrigerant within their tubing. Heating systems have much different heat exchangers that are based on their method of heat production.

9.3.1 Air-Cooled Evaporators

Air-cooled evaporators are evaporators that are designed to directly cool the air in a conditioned space. In a system with an air-cooled evaporator, air is the primary medium for cooling the conditioned space and its contents.

An air-cooled evaporator transfers heat from the air circulating over it to the refrigerant inside its tubing. As the warmer air comes in contact with the evaporator, the air molecules transfer some of their heat to the fins on the evaporator. This heat, in turn, is conducted through the fins to the tubing. The heat then passes to the liquid refrigerant inside the tubing, vaporizing and superheating it, **Figure 9-19**.



Blissfield Manufacturing

Figure 9-19. A fin-and-tube style air-cooling evaporator made of copper and aluminum.

Evaporators used in refrigeration systems can be further categorized into three groups, based on their use and case temperatures maintained:

- Low-temperature (–10°F to 28°F [–23°C to –2.2°C])—frozen foods, such as ice cream, frozen dinners, and frozen vegetables.
- Medium-temperature (28°F to 40°F [–2.2°C to –4.4°C])—fresh foods, such as eggs, vegetables, and lunch meat.
- High-temperature (40°F to 60°F [–4.4°C to –15.5°C])—perishables, such as flowers, candy, and cakes.

Low-Temperature Applications

Evaporators used in low-temperature applications, such as commercial freezers, continuously build up frost when the compressor is operating. As the frost grows thicker on an evaporator coil, it reduces the heat transfer between the refrigerant in the evaporator and the ambient air. Frost acts as a thermal insulator, reducing cooling capacity. Since the system has a cut-in temperature below freezing, the frost that builds up on the evaporator will not melt during the Off cycle.

Heat must be applied to low-temperature evaporators for defrosting. Otherwise, the refrigeration system would need to be left off until the temperature of the air in the conditioned space could rise above freezing and melt the frost. Therefore, evaporators used in low-temperature applications must be equipped with some form of defrost system.

Medium-Temperature Applications

In a medium-temperature application, the evaporator operates at temperatures below 32°F (0°C). This causes frost to accumulate on the evaporator. However, after the compressor shuts off, the evaporator coil may warm up above 32°F (0°C). The frost then melts, even without the aid of a defrost system.

The process of allowing the heat from the air in the conditioned space to melt the frost from the evaporator coils is called ***air defrosting***. It clears the evaporator surfaces of frost, restoring efficient heat transfer. It also keeps a high relative humidity (about 90% to 95%) in the conditioned space. However, this approach requires a relatively small temperature difference between the evaporator and the air in the cabinet. Since the temperature difference between the evaporator and the conditioned air is small, the evaporator must be larger to produce the same amount of cooling.

Evaporators in medium-temperature applications may occasionally have trouble getting rid of moisture. After frost near the top of the evaporator melts, it flows downward over the rest of the evaporator surface. Sometimes, before this moisture can drain away, it freezes around the lower part of the evaporator. This ice accumulation on the evaporator fins may eventually block air circulation around the evaporator. Such blockage interferes with proper refrigeration.

High-Temperature Applications

Evaporators in high-temperature applications operate at temperatures above 32°F (0°C). Frost, therefore, does not normally form on the evaporator. Occasionally, the evaporator may frost up slightly just before the compressor shuts off. However, this frost quickly melts during the Off cycle. Since the evaporators do not frost over, they remove little moisture from inside the cabinet. Therefore, a relative humidity of 75% to 85% is maintained in these cabinets. This helps to keep produce fresh and stops shrinkage weight loss.

Natural-Draft and Forced-Draft Evaporators

In addition to their operating temperatures, evaporators can be further categorized based on their means of circulating conditioned air. There are two main subclasses of air-cooling evaporators:

- Natural draft.
- Forced draft.

A *natural-draft evaporator* is an evaporator that depends on gravity for air circulation. ***Gravitational circulation*** occurs because cold air is denser than warm air and sinks below the warmer, less dense air. Hot air rises as cold air falls.

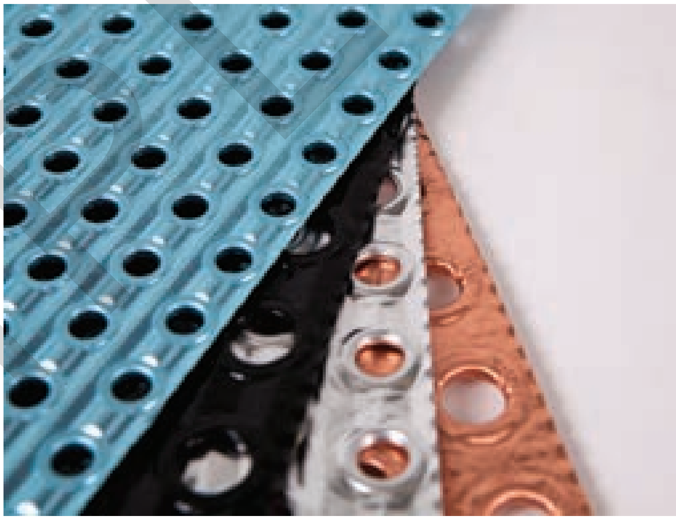
A *forced-draft evaporator* is an evaporator unit equipped with a fan. The fan blows air over the evaporator coil's compact arrangement of refrigerant-cooled tubes and fins. The evaporator coil and fan are usually enclosed in a metal housing.

9.3.2 Fin-and-Tube Evaporators

The major types of air-cooled evaporator construction are fin-and-tube, plate, and microchannel. The most widely used and recognized is the fin-and-tube style of evaporator. ***Fin-and-tube evaporators*** have metal fins of various styles and types connected to the evaporator tubing. These evaporators are available in different arrangements. The parts most commonly varied are the fins, fittings, and tubing. Materials vary as well for different applications. Some common combinations of materials used include copper tubing with aluminum fins, copper tubing with copper fins, and steel tubing with aluminum fins (for ammonia R-717), **Figure 9-20**.

