LEVEL F

Air Conditioning Fundamentals TC070-05-01S SG

Mazda Motor Corporation
Technical Service Training

Masters

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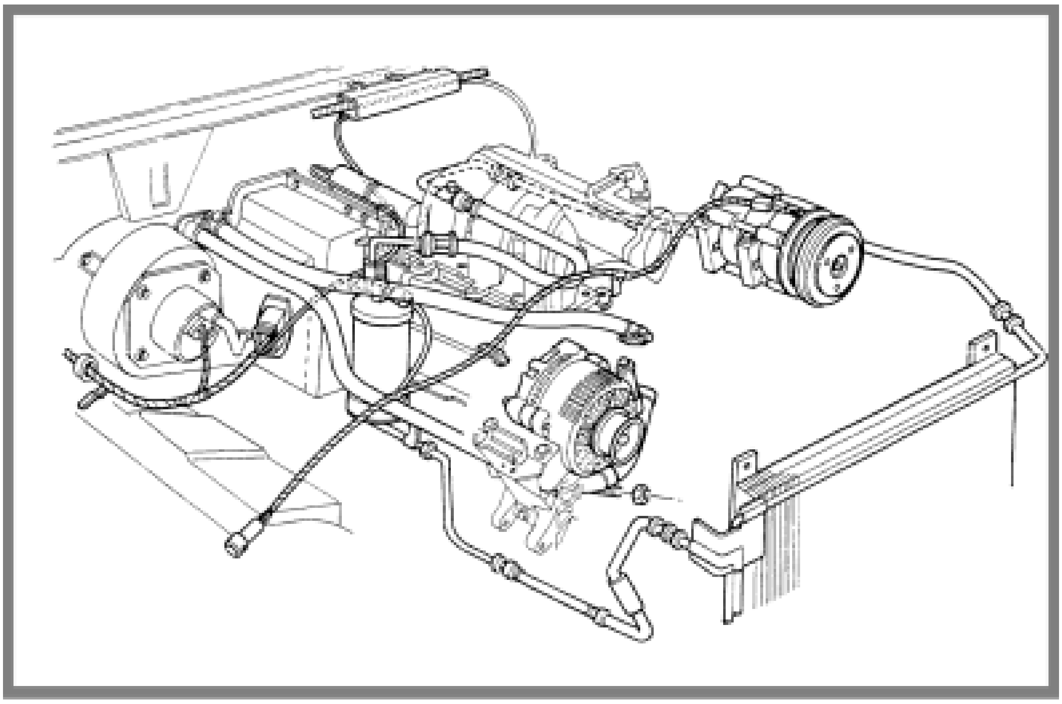
10– SERVICING

COURSE SUMMARY

1 – INTRODUCTION



COURSE OVERVIEW

Welcome to the Mazda self-study guide, *Air Conditioning Fundamentals*. Before you begin, please read the following information.

Audience and Purpose

This guide is designed for entry-level automotive technicians. It introduces the basic principles of air conditioning (A/C) operation and describes major A/C components.

The guide assumes that you have little or no knowledge about automotive A/C operation. Mazda requires the information covered in this guide for more advanced A/C courses.

Course Content and Objectives

In addition to this Introduction (Section 1), this guide includes 9 major sections and a glossary. The objectives for each section follow:

Section 2 — What is Air Conditioning?

- Describe the purpose of automotive air conditioning.
- Describe how various A/C system components contribute to passenger comfort.

Section 3 — Air Conditioning Terms and Concepts

- Define basic terms and concepts related to air conditioning systems.

Section 4 — Principles of Refrigeration

- Describe the following basic principles of refrigeration systems:

  - Heat transfer
  - Relationship of temperature to mass
  - Latent heat of vaporization
  - Latent heat of condensation
  - Relationship of pressure to boiling point
  - Properties of compressed vapor

Section 5 — Manual Air Conditioning Components

- Identify and describe the function of the following A/C components:

  - Compressor
  - Condenser
  - Receiver/Dryer
  - Expansion Valve
  - Evaporator

Section 6 — Refrigeration Cycle

- Describe the changes that take place in refrigerant as it flows through the A/C system.
- Explain the role that each major A/C component plays in the refrigeration cycle.

Section 7 — Refrigerants

- Describe the chemical structure and properties of R-12 refrigerant.
- Describe the chemical structure and properties of R-134a refrigerant.
- Describe the differences between R-12 and R-134a.
- Define recycled, reclaimed, and extracted refrigerant.
- Follow safe procedures for storing recycled refrigerant.
- Describe the two approaches for retrofitting older A/C systems.
- Follow safety procedures and rules when working with A/C systems.

Section 8 — Air Conditioning Lubricants

- Explain the purpose of refrigeration lubrication.
- Identify the differences between mineral oil and PAG oil.
- Describe the characteristics of refrigeration oil.
- Explain why you must add oil to an A/C system when you replace components.

Section 9 — Air Discharge Management

- Describe how the following components direct air flow through the heating and A/C system:

  - Fresh/re-circulated air door
  - Blower fan
  - Temperature blend door
  - Defroster door
  - Vent/face and heater doors

Section 10 — Servicing A/C Systems

- Use a manifold gauge.
- Recover refrigerant.
- Evacuate an A/C system.
- Test for leaks.
- Charge an A/C system using liquid or vapor refrigerant.

Section 11 — Glossary

- Define terms used throughout this guide.

HOW TO USE THIS GUIDE

To get the most benefit from this guide, complete the sections in order, from 1 through 10. Allow enough time to complete each section, and don't try to complete the whole book in one sitting. You will retain more of what you learn if you split up the reading and review exercises over several days.

Section Objectives

Each section begins with a list of learning objectives. These objectives tell you exactly what you will learn in the section. Read these objectives before you begin a section. When you have completed the section, go back and review the objectives to make sure you have learned the material.

Text and Illustrations

Each section includes text and illustrations that explain important concepts and terms. Read the text carefully and study the illustrations. You may also want to take notes as you go along.

Review Exercises

This guide include 12 Review Exercises, which appear at various points throughout the guide. These exercises are designed to check your understanding of the material. Make sure you answer the questions in each Review Exercise. Then check your answers with the answer key.

If you're not sure about one or more of your answers, go back and read the material again. Make sure you understand the previous material before you move on.

2 – WHAT IS AIRCONDITIONING?

OBJECTIVES

After completing this section, you will be able to:

- Describe the purpose of automotive air conditioning.
- Describe how various A/C system components contribute to passenger comfort.

Although once considered a luxury, air conditioning has become one of the most popular automotive features. Air conditioning can relieve drivers' stress and fatigue by providing a comfortable driving environment. Today, about 80 percent of the vehicles sold in this country have air conditioners.

BASIC PRINCIPLE

Air conditioning (A/C) creates a comfortable environment by changing the temperature, humidity, and airflow within the vehicle. The A/C system changes the temperature by absorbing heat from the passenger compartment and discharging the heat outside the vehicle.

The refrigerant used in the A/C system absorbs and releases large amounts of heat as it changes from a liquid to a gas. As the refrigerant circulates through the tubes and hoses of an operating A/C system, it constantly changes from a liquid to a gas and back to a liquid again.

The continuous changing of the refrigerant from a liquid to a gas is known as change of state. This change of state is what allows the refrigerant to remove the heat from the air and lower the temperature inside the vehicle.

COMPONENTS ENHANCING COMFORT

To create a comfortable environment for the driver and passengers, an automotive climate control system uses several components.

Heater

The heater unit uses heated coolant from the engine's cooling system to warm the air entering the passenger compartment. A defroster setting redirects heat to the windshield to remove ice and condensation. Depending on the temperature setting, the heating system may supply a mix of heated and unheated air to the passenger compartment.

Air Conditioning

Air conditioning enhances the comfort of the driver and passengers by cooling and dehumidifying the air in the passenger compartment.

Fan

A variable-speed blower fan draws air into the system, where it is cooled or heated according to system settings. The fan also distributes conditioned air through a series of vents in the passenger compartment. The variable speed settings allow the occupants to tailor the airflow to their personal preferences.

Vent Louvers

A/C and heating vents in the passenger compartment usually include louvers that allow passengers to redirect the airflow up or down, and from side to side. In some cases, passengers can even shut the vent off completely.

2 – WHAT IS AIRCONDITIONING?

BASIC AIR CONDITIONING COMPONENTS

Figure 1 shows the basic components of an air conditioning system.

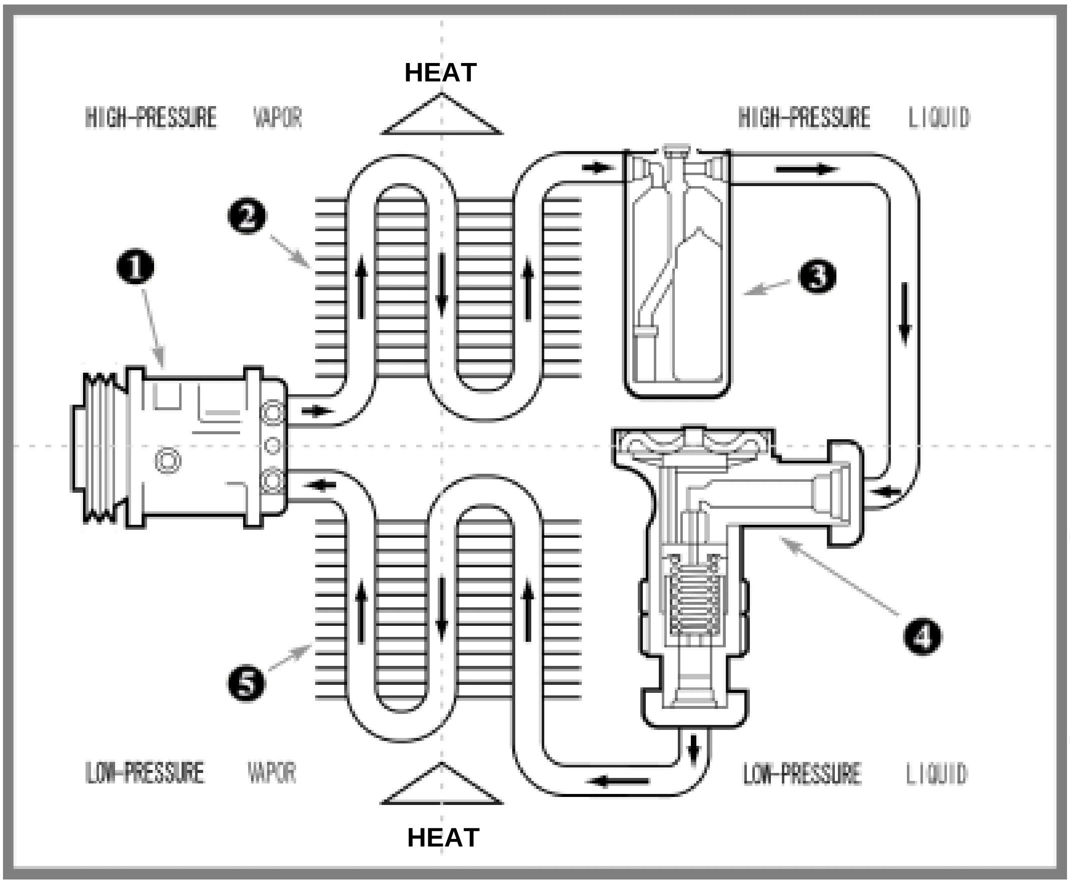


FIGURE 1. An A/C system includes five basic components.

❶ Compressor – Compresses the refrigerant and moves it through the system; increases the refrigerant temperature and pressure.

❷ Condenser – Transfers heat from the refrigerant to the outside air.

❸ Receiver/ Dryer or Accumulator – Removes moisture from refrigerant.

❹ Expansion Valve or Orifice Tube – Regulates refrigerant flow through the evaporator.

❺ Evaporator – Absorbs heat from the inside air and transfers it to the refrigerant.

REVIEW EXERCISE 1

Fill in the words that complete these sentences correctly. Check your answers with the answer on page 12.

1. The three factors that create the comfortable environment, in a vehicle interior are ____________________, ____________________, and ____________________.

2. Refrigerant absorbs and releases large amounts of ____________________ from inside the vehicle.

3. When refrigerant changes from a liquid to a gas, it is know as a _________________________.

4. Vents in the passenger compartment usually have ____________________ that allow passengers to direct airflow up or down, and from side to side.

5. Air Conditioning enhances the comfort of the driver and passengers by ____________________ and ____________________ the air in the passenger compartment.

OBJECTIVE

After completing this section, you will be able to define basic terms and concepts related to air conditioning systems.

INTRODUCTION TO AIR CONDITIONING TERMS

All matter can exist in one of three states: solid, liquid, or gas. The chemical properties of a specific substance like water or iron determine which state it assumes under various temperatures and pressures.

Water, for example, is a liquid at room temperature and sea level. At very cold temperatures, though, water becomes a solid (ice). At high temperatures, water becomes a gas, or vapor (steam).

The chemical changes that occur as matter changes from solid to liquid to gas are the basis for all modern refrigeration systems, including automobile air conditioners. To understand these changes, you need to know the terms used to describe them.

The following pages define and illustrate these important terms. Keep in mind, the remaining sections of this Guide use the vocabulary presented in this section.

PRESSURE

All matter consists of small, moving particles called molecules. If you enclose a gas such as steam in a container, the molecules constantly bump into the sides of the container. The force of gas molecules against the inside surface of a closed container is *pressure*. We measure pressure in pounds per square inch, or *psi*.

Assume we enclose gas in a container and attach a pressure gauge. The gauge shows a pressure of 10 psi. This reading means the molecules of gas are hitting the sides of the container often enough to exert 10 pounds of force on each square inch of the container's inside surface.