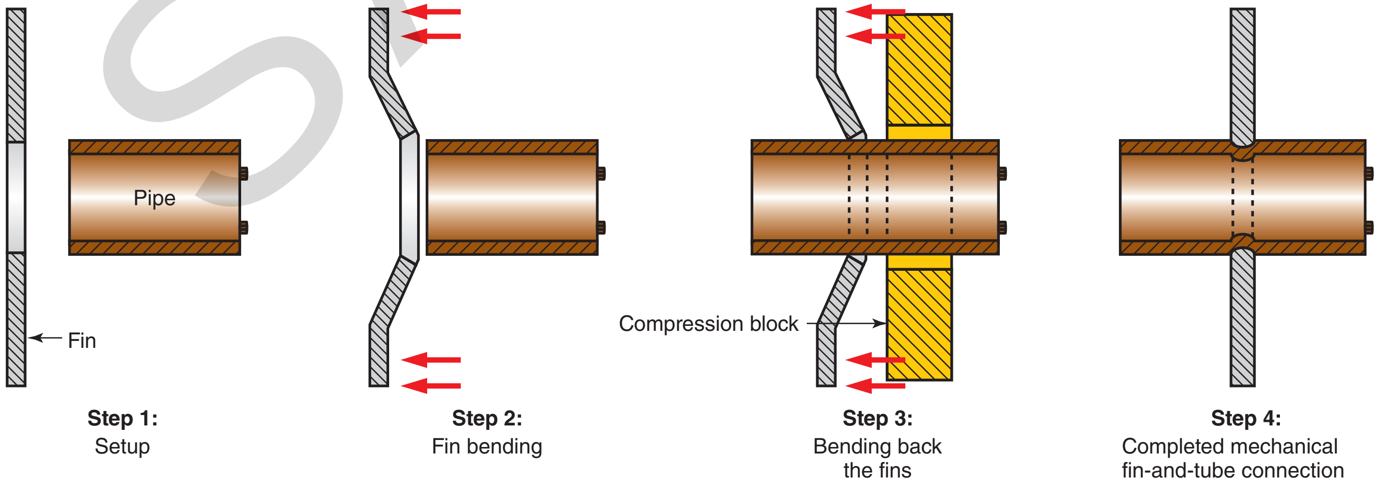
Fin Arrangements

Various methods are used to bond evaporator fins to the evaporator tubing. Some manufacturers attach the fin to the tubing with a press fit, **Figure 9-21**. Another method of bonding tubing to off-center fins is shown in **Figure 9-22**. Flanging can be used to automatically space fins, as shown in **Figure 9-23**.



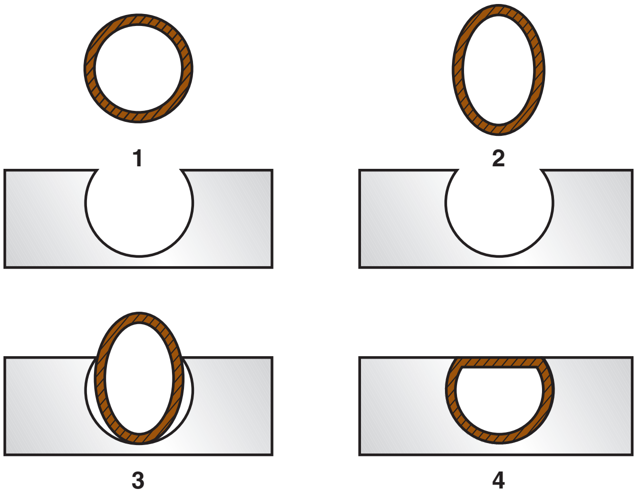
Lordan A.C.S. Ltd

Figure 9-20. Evaporator fins can be made of different material based on the needs of a given application.



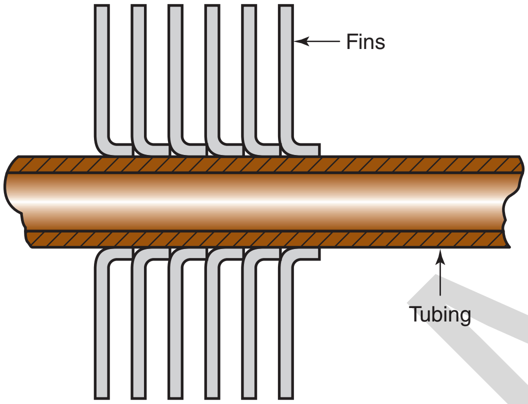
Goodheart-Willcox Publisher

Figure 9-21. One method of mechanically bonding evaporator fins to tubing involves dishing the fins to expand the fin hole for the tubing. After the tube is inserted, a mandrel is used to flatten the fin so it firmly pinches the tubing.



Peerless of America, Inc.

Figure 9-22. Mechanically bonding tubing to off-center fins. 1—Original tubing and fin. 2—Tubing is formed into an elliptical shape. 3—Tubing is inserted into the fin opening. 4—A fixture holds the fins while the tube is pressed into the same shape as the fin openings.



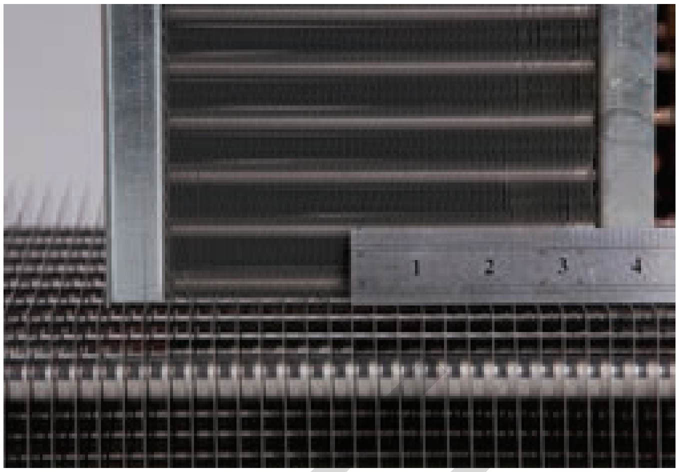
Goodheart-Willcox Publisher

Figure 9-23. Flanged fins mounted on a section of tubing. The flanges determine the fin spacing.

Fin spacing varies between 1/2″ and 1 1/2″ (1 cm and 4 cm) for natural-draft evaporators and 1/16″ to 1/4″ (2 mm and 6 mm) for forced-draft evaporators. The spacing impacts the number of fins that can be used and the amount of surface area exposed to the air that is being cooled. A manufacturer can adjust the cooling ability of an evaporator by changing the spacing and number of fins in the design. Adding more fins increases the exposed surface area and results in greater cooling ability, **Figure 9-24**.

Tubing Arrangements

Some evaporators have one continuous piece of tubing, and others have bends brazed to straight lengths of tubing. Many evaporators are composed of individual refrigerant circuits that run in parallel with each other. Each refrigerant circuit is fed from a distributor attached to the outlet of the metering device, and each circuit feeds into a suction line header. This design evenly distributes heat



Lordan A.C.S. Ltd

Figure 9-24. Fin space differs for heat exchangers based on its application. Since evaporators run the risk of becoming blocked with frost or ice buildup, they cannot always have fins as close together as condensers, which have no risk of frosting.

absorption throughout the evaporator and reduces pressure drop across the evaporator, **Figure 9-25**.

Some evaporator manufacturers use special designs inside the tubing. These inner designs may be incorporated to increase the surface area contact between the tubing and the refrigerant. Other designs are intended to swirl the refrigerant. This improves heat transfer from the circulating air to the boiling refrigerant and helps the refrigerant carry oil.

Baffles

Baffles are surfaces in and along air ducts that direct airflow through the evaporator and throughout the cabinet. They are designed to guide forced air all around the

Lordan A.C.S. Ltd

Figure 9-25. By connecting headers and return bend connectors in different ways, the refrigerant circuit can be shorter, longer, or designed for specific applications.

interior of the conditioned area. This eliminates dead air spots or areas where warm air can collect.

Any horizontal baffle or drain pan should be insulated. The top surface may be in contact with cold air. The under part of the baffle may be in contact with relatively warm air. If the baffle were not insulated, this temperature difference could cause condensation. ***Eddy currents*** (small circular flows of air) would also disturb airflow in the cabinet.

Multiple-baffled evaporators often circulate air using natural drafts. The air flows around the cabinet because of the weight differences of the cold air and the warm air. Warm air is lighter and, therefore, rises in the box. This natural circulation must not be blocked, or the cabinet temperature will not be constant. Baffling the evaporators promotes and accelerates this natural circulation of the air. Baffles may also serve as drain pans.

Fitting Arrangements

Many evaporators are equipped with fittings that are used to connect tubing to the evaporator. In some cases, an external female nut is placed on the tubing before it is flared. Some manufacturers use a male flare fitting brazed to the end fin. **Figure 9-26** shows the two types of evaporator fittings.

Pro Tip

Residential Air-Conditioning Evaporators

Most residential air-conditioning evaporators are direct expansion and forced-draft type. Construction is generally fin-and-tube. A blower fan circulates air through the fins where heat is absorbed from the air into the refrigerant within the tubing. Many evaporators for air conditioning applications are A-coil evaporators, **Figure 9-27**.

9.3.3 Plate Evaporators

Plate evaporators are heat exchangers fabricated from two metal sheets, welded together, that form a series of passages through which refrigerant flows. Plate evaporators can be designed for use as forced-draft evaporators or can be used as natural-draft evaporators, as seen in some domestic refrigerators and freezers. A serpentine flow configuration provides high internal flow velocities and high heat transfer rates, **Figure 9-28**.

9.3.4 Microchannel Evaporators

Microchannel evaporators are more compact and efficient than fin-and-tube evaporators. ***Microchannel*** describes a