We can increase the pressure of the enclosed gas by:

1. Decreasing the size of the container,

2. Adding more gas to the container, or

3. Heating the contents of the container.

Reducing the Size of the Container

If we reduce the size of the container and keep the same amount of gas inside, the space between the molecules will decrease, causing the molecules to strike the sides more often. This results in increased pressure. *When the pressure of the gas rises, its temperature also rises.*

Adding Gas

If we force more gas into the closed container, the molecules will strike the sides more often, and the pressure will rise. If we measure the temperature of the gas at this point, we will also find that its temperature has increased. *As the pressure of a gas increases, so does its temperature.*

Heating the Contents

If we heat the gas, the molecules already in motion will speed up. They will strike the sides more often, causing pressure to rise. Since the molecules are moving faster, the temperature of the substance rises. *As the motion of the molecules increases, so does the temperature.*

Effects of Pressure on Boiling Points

Pressure affects the boiling point of liquids. *Boiling point* is the temperature at which a substance changes from liquid to vapor. When a substance is highly pressurized, it is harder for the molecules to separate and change into vapor. *This means that the higher the pressure of a substance, the higher its boiling point will be.* At lower pressure, the molecules can separate more easily, so the substance will boil at a lower temperature.

Let's assume you want to boil a pot of water. At sea level, atmospheric pressure is about 15 psi, and the water will boil at 212° F (100° C). However, pressure drops as elevation increases. If you took that same pot of water to the top of Pike's Peak (over 14,000 feet above sea level), it would boil at only 187° F.

When you think of boiling water, you think of a very hot liquid. However, not all liquids need to be hot to boil. For example, the refrigerant liquid "R-12" boils at 22° F. Another common refrigerant, "R-134a," boils at -15° F. The chemical makeup of these two substances causes their low boiling points, which make them good refrigerants.

HEAT

You can think of heat as a measure of molecular motion. When you apply heat to matter, the molecules already in motion begin to speed up. The faster the molecules move, the hotter the substance becomes. When you remove heat, the molecules slow down.

For example, as water loses heat, its molecules slow down, growing closer together until they form solid ice. If you add heat to the ice, the water returns to liquid form. If you continue adding heat, the molecules in the liquid speed up and move farther apart, forming the gas we call steam. The same principles hold true for a piece of steel. If you add enough heat, the solid steel will turn to a liquid and then a vapor.

Measuring the Properties of Heat

You cannot measure heat itself. However, heat intensity and quantity are measurable. *Temperature* is the measure of heat intensity, and *British Thermal Units*, or BTUs, measure heat quantity.

Temperature

Temperature measures heat intensity in units called *degrees*. We normally use one of two scales to express temperatures.

On the *Fahrenheit* scale, water freezes at 32 degrees, and boils at 212 degrees. On the *Centigrade* scale, water freezes at 0 degrees, and boils at 100 degrees. Although these two scales are different, they both measure heat intensity.

3 – A/C TERMS AND CONDITIONS

In our previous discussion of pressure, we talked about how an increase in the pressure of a gas causes its temperature to rise, even without adding an external heat source. As you increase pressure, the molecules of gas move closer together, so they contact each other more frequently. These contacts cause friction and accelerated movement, producing heat. The temperature of the gas will continue to rise until you either reduce pressure or apply external cooling.

British Thermal Unit (BTU)

A BTU is the amount of energy needed to raise the temperature of one pound of water at sea level by one degree Fahrenheit.

Latent Heat

Latent heat is the amount of heat you must add or remove from a substance to make it change state. It is called *latent* heat because you cannot measure it with a thermometer.

For example, if you heat a pound of water at sea level to 212° F (100° C), you must continue to apply at least 940 BTU's of heat energy to convert it to steam. As you add these BTUs, though, the water temperature remains unchanged. The energy added to the pan speeds up the water molecules but has no effect on temperature.

The latent heat applied to change a substance from a liquid to a vapor is called the latent heat of *vaporization*. The latent heat removed when a substance changes from a vapor to a liquid is called the latent heat of *condensation*.

HUMIDITY

Humidity is the amount of moisture in a sample of air at a particular pressure and temperature. Warmer air can hold more moisture than cooler air.

Humidity as a Percent

Humidity — also called *relative humidity* — is usually expressed as a percent. For example, *80 percent humidity* means the air is holding 80 percent of the water vapor it *could* hold at its current temperature. One hundred percent humidity means that the air can hold no additional moisture unless its temperature increases.

High Humidity

High humidity makes a hot day feel even hotter because of the way the human body cools itself. To cool off, the body releases water to the atmosphere. During low humidity, the atmosphere absorbs the moisture given off by the body, providing a cooling effect. During high humidity, the atmosphere cannot absorb the moisture the body gives off. The moisture condenses on the skin as sweat, causing an uncomfortable "sticky" feeling.

During periods of high humidity, an otherwise normal air conditioning system may appear to need servicing. When evaluating the performance of an A/C system, you must consider the relative humidity. The following table shows acceptable readings for various combinations of temperature and humidity.

Typical System Temperatures

Ambient Air		A/C System	
Relative Humidity	**Temperature (°F)**	**Evaporator Pressure (psi)**	**Vent Outlet Temperature (°F)**
30%	70	28.0	37
	80	29.0	37
	90	30.5	40
	100	36.0	45
	110	43.0	56
60%	70	28.0	39
	80	30.0	42
	90	35.0	46
	100	43.0	60
90%	70	28.0	41
	80	32.0	48
	90	39.0	56
	100	50.0	72

REVIEW EXERCISE 2

Fill in the words that complete these sentences correctly. Check your answers with the answer key on page 18.

1. The amount of heat required to raise the temperature of one pound of water at sea level by one degree Fahrenheit is called a ______________________.
2. Molecules of gas enclosed in a container constantly bombard the sides of the container. This force, usually measured in pounds per square inch, is called _____________________.
3. Warmer air holds (more or less) _____________________ moisture than cooler air.
4. When you apply _____________________to a substance, the molecules begin to move faster.
5. Heat added to a substance without changing its temperature is called _____________________.
6. On the Centigrade temperature scale, water boils at __________ degrees.
7. If you increase the pressure of a gas in a closed container, the _____________________ of the gas will also increase.

OBJECTIVES

After completing this section, you will be able to describe the following basic principles of refrigeration systems:

- Heat transfer
- Relationship of temperature to mass
- Latent heat of vaporization
- Latent heat of condensation
- Relationship of pressure to boiling point
- Properties of compressed vapor

SIX PRINCIPLES

Air conditioning systems rely on six principles. Understanding these principles will be valuable as you diagnose and repair automotive air conditioners. You can isolate a problem quickly if you understand what is happening to the refrigerant as it travels throughout the system. The result will be a quick, consistent, and accurate diagnosis.

The six principles described in this section are:

1. Heat always travels from hot to cold.
2. The mass of an object remains the same regardless of its temperature.
3. When a liquid changes into a vapor, it absorbs heat.
4. When a vapor changes into a liquid, it releases heat.
5. Changing the pressure of a liquid changes its boiling point.
6. When a vapor compresses, its pressure and temperature increase.

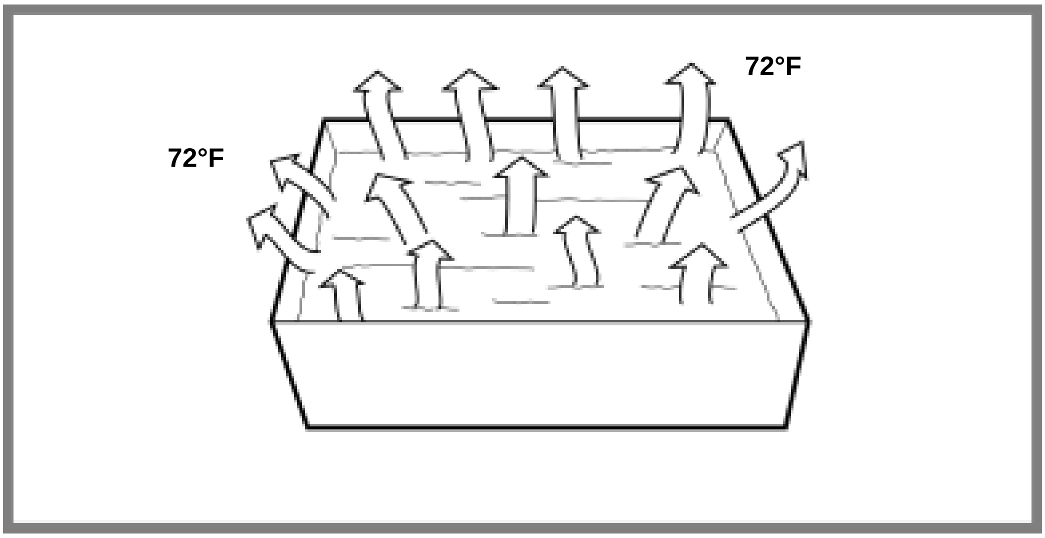
The following topics explain these six principles in detail.

Principle One: Heat Transfer

Principle One states that heat always flows from hot to cold when objects are in contact or connected through a heat conductor. The transfer of heat will continue until both objects reach the same temperature.

For example, the pan of hot water in Figure 2 gives off heat to the surrounding air because the air is cooler than the water

FIGURE 2
***Principle One* – Heat always travels from hot to cold.**



As the difference in temperature between the two objects increases, the rate of transfer also increases. For example, if the air in Figure 2 were even cooler — say 50° F instead of 72° F — the water would cool more quickly. You may have noticed this effect if you have ever left a cup of hot coffee unattended for a while. When you return to the cup, the coffee is about the same temperature as the surrounding air.

Principle Two: Temperature and Mass

According to Principle Two, the mass of an object remains the same regardless of its heat content. For example, the pan of water in Figure 3 weighs one pound whether it is at its freezing point or boiling point.

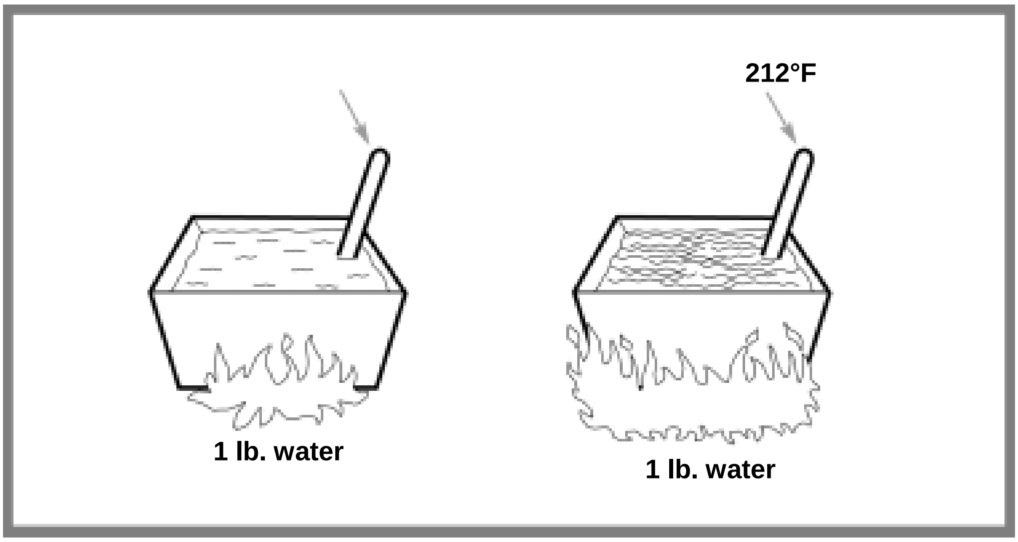


FIGURE 3. *Principle Two* – The mass of an object remains the same regardless of its temperature.

Principle Three: Latent Heat of Vaporization

Principle Three states that when matter changes from a liquid to a vapor, it absorbs a large amount of heat without changing temperature.

Figure 4 illustrates this principle. At sea level, water exists as a liquid between 32° and 212° F (0° and 100° C). At exactly 212° F (100° C), water can be either a liquid or a vapor, depending on how much heat it contains. By adding more heat to the water, you can eventually convert it to steam, but the temperature of the steam will remain 212° F (100° C).

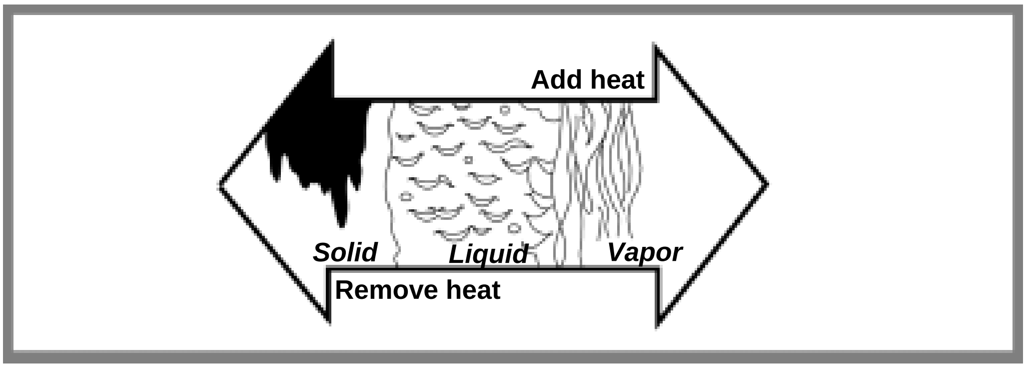
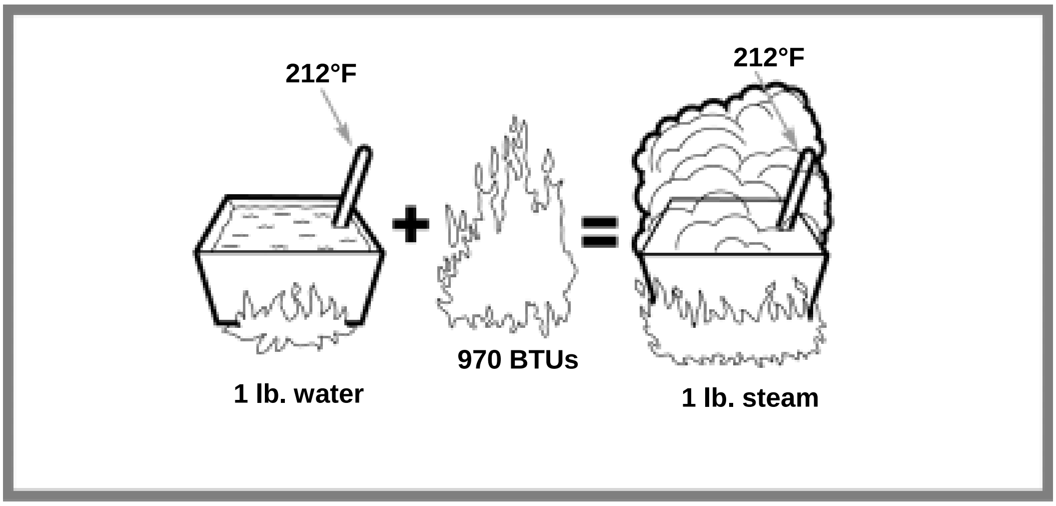


FIGURE 4. *Principle Three* – When matter changes from a liquid to a vapor, it absorbs large amounts of heat without changing temperature

Figure 5 illustrates the latent heat of vaporization. Assume you had a pound of water that was 212° F (100° C), but still a liquid. To change the liquid water into steam, you would have to apply 970 British Thermal Units of heat. Eventually, you would create a pound of steam that would still have a temperature of 212° F (100° C).

FIGURE 5. The latent heat of vaporization is heat stored in a substance as it changes state from a liquid to a vapor.



As steam, the pound of water would have absorbed 970 BTUs of energy without any change in temperature. This “latent” heat absorption is the basis for modern refrigeration systems.

In an A/C system, latent heat of vaporization occurs within the evaporator. When the refrigerant passes through the evaporator, it absorbs heat from inside the vehicle and begins to boil. As heat continues to be absorbed, the refrigerant changes from a low-pressure liquid into a low-pressure vapor.

Principle Four: Latent Heat of Condensation

Principle Four is the reverse of Principle Three. When a vapor cools enough to change into a liquid, it releases the latent heat stored while it was changing into a vapor. The process of changing from a vapor to a liquid is called *condensation*, so the heat released in this change of state is the latent heat of *condensation*.
Figure 6 illustrates this principle.

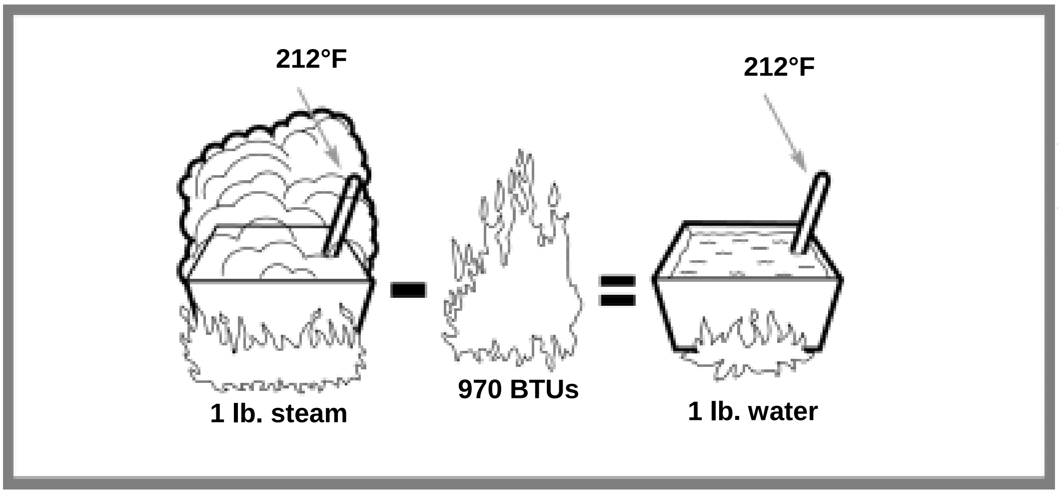


FIGURE 6. The latent heat of condensation is heat released from a substance as it changes state from a vapor to a liquid.

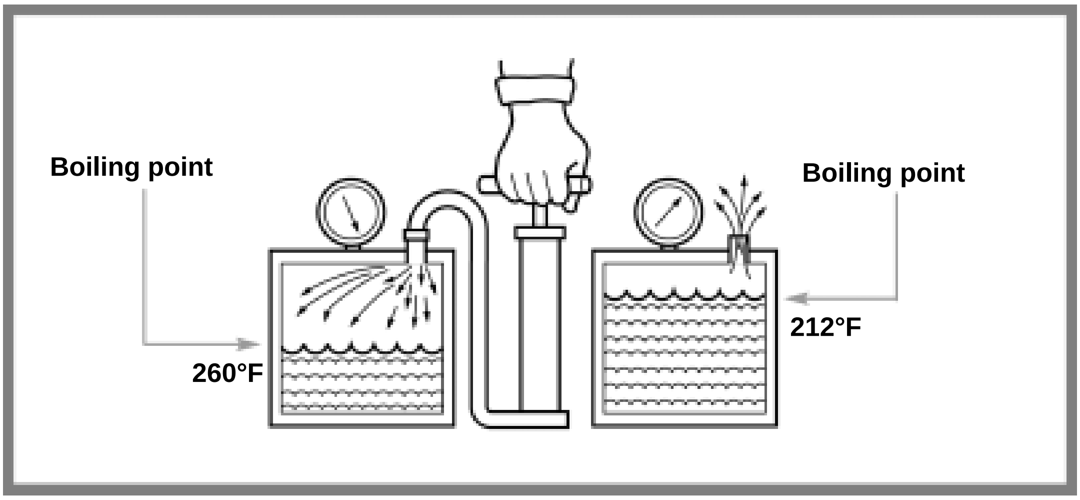
In this example, the pound of steam is cooling to its *dew point* (the temperature at which it turns back into liquid). As the water changes state, it releases 970 BTUs. Notice that the pound of water remains at 212° F (100° C) even though it has released a large amount of heat.

In an A/C system, latent heat of condensation occurs within the condenser. The condenser discharges heat from the refrigerant into the outside air. As the refrigerant cools, it condenses from a high-pressure vapor to a high-pressure liquid.

Principle Five: Pressure and Boiling Point

Principle Five states that changing the pressure of a liquid or vapor changes its boiling point. Higher pressure increases the boiling point, while lower pressure decreases the boiling point, as shown in Figure 7. An auto air conditioning system uses this principle to remove heat from the interior of the vehicle.

FIGURE 7. To increase the boiling point of a liquid, increase its pressure. To decrease the boiling point, decrease the pressure.



Previously, we compared boiling water at sea level and at the top of Pike’s Peak. At sea level, water boils at 212° F (100° C). The lower atmospheric pressure at Pike’s Peak allows water to boil at only 187° F (86° C).

Figure 7 shows what happens if you increase the pressure of the water. At the higher pressure shown in this figure, water will have to reach 260° F (127° C) before it boils.

Principle Six: Compressed Vapor

The sixth and final principle states that when you compress a vapor, its pressure and temperature will increase even though you add no heat. The refrigerant vapor in an automotive air conditioning system is compressed to as much as 250 psi or more. This raises the temperature of the vapor, as well as the boiling and condensation points. Figure 8 shows this principle in action.

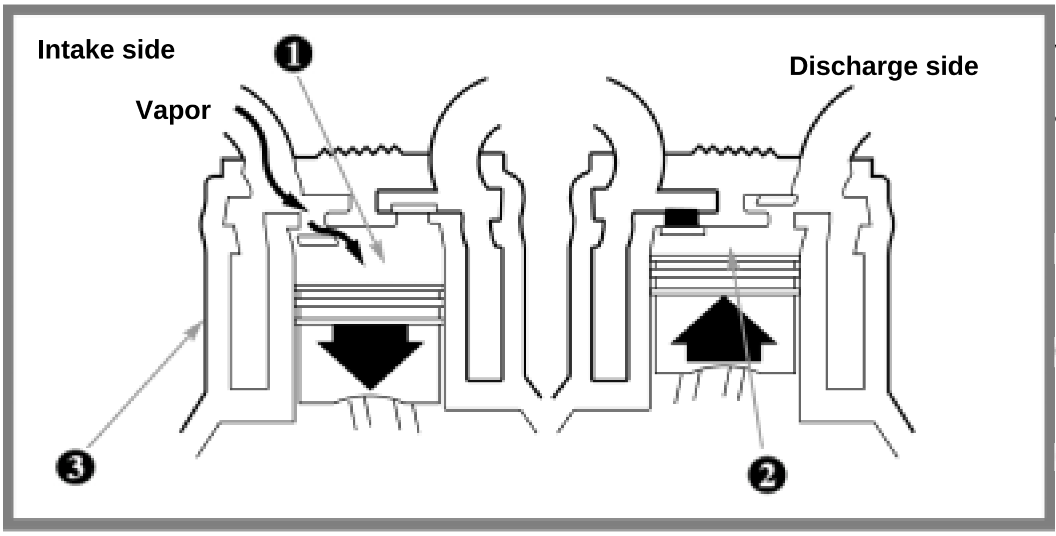


FIGURE 8. When a vapor compresses, its temperature and pressure increase without heat being added.

1 Vapor @ 30 psi. 32° F (0° C)

2 Vapor @ 175 psi, 130° F (54° C)

3 Compressor

As the illustration shows, if you compress a refrigerant from 30 psi to 175 psi, the vapor temperature increases from 32° F (0° C) to 130° F (54° C). At the same time — according to Principle Five — the boiling point and condensation point of the vapor also increase, since the vapor is under higher pressure.

This increase in the temperature of the compressed vapor is not due to any increase in heat stored in the vapor. If you remove heat from the 130° F (54° C) vapor, it will condense into a liquid without changing temperature. The heat given up during this change of state is the latent heat of condensation. Moreover — according to Principle Four — the temperature of the refrigerant will not decrease until the entire vapor condenses into liquid.

REVIEW EXERCISE 3

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 26.

1. As a substance changes state from a liquid to a vapor, it stores a large amount of heat energy without a rise in temperature. This process is called the ____________________________________.
2. Principle One states that heat flows from ___________________ to ___________________ when objects are in contact or connected by a good heat conductor.
3. If you lower the pressure of a liquid, the boiling point of the liquid ___________________.
4. If you compress a vapor, its temperature ___________________.
5. When a vapor changes back into a liquid, it ___________________ heat without changing temperature.
6. If you freeze five pounds of water, the resulting ice block will weigh ___________________ pounds.
7. If you lower the pressure of a compressed vapor, its temperature ___________________.

OBJECTIVES

After completing this section, you will be able to identify and describe the function of the following A/C components:

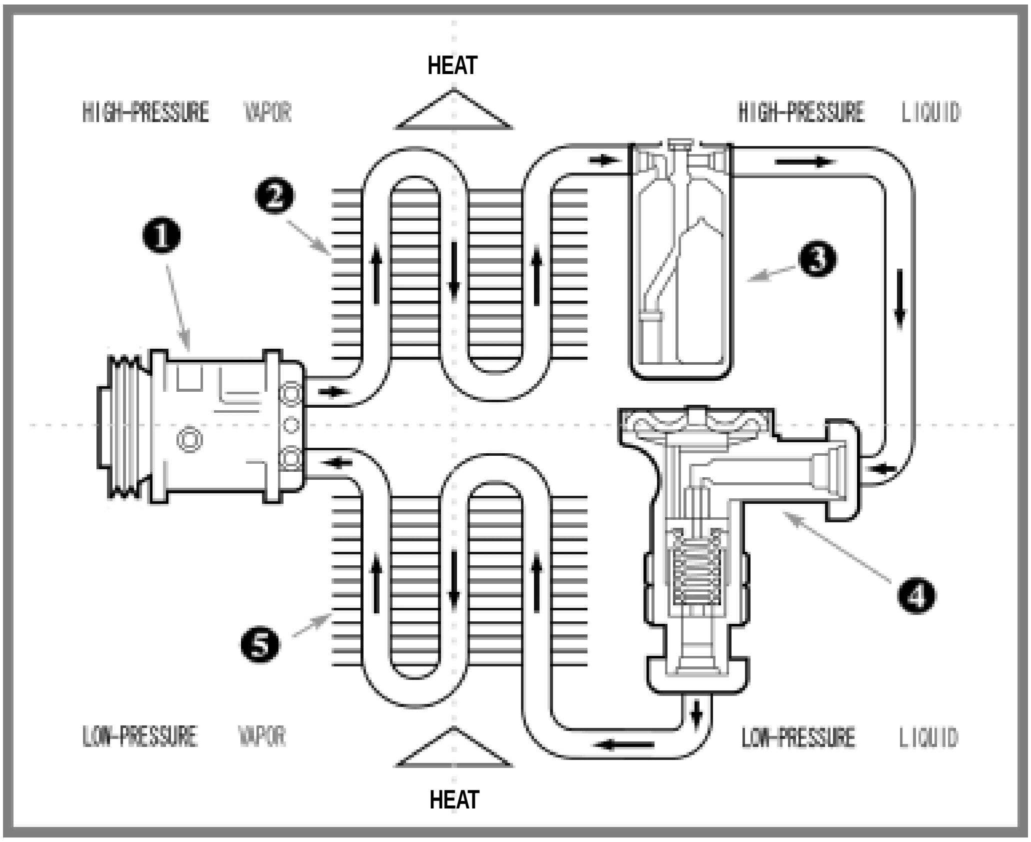
- Compressor
- Condenser
- Receiver/Dryer
- Expansion Valve
- Orifice Tube
- Evaporator
- Accumulator

OVERVIEW

Figure 9 shows the major components in an automotive A/C system.