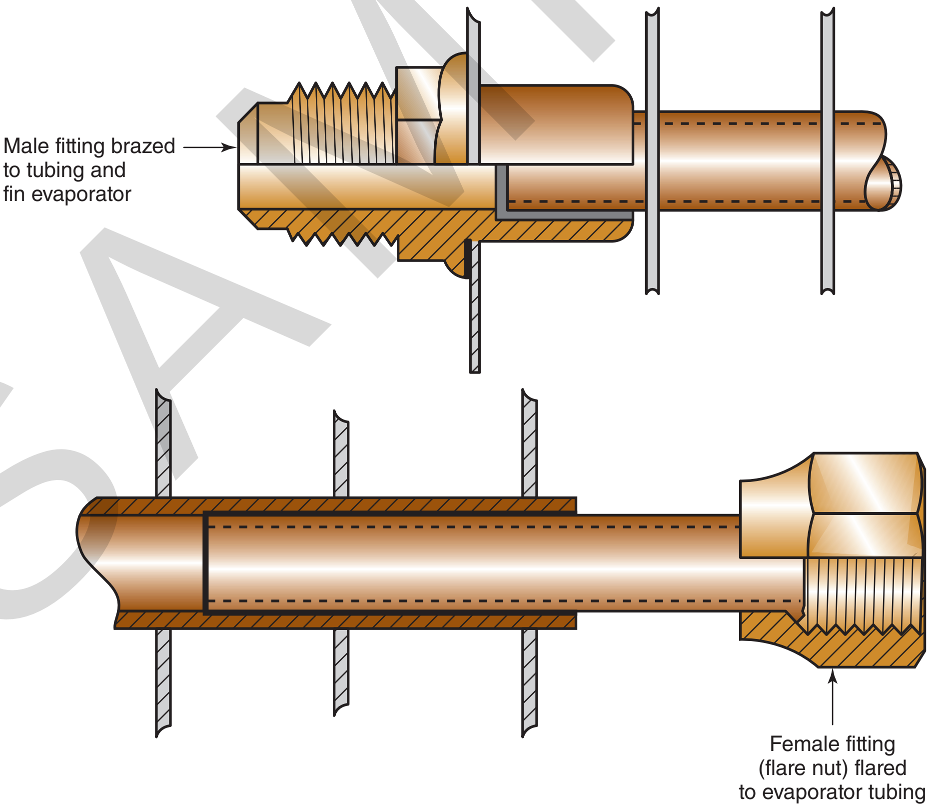


Figure 9-26. Fittings used to attach refrigeration lines to an evaporator.

Figure 9-27. The evaporator in this upflow residential air handler is a modified A-coil. The lengths of return bends along the side indicate the location angles of the refrigerant coils.

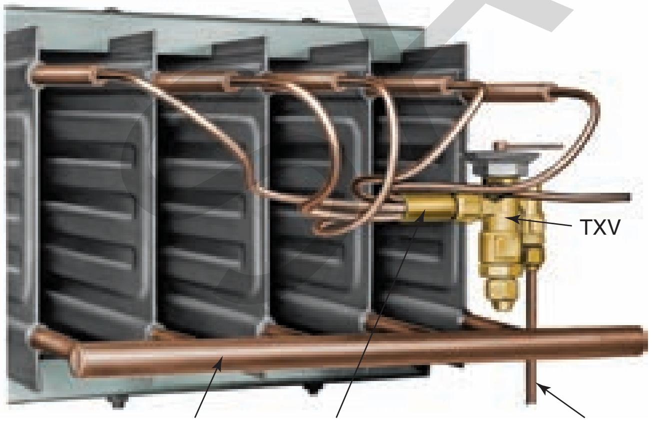


Figure 9-28. A serpentine coil plate evaporator.

construction in which fluid passages are less than 1 mm in diameter. These small refrigerant passages are surrounded by tightly packed fins that further increase surface area for efficient heat transfer.

Microchannel evaporators are made of extruded aluminum to create small passages through a flat tube as shown in **Figure 9-29**. Refrigerant flows through the header and into the small holes in the tubes. By using flat tubes, the microchannel evaporator has more tube surface contacting the fins. This improves conduction. There is also a greater number of fins per square inch, which improves convection, **Figure 9-30**.

Microchannel evaporators are up to 30% more efficient than the traditional copper fin-and-tube evaporators, so their size can be relatively small for the same cooling capacity as fin-and-tube. The use of lightweight aluminum is also a benefit of this design, **Figure 9-31**.

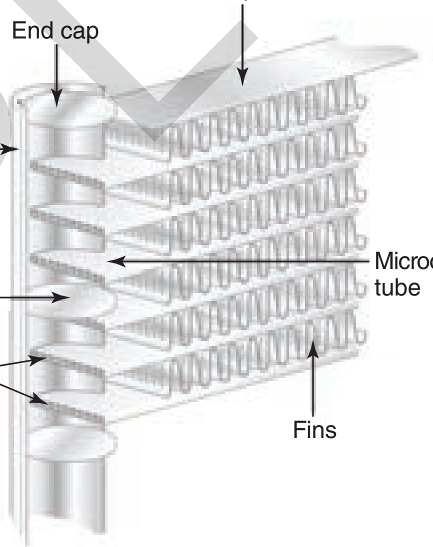
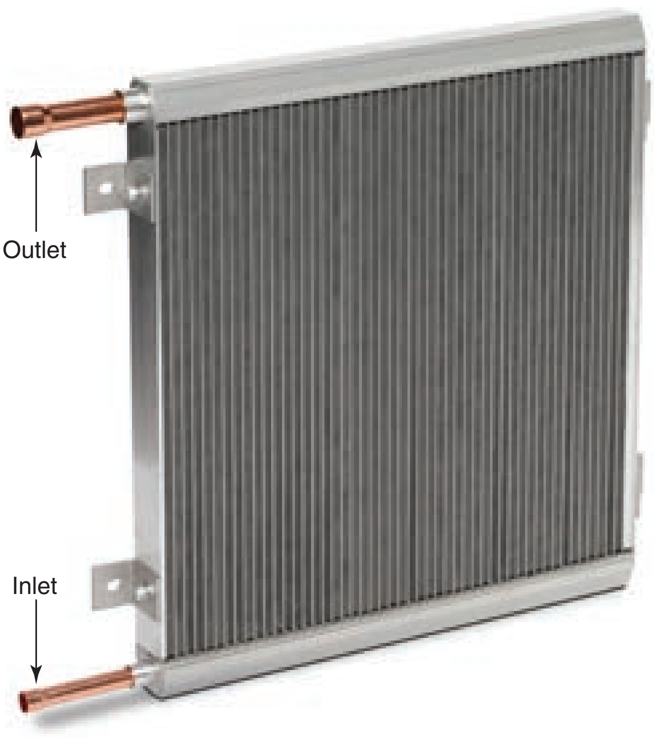


Figure 9-29. Note the small refrigerant passages in this microchannel evaporator.

Figure 9-30. Cutaway of microchannel evaporator tubes and fins. Tightly packed fins provide increased convection.



Alcoil

Figure 9-31. A flat panel microchannel evaporator.