FIGURE 9. A typical automotive A/C system includes:

- **❶ Compressor**
- **❷ Condenser**
- **❸ Receiver/ dryer**
- **❹ Expansion valve**
- **❺ Evaporator**



Warm, low-pressure vapor entering the compressor

Hot, high-pressure vapor entering the condenser

Warm, high-pressure liquid entering the receiver/dryer

Cold, low-pressure liquid exiting the expansion valve

Cold, low-pressure liquid entering the evaporator

These changes of state and temperature transfer heat from the passenger compartment of the vehicle to the outside air. The following topics describe each component in detail.

COMPRESSOR

The compressor (Figure 10) is the refrigerant pump for the A/C system. A drive belt and pulley connect the compressor to the engine crankshaft, which provides the power to operate the compressor. It draws in warm, low-pressure vapor from the evaporator, drastically raises the pressure (and temperature) of the vapor, and then passes it on to the condenser.

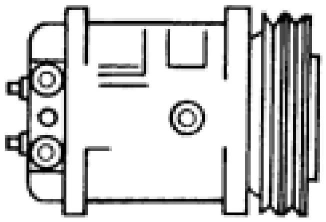


FIGURE 10. The compressor draws in warm, low-pressure vapor from the evaporator and compresses it into a hot, high- pressure vapor, which moves on to the condenser.

The compressor operates only with refrigerant in its gaseous state. Liquid refrigerant in the compressor will lock it up, damaging the compressor and other A/C components.

There are two types of compressors commonly used today.

1. Axial (Piston-Type)
2. Vane (Non-piston-Type)

Axial (Piston-Type) Compressors

Axial compressors create suction and pressure as shown in Figure 11.

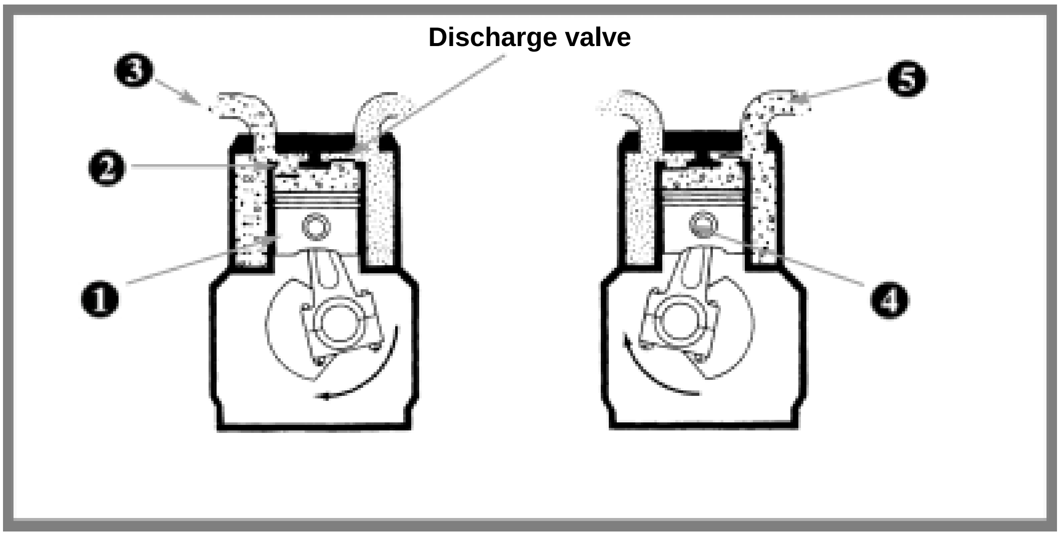


FIGURE 11. An axial compressor draws in low-pressure vapor, compresses it in a cylinder, and outputs high-pressure vapor.

❶ Piston on downstroke

❷ Inlet valve

❸ Low-pressure vapor (from evaporator)

❹ Piston on upstroke

❺ High-pressure vapor (to condensor)

Piston movement pressurizes the refrigerant vapor as follows:
❶ The piston moves down in the cylinder, creating suction.
❷ The discharge valve closes and the inlet valve opens.
❸ Low-pressure refrigerant vapor is drawn into the cylinder.
❹ The piston starts to move up again. The inlet valve closes, causing the pressure in the cylinder to rise.
❺ When the piston nears the top of its stroke, the discharge valve opens. The piston forces the high-pressure vapor out of the cylinder, into the discharge line to the condenser.

The cylinders on an axial compressor face toward the front and back of the compressor, along its axis, as shown in Figure 12. The main drive shaft has a round plate, called a swash plate, mounted to the shaft on an angle. As the shaft turns, the outer edge of the plate moves back and forth. This action moves the pistons back and forth in their cylinders.

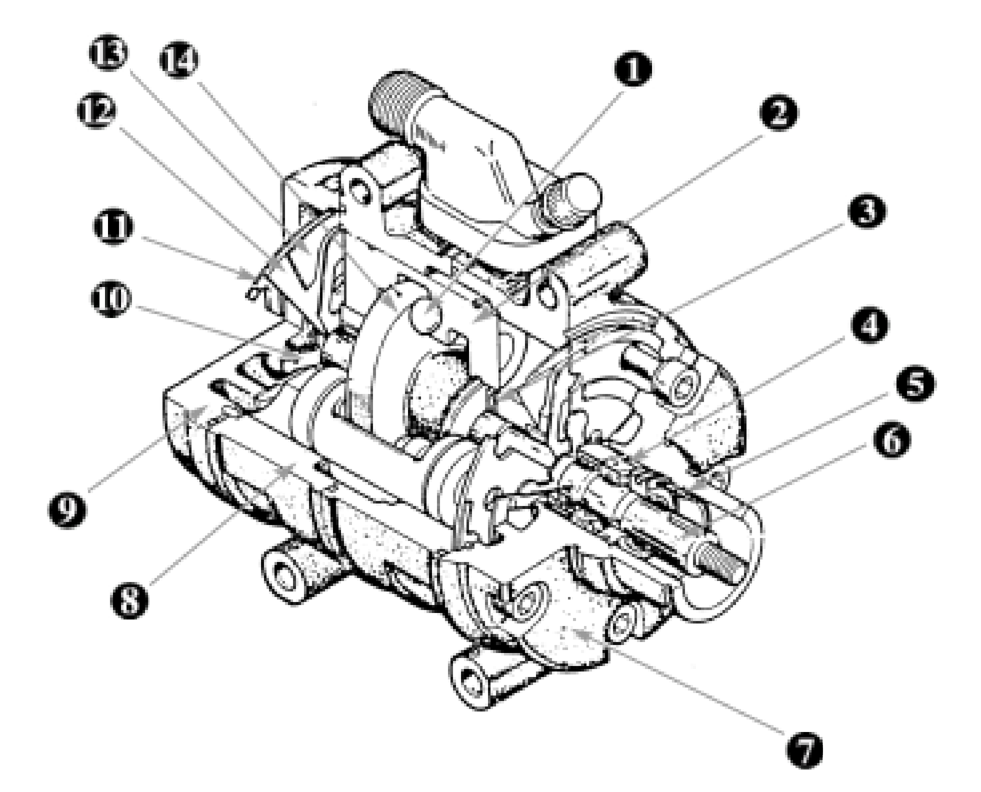


FIGURE 12. Double-ended piston axial compressors have pistons that straddle the swash plate.

1 Hemisphere shoe
2 Piston
3 Thrust bearing
4 Shaft seal
5 Felt
6 Shaft
7 Front housing
8 Cylinder
9 Rear housing
10 Discharge valve
11 Steel gasket
12 Valve plate
13 Suction valve
14 Swash plate

There are two different configurations of axial compressors:

1. Double-ended piston axial compressors

2. Single-ended piston axial compressors.

Double-Ended Piston Axial Compressors

Axial compressors have double-ended pistons that straddle the swash plate. Each piston has two opposing cylinders. As one end of the piston moves back in one cylinder, the other end of the piston moves forward in the opposing cylinder.

Single-Ended Piston Axial Compressors

Single-ended piston axial compressors have all their pistons and cylinders mounted side-by-side in the compressor, facing the same direction, as shown in Figure 13.

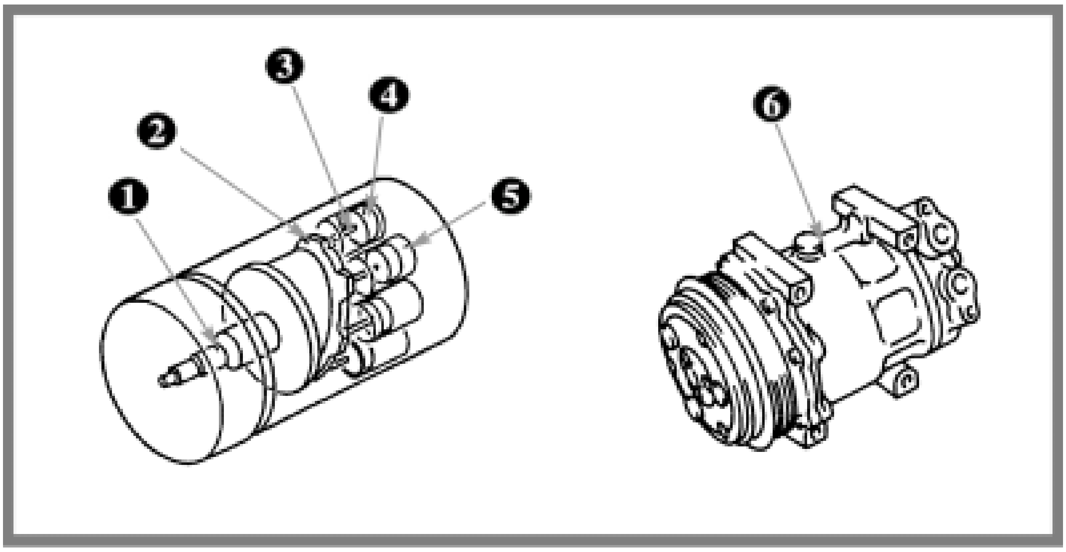


FIGURE 13. Single-ended piston axial compressors have all pistons and cylinders mounted side-by-side in the compressor, facing the same direction.

- **1 Shaft**
- **2 Swash plate**
- **3 Rod**
- **4 Piston**
- **5 Cylinder**
- **6 Drain Plug**

Just as with the double-ended piston axial compressor, the pistons travel along the outer edge of the swash plate, connected to a similar plate by connecting rods and ball-sockets. As the swash plate turns, it moves the adjoining plate, which moves pistons back and forth in the cylinders.

Vane (Non-Piston-Type) Compressors

The vane-type compressor (see Figure 14) operates in a similar way to air pumps, power steering pumps, and other impeller-style pumps. The vanes in some compressors are driven outward by centrifugal force as well as the pressure behind the back of the vane.

The benefit of the vane-type compressor is that there is no efficiency loss from reciprocating pistons. The compressor provides low-friction operation by having vanes and a rotor in an elliptical housing. The vanes compress the refrigerant vapor into a smaller area and push it through spring-loaded discharge reed valves.

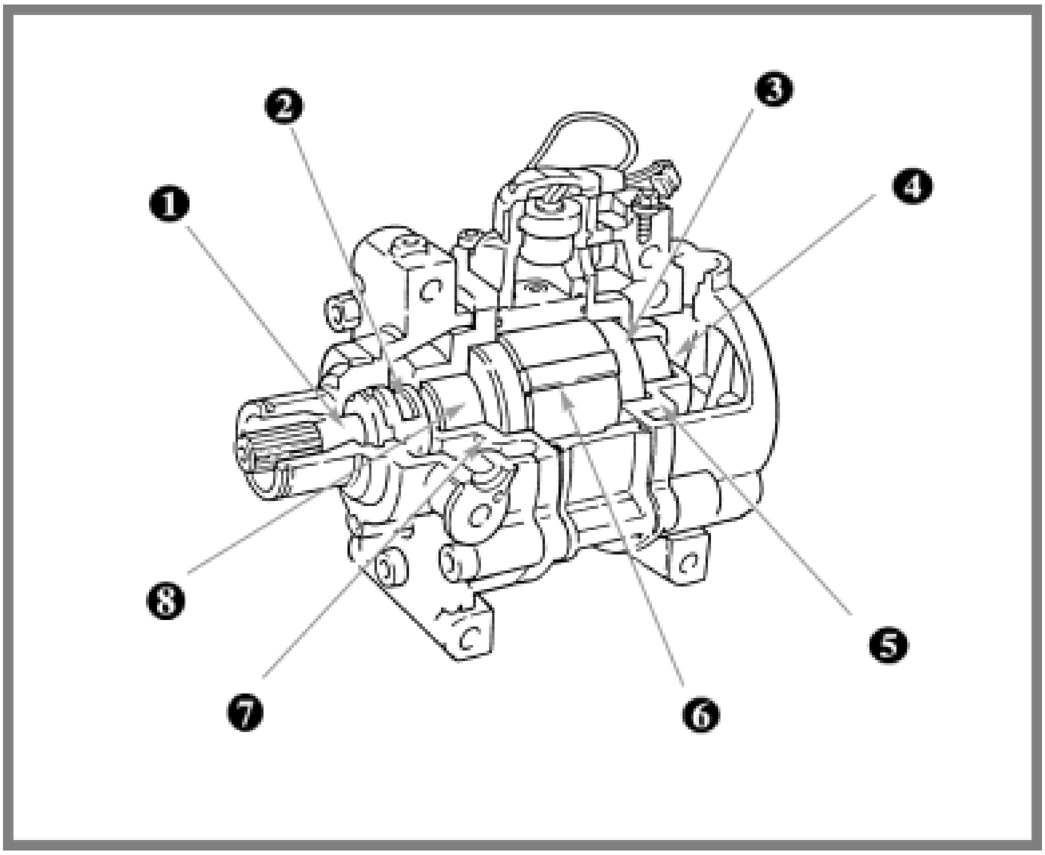


FIGURE 14. The vane-type compressor provides low-friction operation by having vanes and a rotor in an elliptical housing.