9.4 Condensers

While an evaporator is designed to absorb unwanted heat, a condenser is designed to expel unwanted heat. High-temperature, high-pressure vapor refrigerant enters the condenser from the discharge line of the compressor. Heat is rejected from the refrigerant as it flows through the condenser. This causes the refrigerant to change state from a vapor to a liquid. As it continues to lose heat, its temperature drops somewhat. As the refrigerant exits the condenser, it is a warm, high-pressure liquid. The job of the condenser is to release the heat that was absorbed from the conditioned space. Condensers operate under much higher pressure than evaporators, so they are built with stronger tubing.

There are three basic types of condensers: air-cooled, water-cooled, and evaporative. Water-cooled condensers use various tube designs and arrangements. Evaporative condensers spray water over the condenser tubes to cool them down. Water-cooled and evaporative condensers are more commonly used in commercial systems and will be discussed in later chapters.

Air-cooled condensers are condensers that use the air movement of either natural convection or forced drafts to remove heat from a system's refrigerant. These are quite common in residential and commercial systems. Most air-cooled condensers are located outside. Outdoor air-cooled condensing units may be mounted on the roof, on the outside wall, or at ground level, **Figure 9-32**.

dotspencer/Shutterstock.com

Figure 9-32. Two outdoor condensing units installed at a residence.

Condensers for residential systems vary by manufacturer. Many are air-cooled condensers. Traditionally, these are square, rectangular, or cylindrical. A cooling fan mounted in the center beneath a grille draws air in through the sides of the condenser and expels it upward and out. Louvers, cages, or other structures protect the tubing and fins from damage, **Figure 9-33**.

Newer residential condensers are available in different designs, such as the slim stack, as seen on some ductless split air-conditioning systems, **Figure 9-34**. The size and shape of these condensers varies by model.

Tempstar

Figure 9-33. Air-cooled condenser for a residential air-conditioning application using a cage design to protect the tubing.

Fujitsu General America, Inc.

Figure 9-34. A slim-stack air-cooled condenser.

Emerson Climate Technologies

Figure 9-35. Clear canister liquid line filter-drier shows that it uses compacted beads as a desiccant.

9.5 Other Basic System Components

In addition to the four primary components (compressor, metering device, evaporator, and condenser), residential refrigeration and air-conditioning systems include a variety of other components. The following sections introduce three common components: liquid line filter-drier, sight glass, and service valves. Other system components are discussed in later chapters.

9.5.1 Liquid Line Filter-Driers

The efficient operation of an HVACR system depends greatly on the internal cleanliness of the refrigerant circuit. Only clean, dry refrigerant and clean, dry oil should circulate in the system. All impurities, such as dirt and water, must be removed. Contaminants must be trapped in some part of the system where they cannot do harm. Devices used for removing moisture and devices used for removing contaminants may be in separate cylinders; however, they are often built into a single cylinder (called a filter-drier) that filters and adsorbs, **Figure 9-35**.

Adsorption is the ability to collect and retain gas or vapor substances on the surface of a solid or liquid in a condensed layer through physical attraction and capillary action. Enough drying material must be used for both the high and low moisture ranges.

Filter-driers are usually installed in the liquid line. Disposable filter-driers are used in systems 20 tons and less. Systems over 20 tons use canister style filter-driers with replaceable cores. Sizing of a drier is based upon the capacity rating of a system.

A filter-drier should be replaced any time the system is opened for service. For large systems, it is recommended that the filter-drier be replaced yearly or when opened for service.

Cleaning a refrigeration system involves four basic tasks:

- Removing moisture.
- Removing acid.
- Filtering out circulating solids.
- Measuring when the drying job is completed.

Filter-driers perform the first three tasks. A moisture indicator is required for the fourth.

All filter-driers use screens or strainers to trap solids in the refrigerant. There are several types of screens or strainers. They are usually made of bronze, brass, stainless steel, or Monel wire.

Filter materials vary and may include felt, wool batt, and processed coarse cotton yarn wound in a diamond pattern over a metal frame. Some filters make use of powdered metal pressure castings.

A conventional straight-through filter-drier is a cylinder made of brass, copper, or steel. The drier is filled with a desiccant chemical, such as activated alumina, silica gel, or zeolite. These chemicals can adsorb 12% to 16% of their weight in water. Both ends of a filter-drier's cylinder usually contain filter elements. The end caps are fitted with either flare or soldered connections.

Refrigerant with safe amounts of moisture avoids many problems in the system. Experience shows that corrosion, oil breakdown, and motor burnouts are almost eliminated if filter-drier manufacturer guidelines are followed. Indicators of when a filter needs to be replaced include:

- A moisture indicator shows high moisture content.
- A pressure drop across the filter (as indicated by bubbles in the sight glass or a temperature drop as measured across the filter).
- A main component of the system, such as the compressor, has been replaced.
- The refrigerant circuit is opened, such as when an expansion valve is replaced.

9.5.2 Sight Glasses

A ***sight glass*** is a small viewport installed in a refrigerant line. It allows an HVACR technician to visually inspect the circulating fluids (refrigerant or oil) in a system. A sight glass is usually installed in a commercial refrigeration system's liquid line. In some cases, if a system is low on refrigerant, bubbles can be seen through the sight glass.

Pro Tip

Sight Glass Bubbles

Bubbles in a sight glass do not always indicate a shortage of refrigerant. When a system starts or stops, a sight glass may show a few bubbles. These are normal equalizing actions and do not indicate a shortage of refrigerant. Bubbles may also appear if the compressor is partially unloaded or if there is a restriction in the line ahead of the sight glass, such as a partially clogged filter-drier.

Most sight glasses have long extensions that allow the connections to be brazed without damage to the sight glass. Some liquid line filter-driers have a sight glass built into their outlets. Although sight glass connections are typically limited to diameters under 2 1/2″, they can still be used in systems that have a liquid line with a larger diameter. This is done by installing smaller-diameter tubing and a sight glass parallel to the liquid line, as shown in **Figure 9-36**. If there are bubbles in the liquid line, some of them will be diverted through the smaller tubing and sight glass.

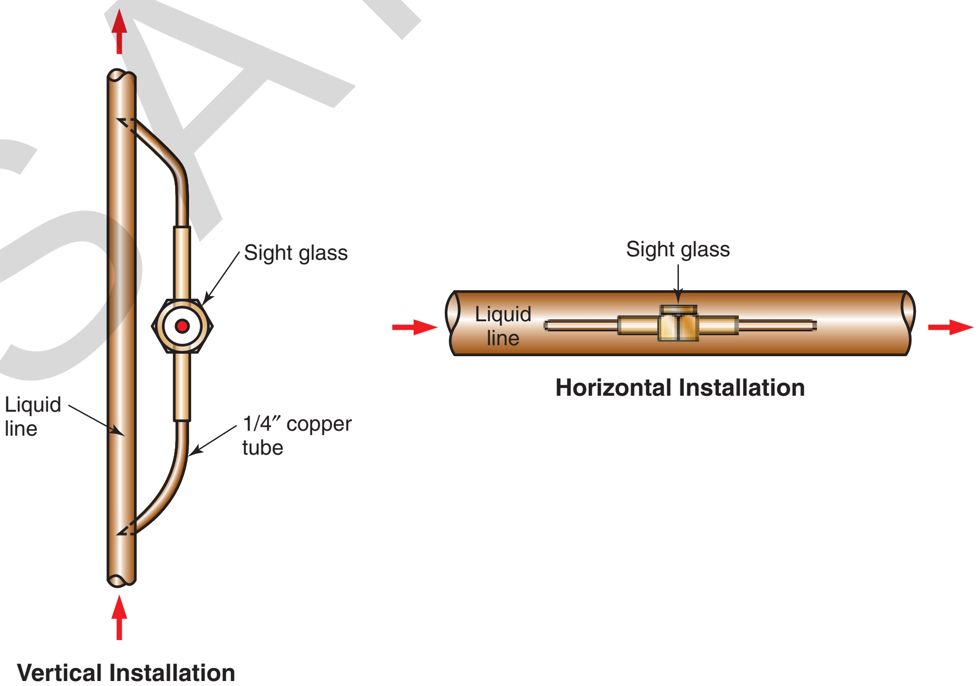
A ***moisture indicator*** is a sight glass with a color-changing element that is used to indicate a system's moisture content. The color-changing element changes color based on the amount of moisture in the refrigerant. Some types of moisture indicators undergo a single color change when the moisture in the refrigerant exceeds a maximum limit. Another type of moisture indicator changes color progressively based on the moisture content of the refrigerant. See **Figure 9-37**.

Pro Tip

Oil and Moisture Indicators

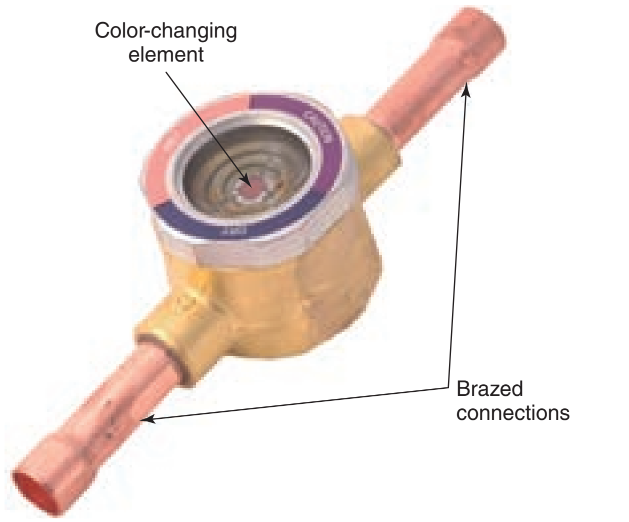
Circulating refrigerant oil can turn a moisture indicator tan. Flushing the indicator with clear refrigerant will remove the color. However, if the indicator continues to turn tan, the system has too much oil.

While most moisture indicators are the in-line style that are installed as part of the main liquid line, they may also be socket types attached to liquid receivers or other pressurized vessels. Moisture indicators are often installed just after the filter-drier in the liquid line, **Figure 9-38**.



Goodheart-Willcox Publisher

Figure 9-36. A sight glass installed in smaller tubing that is parallel to the larger liquid line. Connections are usually brazed.



Emerson Climate Technologies

Figure 9-37. A moisture indicator that changes color progressively from blue, to purple, to pink as the moisture content of the refrigerant increases.

Caution

Color Codes

Moisture indicators made by different manufacturers may have varying color codes for indicating moisture in a system. Be certain to check the manufacturer's specifications. With some moisture indicators, the words "wet" or "dry" appear when the chemical in the indicator changes color.