- **1 Front shaft**
- **2 Seal**
- **3 Rear shaft**
- **4 Bearing**
- **5 Rear housing**
- **6 Vane**
- **7 Front housing**
- **8 Bearing**

Most vane-type compressors use a temperature-protection switch mounted on the compressor. This switch shuts down the compressor if it gets too hot.

The variable displacement vane-type compressor changes its pumping capacity to compensate for load. A single control valve controls compressor displacement like the variable displacement piston compressor. A rotating plate throttles the volume of refrigerant entering the compression chamber.

Vane-type pumps have several advantages over piston-type pumps. They are:

• Smaller

• Lighter

• More efficient

• Have very few moving parts

CONDENSER

The condenser (Figure 15) is located in front of the radiator. It receives hot, high- pressure refrigerant gas from the compressor and transfers the heat to the outside air.

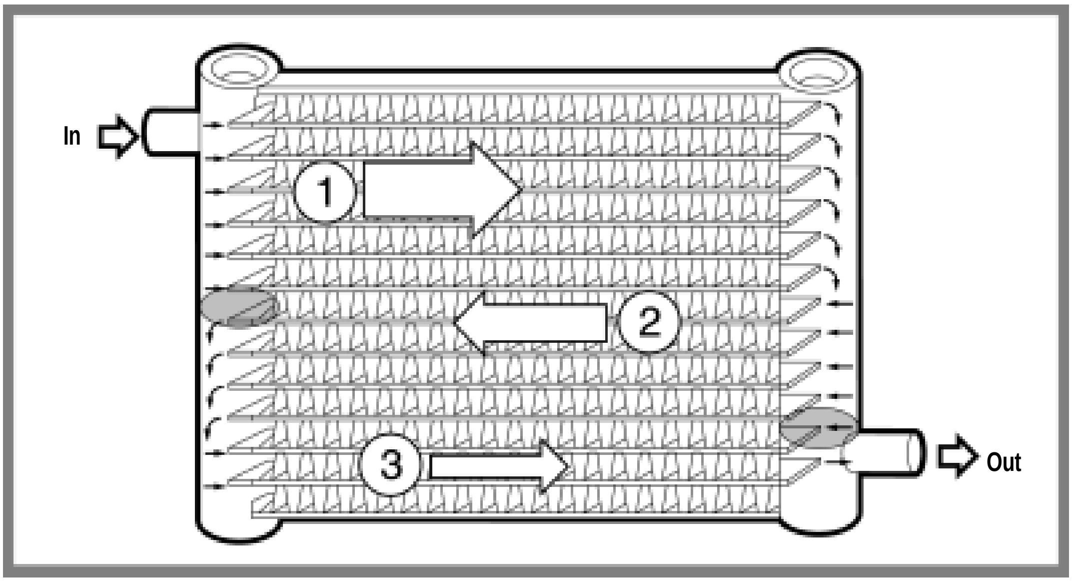


FIGURE 15. The condenser transfers heat from the compressed refrigerant vapor to the outside air. As the refrigerant cools, it changes into a liquid, releasing latent heat of condensation.

Like the evaporator, the condenser circulates refrigerant through a series of tubes and fins. A fan draws outside air over the condenser's surface area, allowing the hot refrigerant to pass its heat to the air (latent heat of condensation).

As the refrigerant cools, it changes from a high-pressure gas to a high-pressure liquid. After changing from a vapor to a liquid, the refrigerant undergoes additional cooling in the bottom of the condenser (sub-cooling).

The efficiency of the condenser is critical to A/C operation. The outside air must absorb the stored heat from the vehicle interior plus the additional heat that results from compressing the gas. The more heat transferred by the condenser, the more cooling the evaporator can provide. For example, a larger capacity condenser and a more efficient fan will drop the interior cooling temperature significantly.

To prevent damage to A/C components, any malfunction in the condenser fan normally causes the A/C system to shut down by opening the circuit to the compressor clutch.

REVIEW EXERCISE 4

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 34.

1. The compressor receives warm, low-pressure refrigerant vapor from the __________________________.

2. The two main types of compressors commonly used today are the __________________________ type and the __________________________ type.

3. The back-and-forth movement of the ___________ ___________ moves the compressor's pistons back and forth in their cylinders.

4. Which type of A/C compressor is lighter and smaller? __________________________

5. The condenser receives hot, high-pressure refrigerant vapor from the __________________________.

6. __________________________-ended piston compressors have all of their piston cylinders mounted side-by-side in the compressor.

RECEIVER / DRYER

Located near the outlet of the condenser, the receiver / dryer (Figure 16) filters moisture and foreign matter from the liquid refrigerant and serves as a storage area for refrigerant. This storage area traps any refrigerant not completely liquefied in the condenser. Any remaining gaseous refrigerant could damage the expansion valve or evaporator.

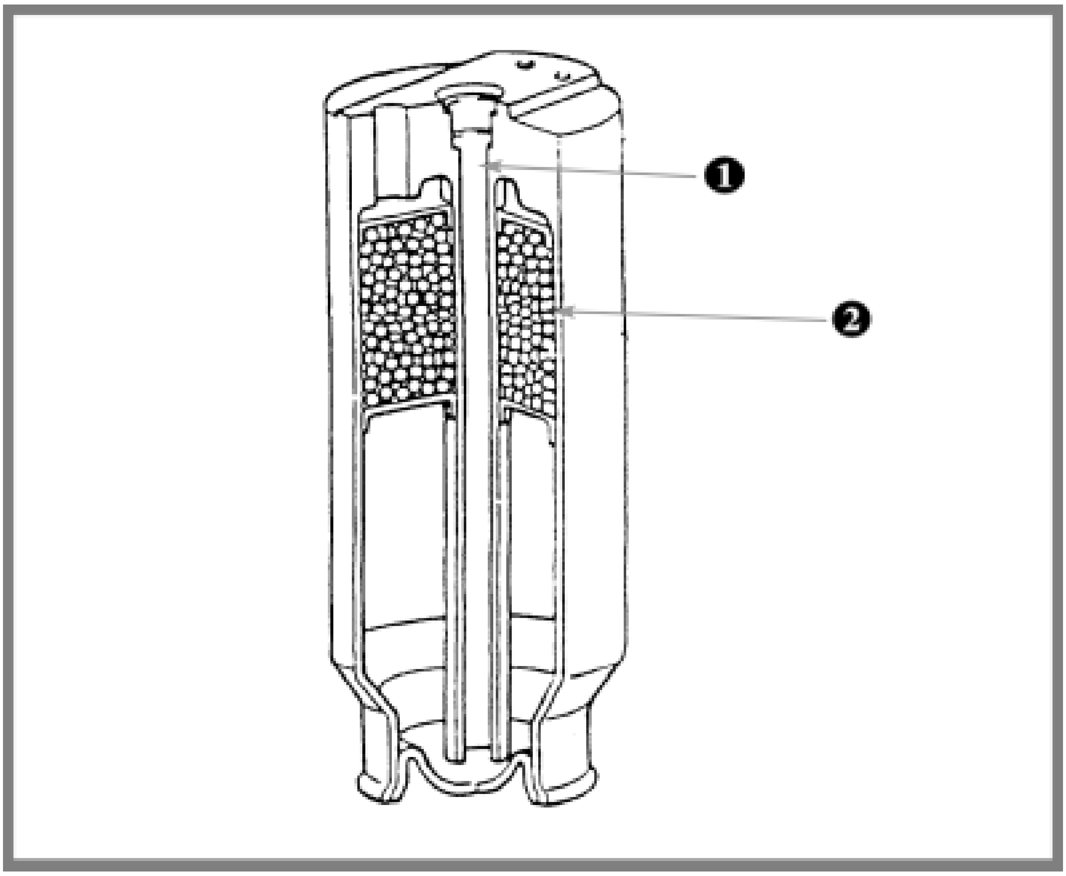


FIGURE 16. The receiver / dryer collects moisture and contaminants from the refrigerant and stores refrigerant to keep system pressures constant.

❶ Receiver tube

❷ Dessicant

The moisture-collecting material in the receiver / dryer (called *desiccant*) matches the type of refrigerant used in the system, either R-12 or R-134a. If the receiver / dryer collects excessive moisture from the refrigerant, it can freeze and block the liquid refrigerant from reaching the evaporator. If this happens, the A/C system will usually produce normal cooling at first, followed by slowly diminished cooling.

EXPANSION VALVE / ORIFICE TUBE

An *expansion valve* or *orifice* tube regulates the flow of refrigerant to the evaporator. To get maximum cooling potential, the pressure of the liquid refrigerant must be lowered before it enters the evaporator. At lower pressure, the refrigerant's temperature and boiling point drop, allowing it to absorb more heat as it passes through the evaporator.

Expansion Valve

Although they perform the same function, expansion valves and orifice tubes operate differently. Figure 17 shows a typical expansion valve.

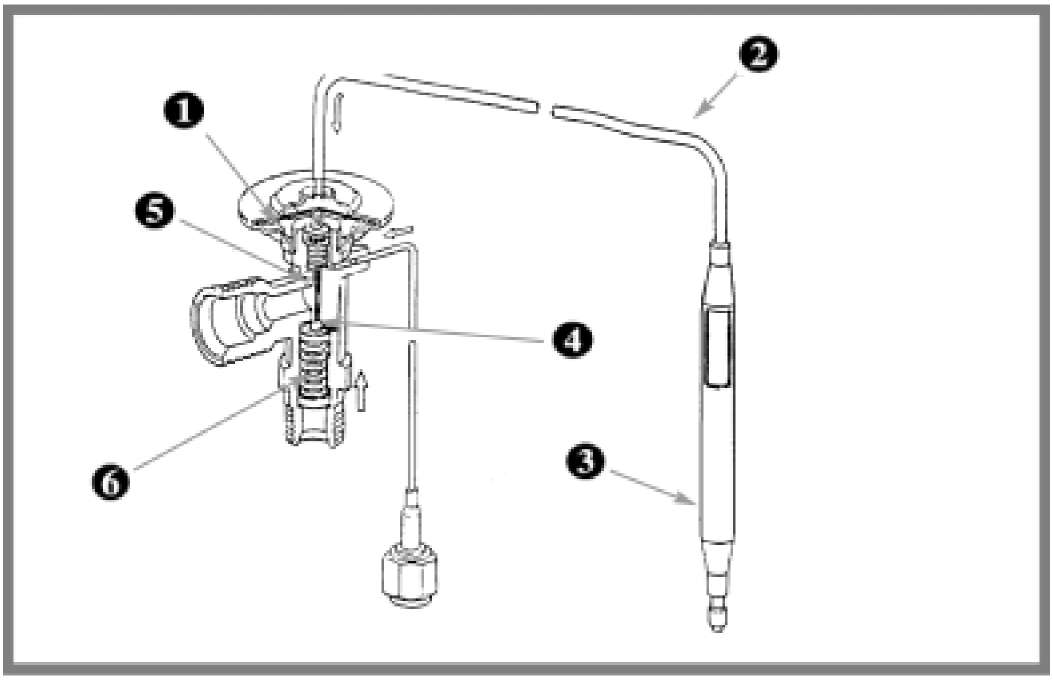


FIGURE 17. The expansion valve restricts the flow of refrigerant to the evaporator. Lowering the pressure of the refrigerant allows it to absorb more heat as it passes through the evaporator.

- **1 Diaphragm**
- **2 Capillary tube**
- **3 Temperature-sensing bulb**
- **4 Valve**
- **5 Pintle**
- **6 Pressure spring**

A bulb 3 on the evaporator sends information about evaporator temperature through a capillary tube 2 . This tube is attached to the diaphragm 1 on the expansion valve.

If the evaporator becomes too cold, the diaphragm pulls the needle-shaped pintle 5 , closing the valve 4 and restricting refrigerant flow. As the evaporator temperature rises, the diaphragm presses down on the pintle, opening the valve and letting more refrigerant through.

Orifice Tube

Like an expansion valve, an orifice tube divides the high-and low-pressure parts of the A/C system. Figure 18 shows a typical orifice tube.

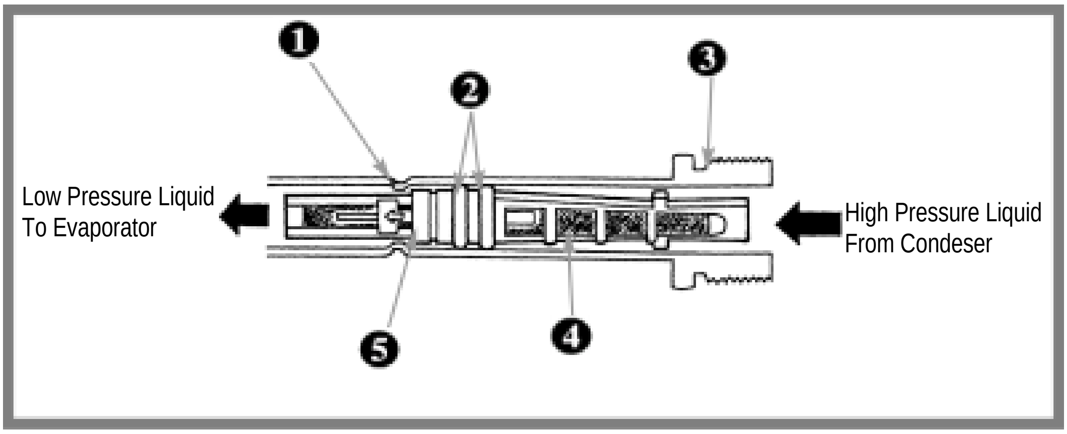


FIGURE 18. An orifice tube restricts refrigerant flow between the high- and low-pressure sides of the A/C system.