Pro Tip

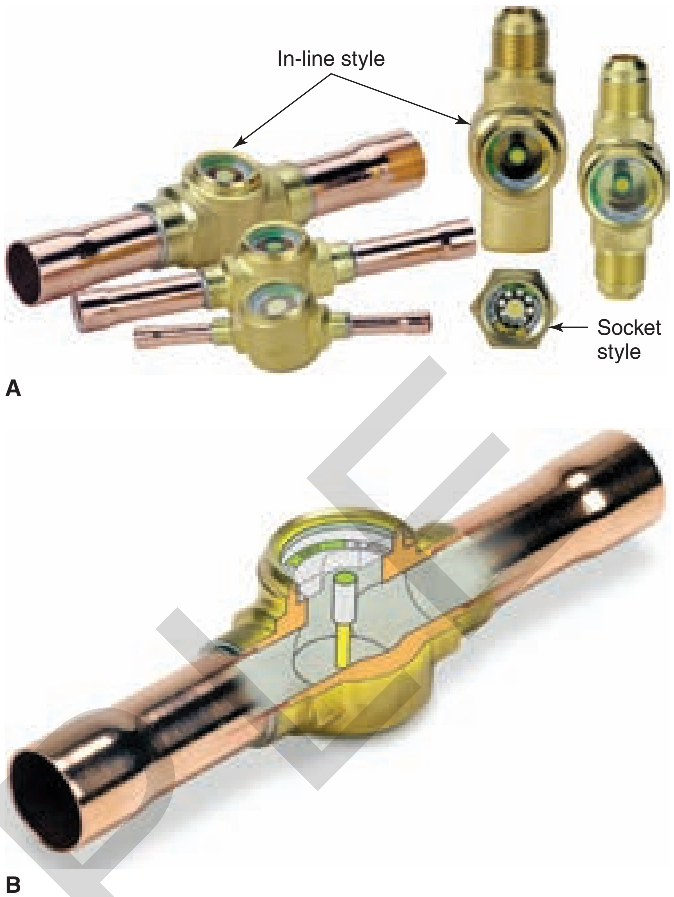
Temperature and Moisture Indicators

The higher the liquid refrigerant temperature, the higher the moisture content needed to produce a color change in a moisture indicator. An indicator, if hot, can show a "dry" condition even though the system has too much moisture. Refer to the sight glass manufacturer's resources for specific information about the effect of ambient temperature on color indicators.

9.5.3 Service Valves

Service valves enable technicians to seal off parts of a refrigeration and air-conditioning system and provide a connection to the system for taking pressure readings, adding or removing refrigerant or oil, and other service work. Several types of service valves are available, **Figure 9-39**. Larger service valves may have handwheels on their valve stems, but most valve stems are made so that a refrigeration service valve wrench is needed to turn them. Valve bodies are usually made of drop-forged brass, and valve stems are made of steel or brass. Packing and a packing nut are installed around the valve stem to keep it from leaking.

Service valves are fastened to tubing or pipe using flared or brazed connections. They may also be attached by pipe threads or bolted flanges. Most systems have service valves installed in the suction and discharge lines at the compressor. Many systems are also equipped with additional service valves, such as a service valve at the outlet of the liquid receiver (king valve) and the inlet of the receiver (queen valve). See Chapter 11, *Equipment and Instruments for Refrigerant Handling and Service*, for additional information about service valves.



Danfoss

Figure 9-38. A—Moisture indicators are often available with flare or brazed connections. B—In-line moisture indicator cutaway.

Sporlan Division – Parker Hannifin Corporation

Figure 9-39. Service valves typically installed on a residential air-conditioning system.

Chapter Review

SUMMARY

9.1 Compressors

- Compressors are driven by an electric motor, which may be mounted outside the unit or inside its housing. Compressors driven by an external source of mechanical power are called open-drive compressors. Hermetic compressors include an integrated drive motor in a sealed unit.
- There are three basic types of compressors used in residential refrigeration systems: reciprocating, rotary, and scroll.
- A reciprocating compressor functions by changing the rotational movement of a crankshaft into the reciprocating motion of the pistons within cylinders.
- The two types of rotary compressors are the rotating-vane and the stationary-blade compressors.
- A scroll compressor consists of two intertwined scrolls. One scroll is fixed, and the other scroll orbits around the center of the fixed scroll. Pockets of refrigerant are captured between the scrolls and are compressed as the movable scroll orbits. The compressed refrigerant is discharged from the center of the scrolls.
- Compressors are mechanical devices that require lubrication and cooling for safe and efficient operation. Safety devices are used to ensure clean oil at proper levels and sufficient vapor flow for cooling.
- Compressor protection devices stop operation based on the monitoring of several variables: current on the compressor motor, head pressure, temperature of the compressor dome, and temperature of the discharge line.
- Overcurrent protection for compressors is available in the forms of fuses, circuit breakers, and internal overload devices. Thermal overloads protect compressors from high internal and ambient temperatures.

9.2 Metering Devices

- Metering devices restrict refrigerant flow from the liquid line into the evaporator maintaining the proper pressure drop between the high side and low side of an HVACR system.
- Fixed metering devices have a fixed diameter passage through which the refrigerant must pass to enter the evaporator. Modulating metering devices can change their orifice size to account for changes in cooling loads.
- Capillary tubes consist of a length of seamless tubing with a small and precisely formed inside diameter to decrease refrigerant pressure.
- A metering orifice is installed between the condenser and evaporator and provides the pressure drop between the high side and low side of the system. It can be removed and cleaned for service.
- Thermostatic expansion valves (TXVs) adjust to changes in low-side pressure and evaporator temperature to maintain a predetermined superheat.

9.3 Evaporators

- Air-cooled evaporators are designed to cool the air circulating through a conditioned space. They can be either natural-draft or forced-draft.
- There are three main types of air-cooling evaporator construction: fin-and-tube, plate, and microchannel. Fin-and-tube is the most widely used.
- Plate evaporators consist of sheets of metal welded together to form passages for refrigerant flow.
- Microchannel evaporators consist of fin arrangements attached to tubes with numerous refrigerant passages that are less than 1 mm in diameter.

9.4 Condensers

- Condensers can be air-cooled, water-cooled, or evaporative.
- Air-cooled condensers use the air movement of either natural convection or forced drafts to remove heat from a system's refrigerant. Many residential condensers are air-cooled and come in various designs.