- **1 Pipe caulking**
- **2 O-rings**
- **3 Cooler pipe**
- **4 Mesh screen**
- **5 Orifice tube**

The orifice tube has a fixed opening. The flow rate of the refrigerant through the opening is determined by the cycling of the compressor clutch. In response to changes in temperature and pressure, the clutch turns on and off to engage the compressor.

EVAPORATOR

The evaporator (Figure 19) is located under the dash. It removes heat from the passenger compartment and transfers it to the refrigerant. Refrigerant enters the evaporator as a cool, low-pressure liquid mist, which circulates through the evaporator's tubes and fins (much like coolant circulates through an engine's radiator).

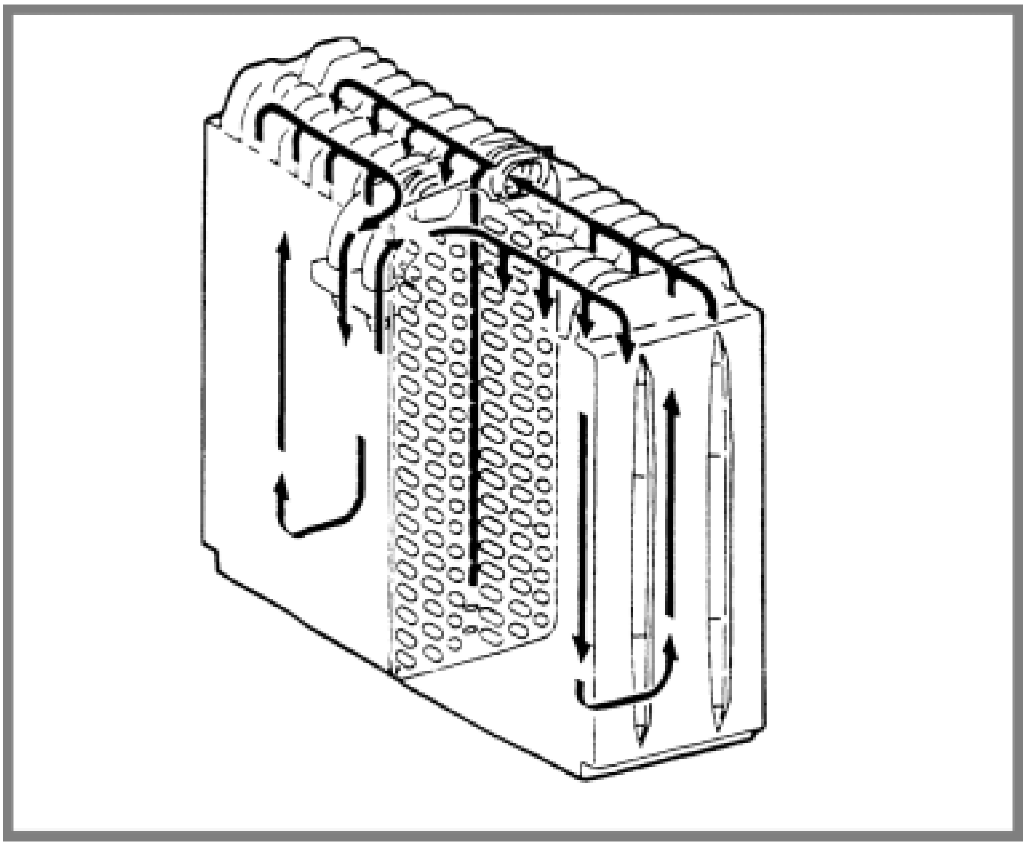


FIGURE 19. The evaporator removes heat from the passenger compartment and transfers it to the refrigerant as latent heat of vaporization.

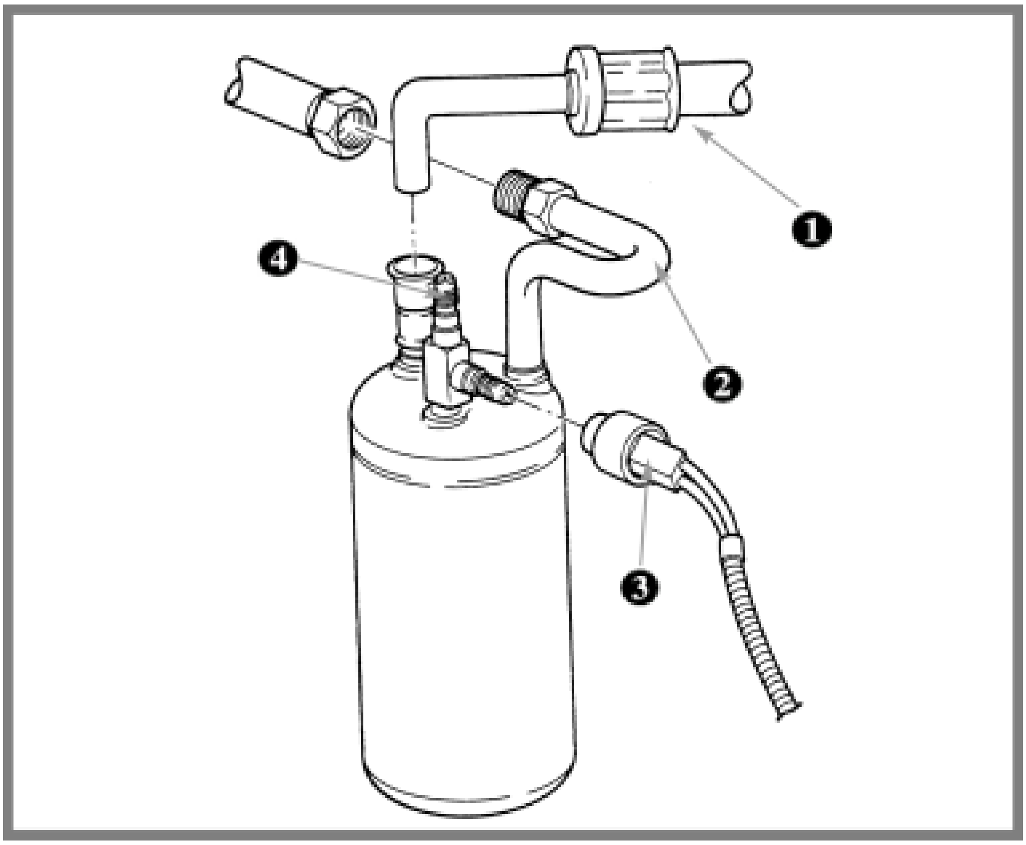
The blower fan forces warm air from the vehicle's interior over the surface of the evaporator. The refrigerant absorbs this heat as it changes from a liquid to a vapor (latent heat of vaporization). The refrigerant then exits the evaporator as a warm, low-pressure vapor.

ACCUMULATOR

The accumulator (Figure 20) is used in AC systems with an orifice tube. The accumulator is located after the evaporator and before the compressor, on the low-pressure side of the AC system.

FIGURE 20. The accumulator is located after the evaporator and before the compressor on the low-pressure side of the AC system.

- ❶ **To compressor suction line**
- ❷ **From evap. core**
- ❸ **Clutch cycling pressure switch**
- ❹ **Low pressure service port**



The accumulator functions very much like the receiver/dryer in an expansion valve system. However, the receiver/dryer is located on the high-pressure side of the system, between the compressor and condenser.

Figure 21 shows how an accumulator operates. The accumulator tank separates liquid refrigerant from gaseous refrigerant. Desiccant in the accumulator tank removes moisture from the refrigerant before it is sent on to the compressor.

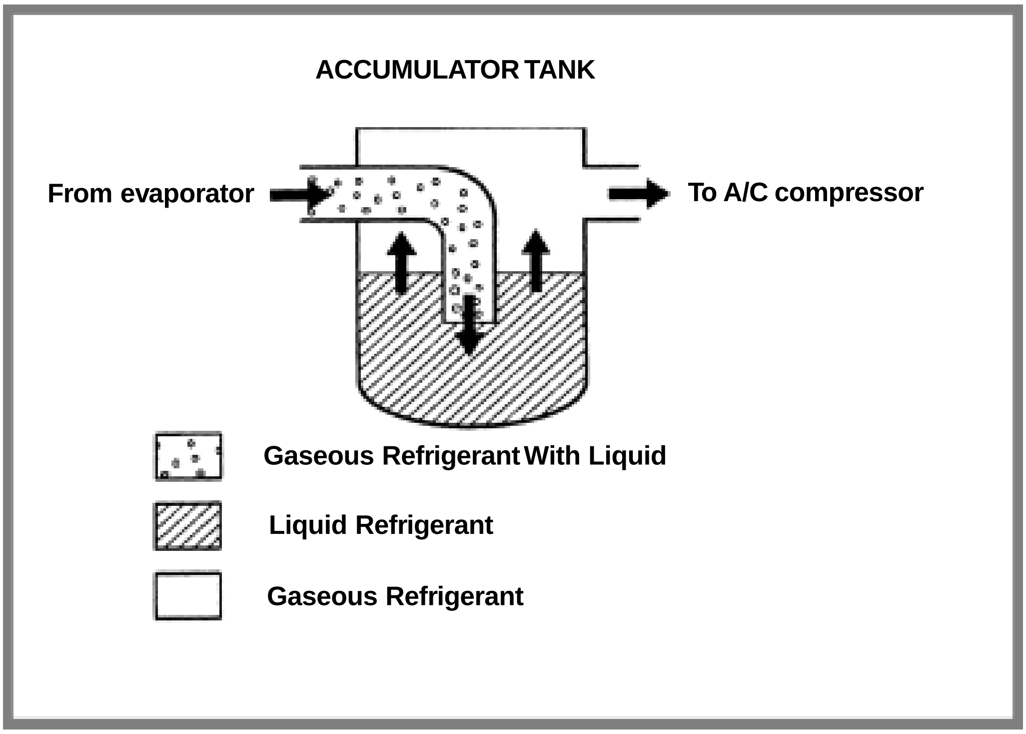


FIGURE 21. The accumulator tank prevents liquid refrigerant from entering the compressor, where it could damage the A/C system.

REVIEW EXERCISE 5

Match each component on the left to one of the descriptions on the right. Check your answers with the answer key on page 42.

1.	Receiver/Dryer	_____	A.	Transfers heat from passenger compartment to refrigerant
2.	Compressor	_____	B.	Lowers pressure by restricting refrigerant flow through a fixed opening
3.	Expansion valve	_____	C	Transfers heat from refrigerant to outside air
4.	Evaporator	_____	D.	Removes moisture from refrigerant
5.	Orifice tube	_____	E.	Lowers pressure by restricting refrigerant flow through a pintle valve
6.	Condenser	_____	F.	Raises pressure of refrigerant

OBJECTIVES

After completing this section, you will be able to:

- Describe the changes that take place in refrigerant as it flows through the A/C system.
- Explain the role that each major A/C component plays in the refrigeration cycle.

STAGES OF THE REFRIGERATION CYCLE

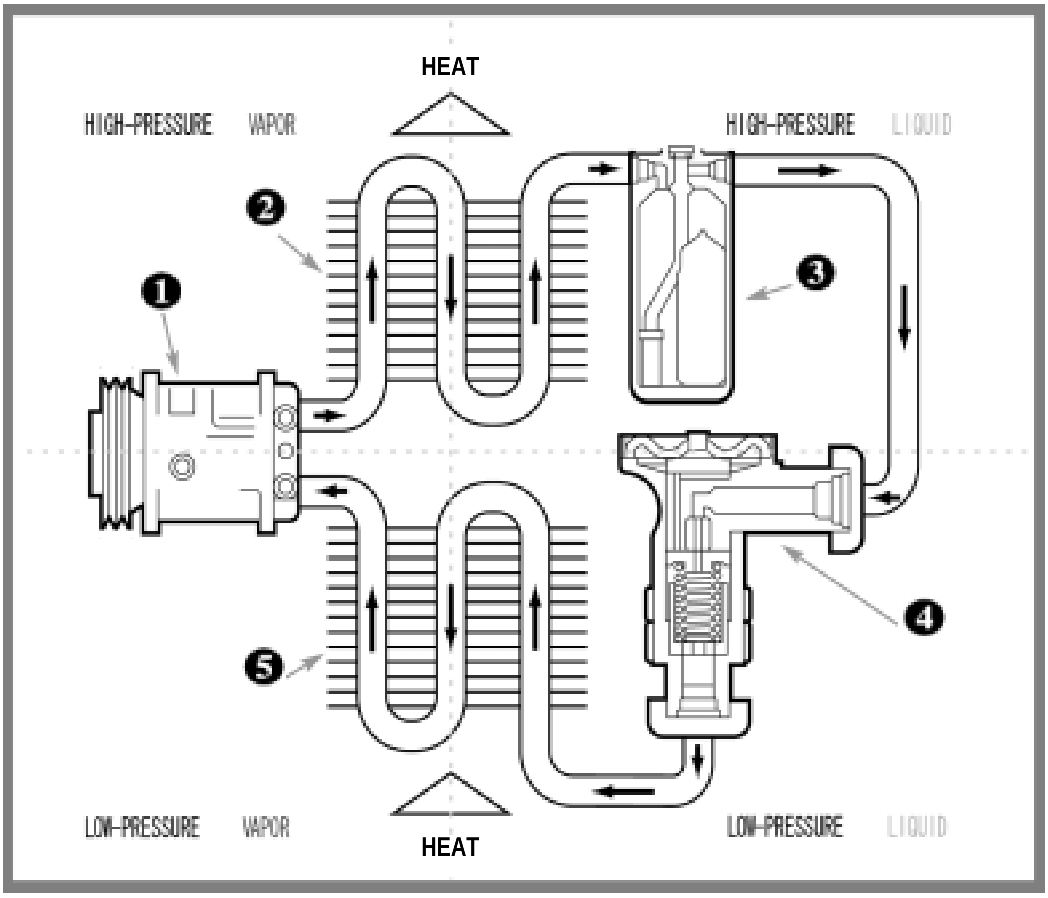
Overview

The previous section of this Guide showed that an automotive A/C system is a set of components that circulate refrigerant through a closed circuit. Refrigerants are special chemicals designed to absorb and release heat quickly. They have a very low boiling point — well below 0° F (-18° C) at sea level — and they respond predictably to changes in pressure. (The next section of this Guide describes refrigerants in more detail.)

Figure 22 shows how refrigerant circulates through an A/C system. As it flows through a complete cycle, the refrigerant undergoes two changes in pressure and two changes of state. The four sections of the illustration show the changes.

FIGURE 22 The refrigeration cycle includes a high-pressure side (top) and a low-pressure side (bottom). In addition, the refrigerant changes from a vapor (left) to a liquid (right).

- ❶ **Compressor**
- ❷ **Condenser**
- ❸ **Receiver/ dryer**
- ❹ **Expansion valve**
- ❺ **Evaporator**



The horizontal line divides the cycle into a “high-pressure side” on top and a “low-pressure side” on the bottom. The high-pressure side starts at the compressor outlet, extends through the condenser and receiver/dryer, and ends at the expansion valve.

When refrigerant leaves the expansion valve, its pressure drops and it enters the low-pressure side. The low-pressure side extends through the evaporator and into the compressor’s inlet.

The vertical line in the illustration marks the points where the refrigerant changes state. On the left side of the circuit, the refrigerant is a vapor; on the right side, it is a liquid.

High Pressure

We will begin the refrigeration cycle at the compressor, located on the left side of Figure 23.The compressor draws in low-pressure vapor (about 30 psi) from the evaporator and compresses it to about 175 psi. A drive belt on the engine turns the compressor pulley, which spins the compressor when its magnetic clutch is engaged. The system monitors refrigerant pressure and activates the compressor only when needed.

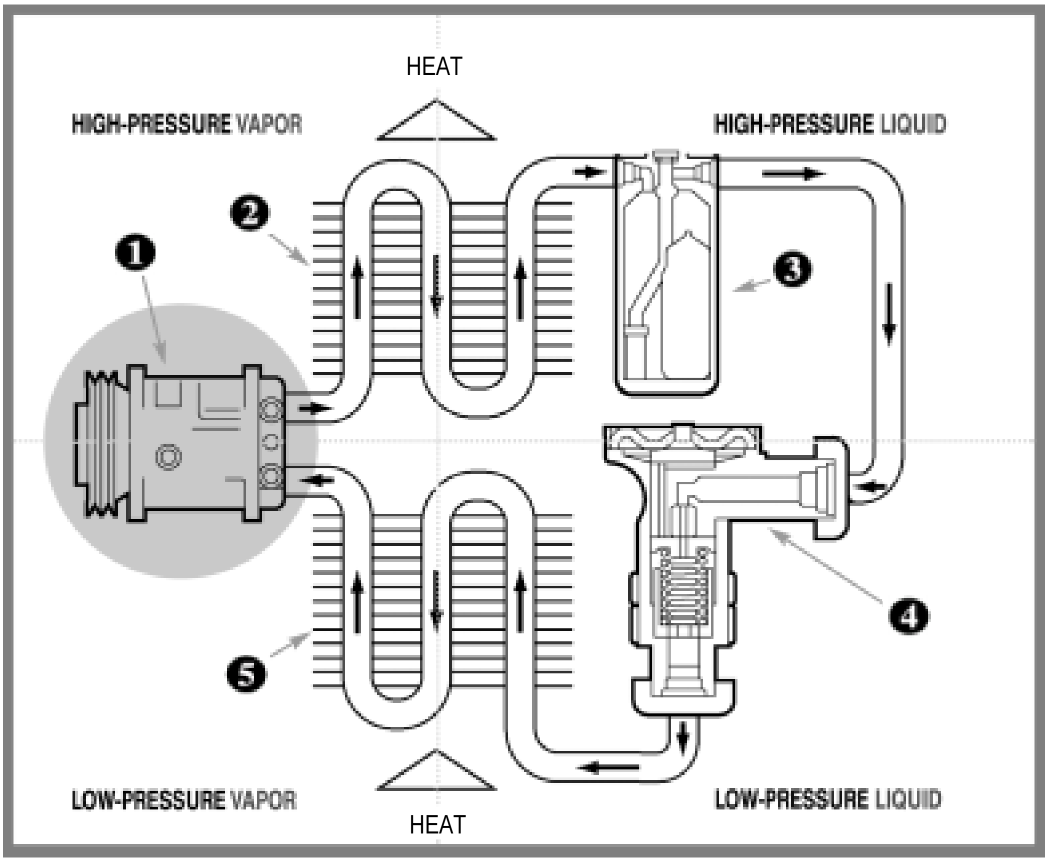


FIGURE 23 The compressor draws in warm, low-pressure vapor from the evaporator and pushes out highly compressed, hot vapor. Pressure on the "high side" remains elevated because the expansion valve restricts flow in the circuit.

1. **Compressor**
2. **Condenser**
3. **Receiver/ dryer**
4. **Expansion valve**
5. **Evaporator**

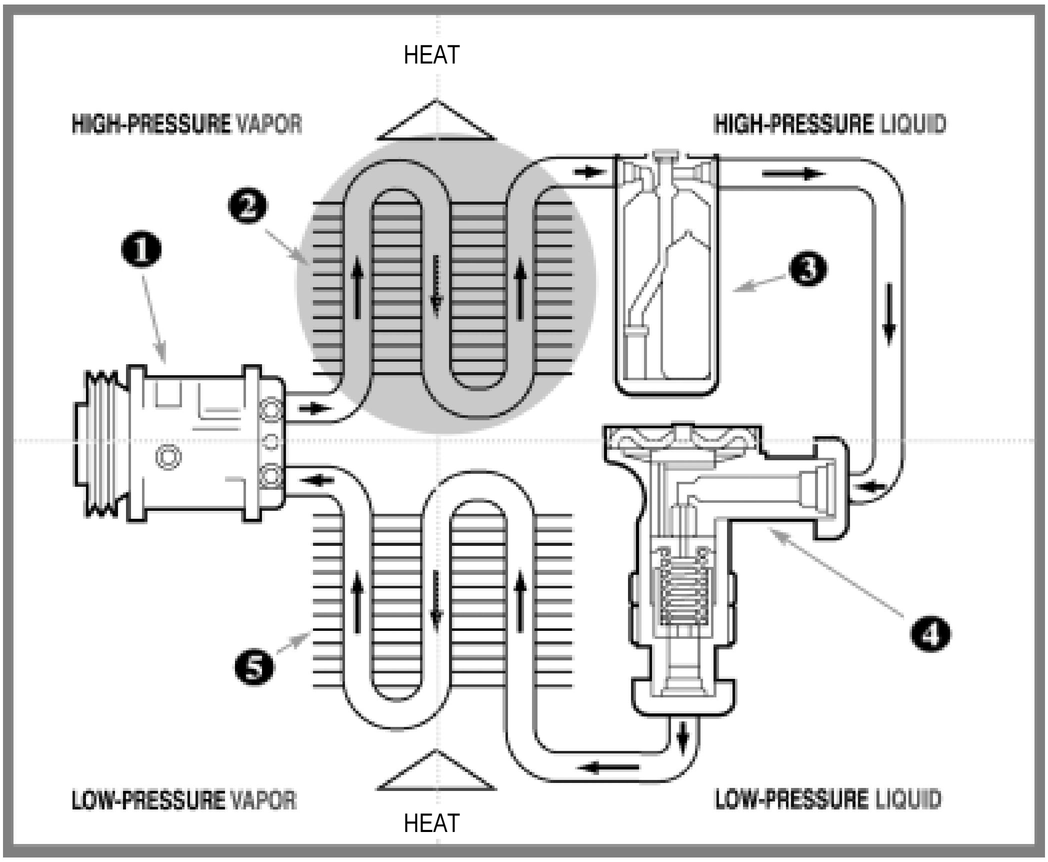
The compressor pushes this vapor through the outlet to the condenser. (The expansion valve is the "plug" in the circuit that allows pressure to build on the high-pressure side of the system.) This hot, high-pressure vapor carries heat picked up in the evaporator, as well as additional heat from the increased pressure provided by the compressor. At this point, the refrigerant may be as hot as 130° F (54° C).

Condensation

The hot, high-pressure vapor from the compressor next enters the condenser, as shown in Figure 24.

FIGURE 24. The hot, high- pressure vapor entering the condenser quickly cools and turns to liquid, releasing latent heat of condensation.

1. **Compressor**
2. **Condenser**
3. **Receiver/ dryer**
4. **Expansion valve**
5. **Evaporator**



The refrigerant is now under high pressure (about 175 psi), so its boiling point is also higher. In addition, the difference between the temperature of the outside air and the refrigerant is great, so the refrigerant will quickly release heat to the air flowing over the surface of the condenser. The hot gas (approximately 130° F [54° C]) quickly cools below its high boiling point. As the vapor condenses to a liquid, it releases large amounts of heat (latent heat of condensation).

Airflow across the condenser may decrease when the vehicle is not moving or in stop-and-go traffic. To compensate, most A/C systems include an electric fan to supply additional airflow when needed.

Pressure Reduction

After flowing through the receiver/dryer, which removes moisture and contaminants, the liquid refrigerant next enters the expansion valve, as shown in Figure 25.

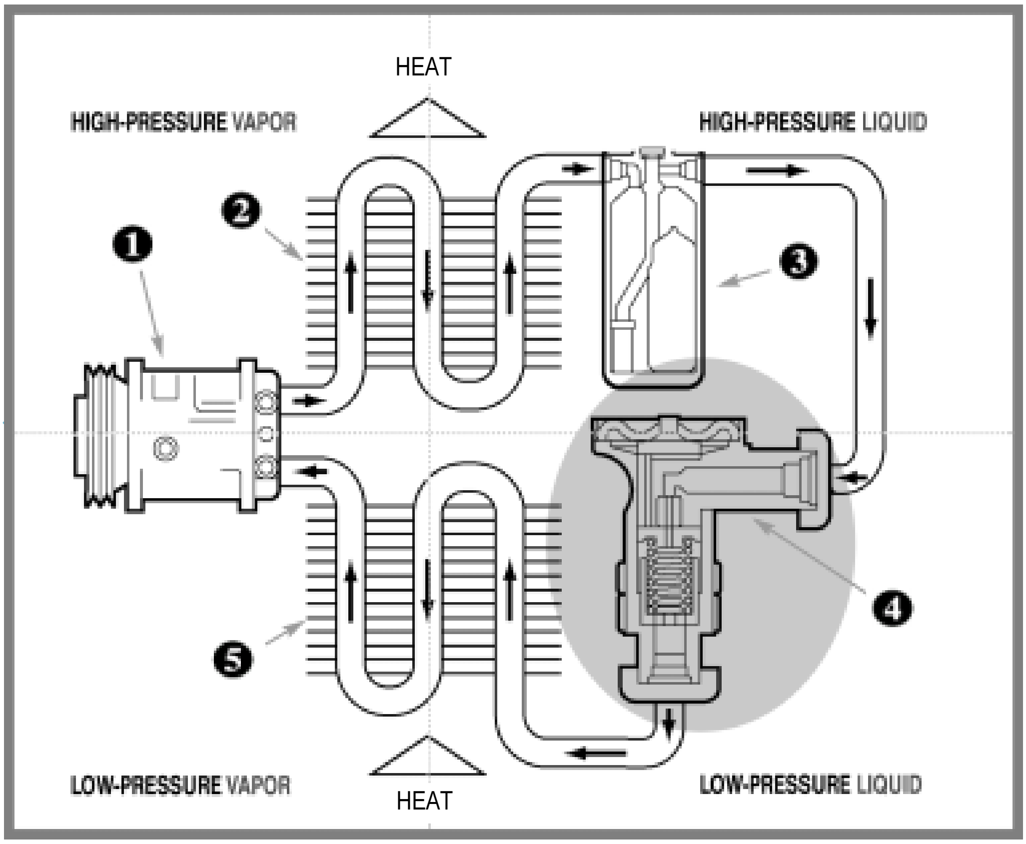


FIGURE 25. The expansion valve restricts the flow of refrigerant, decreasing its pressure, temperature, and boiling point.

- **1 Compressor**
- **2 Condenser**
- **3 Receiver/ dryer**
- **4 Expansion valve**
- **5 Evaporator**

The expansion valve restricts the flow of refrigerant, allowing only a small amount to pass through on its way to the evaporator. Refrigerant pressure on the high side of the expansion valve can be as high as 250 psi or more. The expansion valve reduces that pressure to about 30 psi on the low side.

At this low pressure, the temperature of the liquid refrigerant drops from about 130° F (54° C) to about 30° F (-1° C), and its boiling point decreases.

As the refrigerant passes through the expansion valve, it is *atomized,* or turned into a fine, liquid mist. This process increases the surface area of the refrigerant so it will easily absorb heat when it passes through the evaporator.

Evaporation

As the refrigerant flows into the evaporator (Figure 26), it is a cold, low-pressure liquid mist.