9.5 Other Basic System Components

- Liquid line filter-driers are installed between the liquid receiver (or condenser if the system does not include a liquid receiver) and the metering device.
- A sight glass is a small viewport in a refrigerant line used to visually inspect the circulating fluids in a system. A moisture indicator is a sight glass that changes color based on the moisture content of the refrigerant.
- Service valves are manual valves that provide a connection to a system so that technicians can take pressure readings, charge the system, or evacuate the system.

REVIEW QUESTIONS

9.1 Compressors

1. _____ compressors cannot be serviced without cutting open the shell, which is why they are considered "throw-away" compressors.
   A. Fully welded
   B. Semi-hermetic
   C. Open-drive
   D. Reciprocating
2. Reciprocating compressors are classified by all of the following, *except* _____.
   A. cylinder arrangement
   B. number of cylinders
   C. price
   D. construction
3. Which of the following statements regarding rotary compressors is *not* true?
   A. Rotary compressors have low volumetric efficiency.
   B. Vapor compression takes place between the cylinder wall and side of an off-center rotor.
   C. Rotary compressors are commonly used to power window air conditioners.
   D. Check valves are used to prevent backflow of refrigerant during the Off cycle.
4. Which of the following statements regarding scroll compressors is *not* true?
   A. Scroll compressors operate with continuous suction and discharge, resulting in a very smooth compression cycle.
   B. In a scroll compressor, vapor is compressed by a series of pistons that travel in a spiral pattern through a fixed scroll.
   C. Compressed vapor is discharged from the center of the scroll.
   D. Scroll compressors produce low noise and low vibration levels.
5. To prevent damage to the mechanical parts of a compressor, it should only be pumping _____ from the low to high side.
   A. contaminant-free oil
   B. filtered water
   C. liquid refrigerant
   D. vapor refrigerant
6. Compressor overcurrent protection may be provided by the following devices, *except* for _____.
   A. accumulators
   B. circuit breakers
   C. fuses
   D. internal overload devices
7. A thermal overload monitors _____ and turns off the compressor when levels are too high.
   A. crankcase pressure
   B. discharge line pressure
   C. discharge line temperature
   D. temperature of the compressor and ambient air

9.2 Metering Devices

8. The simplest type of the following metering devices is the _____.
   A. thermostatic expansion valve
   B. automatic expansion valve
   C. low-side float
   D. capillary tube
9. _____ metering devices automatically change their orifice sizes to account for changes in load.
   A. Adsorption
   B. Equalizer
   C. Fixed
   D. Modulating
10. Which of the following statements regarding capillary tubes is *not* true?
    A. It equalizes pressure between the high and low side during the Off cycle.
    B. It works with the suction line as a heat exchanger for improved system efficiency.
    C. Having a proper refrigerant charge is less critical in a system with a capillary tube than it is in a system with a thermostatic expansion valve.
    D. Its performance is determined by its inside diameter, its length, and the number of turns.
11. A(n) _____ is a fixed-orifice metering device that consists of a fitting with a hole between the fitting's inlet and outlet.
    A. metering orifice
    B. electronic expansion valve
    C. heat exchanger
    D. equalizer
12. The top of a thermostatic expansion valve's diaphragm is exposed to _____, which works to open the valve.
    A. atmospheric pressure
    B. high-side pressure
    C. low-side pressure
    D. sensing bulb pressure

13. The purpose of a bleed valve or bleed port in a thermostatic expansion valve is to _____.
   A. ensure that the underside of the diaphragm is exposed to the same pressure as the evaporator outlet
   B. equalize low-side and high-side pressure during the Off cycle
   C. reduce valve hunting during operation
   D. vent refrigerant to the atmosphere if high-side pressure becomes excessive

9.3 Evaporators

14. Gravitational circulation of air is used by _____ evaporators.
   A. forced-draft
   B. immersed
   C. microchannel
   D. natural-draft
15. Fin spacing in fin-and-tube evaporators impacts the number of fins that can be used and the _____.
   A. amount of tubing required
   B. amount of surface area exposed to the air that is being cooled
   C. size of the evaporator
   D. refrigerant that can be used
16. An evaporator fabricated from two metal sheets, welded together, that form a series of passages through which refrigerant flows describes a _____ evaporator.
   A. fin-and-tube
   B. direct expansion
   C. microchannel
   D. plate
17. An evaporator with refrigerant passages that are less than 1 mm in diameter is a _____ evaporator.
   A. fin-and-tube
   B. direct expansion
   C. microchannel
   D. plate

9.4 Condensers

18. As refrigerant exits the condenser, it is a warm, _____.
   A. high-pressure vapor
   B. low-pressure vapor
   C. high-pressure liquid
   D. low-pressure liquid
19. _____ condensers use air movement of either natural convection or forced drafts to remove heat from a system's refrigerant.
   A. Air-cooled
   B. Evaporative
   C. Microchannel
   D. Water-cooled

9.5 Other Basic System Components

20. Cleaning a refrigeration system includes all of the following, *except* _____.
   A. removing moisture
   B. removing acid
   C. removing refrigerant
   D. measuring when the drying job is completed
21. Moisture indicators are often installed _____.
   A. between the metering device and distributor
   B. in the discharge line
   C. just after the liquid line filter-drier
   D. just after the suction line filter-drier
22. Which of the following statements regarding service valves is *not* true?
   A. Service valves are fastened to tubing using soldered connections.
   B. Service valves provide access for taking pressure readings.
   C. Many systems have a service valve at the outlet of the liquid receiver.
   D. Service valves provide access for adding or removing refrigerant or oil.

CRITICAL THINKING

1. Explain the requirements to ensure ideal operation of a compressor.
2. Capillary tube performance depends on the tube length, inside diameter, and the number of turns. Explain how each of these three variables affects performance.
3. Explain why and how gravitational circulation occurs in a natural-draft evaporator unit.
4. Describe how condensers expel unwanted heat from a refrigeration system.
5. What are four indications that a liquid line filter needs to be replaced?