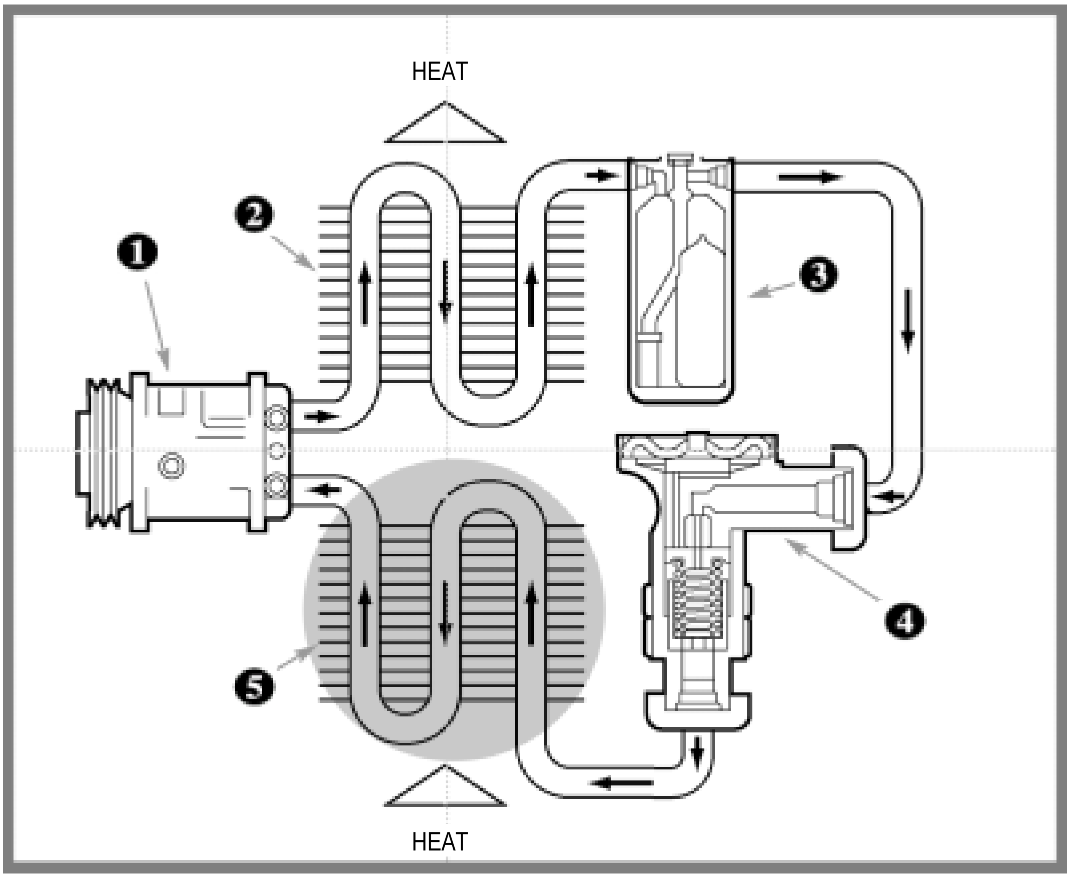


FIGURE 26. In the evaporator, the refrigerant picks up heat from the passenger compartment and changes into a low-pressure vapor. The compressor draws in this warm vapor and compresses it to begin the refrigeration cycle.

1. **Compressor**
2. **Condenser**
3. **Receiver/ dryer**
4. **Expansion valve**
5. **Evaporator**

At this low temperature (about 30° F [-1° C]), the refrigerant readily picks up heat from the passenger compartment. A blower fan pushes warm interior air over the evaporator, where it gives up its heat and returns to the passenger compartment as cool air. Since the refrigerant's boiling point is lower, it quickly changes into a vapor, allowing it to store large amounts of heat as latent heat of vaporization.

After picking up heat in the evaporator, the refrigerant gas is drawn into the inlet side of the compressor, where it begins another refrigeration cycle.

Orifice Tube System

An orifice tube system works similar to an expansion valve system. However, since the orifice tube is a fixed size, the tube must flood the evaporator to work properly under all conditions. As the refrigerant passes through the evaporator, most of it changes into vapor and then travels to the accumulator, as shown in Figure 27.

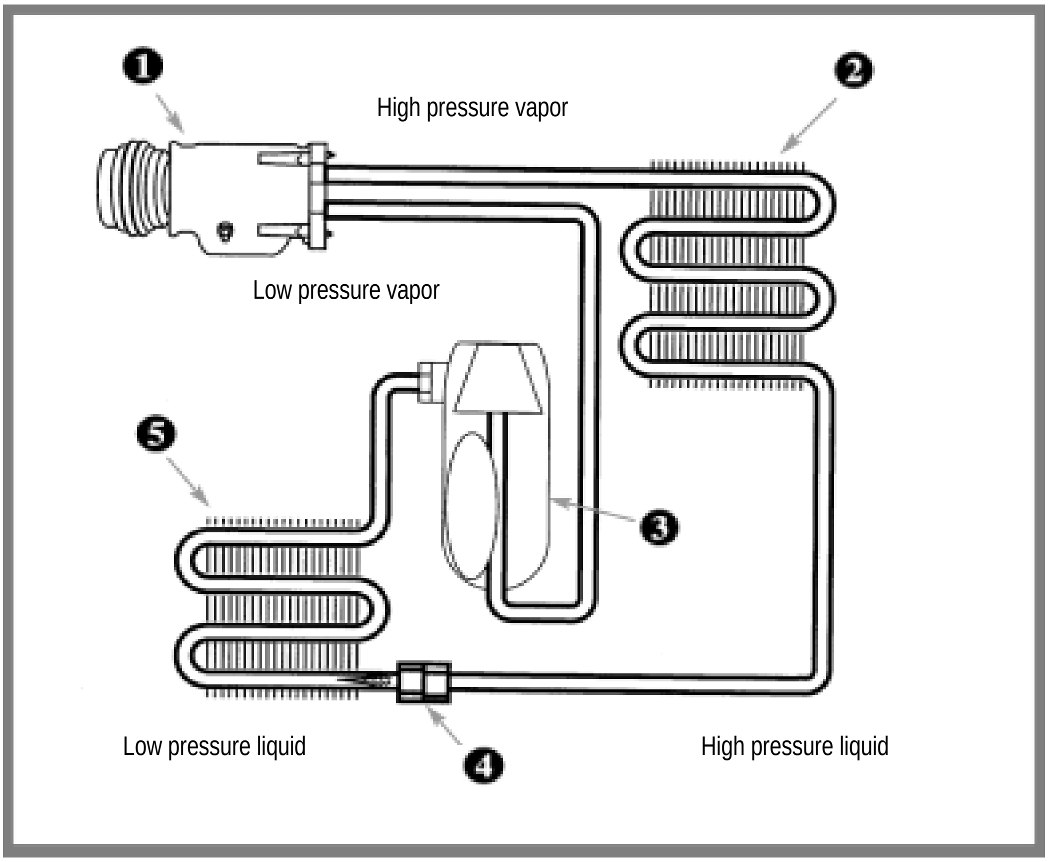


FIGURE 27. As the refrigerant passes through the evaporator, most of it changes into vapor and then travels to the accumulator.

1. **Compressor**
2. **Condenser**
3. **Accumulator**
4. **Orifice tube**
5. **Evaporator**

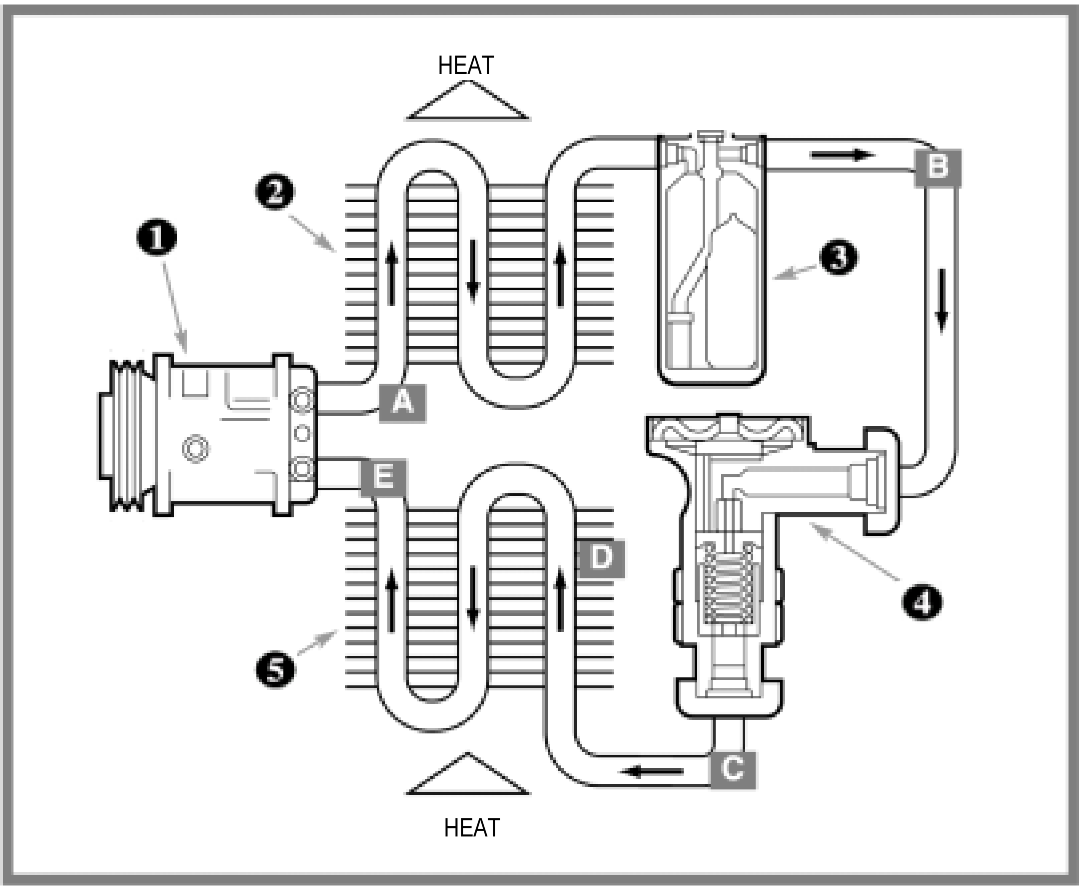
As we discussed before, the accumulator replaces the receiver / dryer in the system. The accumulator separates the liquid refrigerant from the refrigerant vapor. This prevents liquid refrigerant from getting back into the compressor, and allows higher heat loads by keeping the remaining liquid on hand.

REVIEW EXERCISE 6

Use the diagram below to answer the following questions. Check your answers with the answer on page 50.

1. At point **A** in the diagram, is the refrigerant pressure high or low?
2. At point **A**, is the refrigerant a vapor or a liquid?
3. Is the refrigerant at point **A** hotter or colder than the refrigerant at point **C**?
4. At point **B**, is the refrigerant a vapor or a liquid?
5. At point **C**, is the pressure of the refrigerant low or high?
6. At point **D**, does the refrigerant absorb or release heat?
7. Is the refrigerant at point **E** hotter or colder than the refrigerant at point **A** ?
8. At point **E**, is the refrigerant a vapor or a liquid?

1 Compressor
2 Condenser
3 Receiver/ dryer
4 Expansion valve
5 Evaporator



7 – REFRIGERANTS

OBJECTIVES

After completing this section, you will be able to:

- Describe the chemical structure and properties of R-12 refrigerant.
- Describe the chemical structure and properties of R-134a refrigerant.
- Describe the differences between R-12 and R-134a.
- Define recycled, reclaimed, and extracted refrigerant.
- Explain procedures for storing recycled refrigerant.
- Describe the two approaches for retrofitting older A/C systems.
- Follow safety procedures and rules when working with A/C systems.

INTRODUCTION TO REFRIGERANTS

Auto air conditioning systems typically use one of two types of refrigerant, either R-12 (in older vehicles) or R-134a (in newer vehicles). The R stands for refrigerant. Both chemicals are suitable A/C refrigerants because they have very low boiling points.

Though similar in many respects, R-12 and R-134a affect the environment differently. The following pages describe these two refrigerants, highlighting the differences between them, as well as proper storage and handling techniques.

CFC-12 (R-12)

R-12 is the common name for *Dichlorodifluoromethane-12* (CFC-12), a chemical used in many types of refrigeration systems up until about 1990.

Chemical Structure

Figure 28 shows the chemical structure of CFC-12. It contains a single carbon atom, surrounded by two fluorine atoms and two chlorine atoms. The chemical formula for CFC-12 is CCl2F2

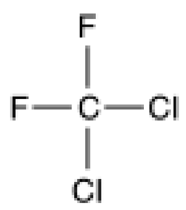


FIGURE 28. CFC-12 contains carbon, fluorine, and chlorine. It was commonly used as a refrigerant until about 1990.

Properties of R-12

R-12 is a suitable refrigerant because of its excellent ability to absorb large quantities of heat. In addition, R-12:

- Is odorless, tasteless, non-toxic, and non-corrosive.
- Does not damage rubber seals used in the system.
- Is soluble in oil, which is important because the refrigerant carries the lubricating oil to the A/C system compressor.
- Has a very low boiling point of -22° F (-30° C) at sea level; this property allows R-12 to absorb and carry off large quantities of heat.
- Has a direct, predictable relationship between its temperature and pressure, which lets R-12 absorb or release large amounts of heat in response to changes in pressure.

In the mid-1980s, scientists discovered that chemicals called chloro-fluorocarbons (CFCs) were destroying the ozone in the atmosphere. Ozone protects the earth from harmful ultraviolet rays released by the sun.

One of the major contributors to CFCs in the atmosphere was R-12, which often leaked into the atmosphere during servicing of A/C systems. In 1987, the United States and 22 other countries signed an international agreement calling for the gradual phase-out of CFCs.

In 1990, the United States revised the federal Clean Air Act, adding stricter CFC standards than the international agreement. As a result, R-12 was phased out of most automotive A/C systems in about 1990. By the year 2000, R-12 will be banned completely.

HFC134a (R-134a)

Because of the environmental damage caused by R-12, scientists developed an alternative refrigerant called R-134a. Most vehicles manufactured from 1990 to the present use R-134a as an A/C refrigerant.

Chemical Structure

R-134a is the common name for *Tetrafluoroethane-134a* (HFC-134a), whose chemical formula is CH2FCF3. Unlike R-12, R-134a does not contain CFCs. Instead, it contains hydrofluorocarbons (HFCs), which do not damage the ozone layer.

Figure 29 shows the chemical structure of R-134a, which contains two carbon atoms, two hydrogen atoms, and four fluorine atoms.

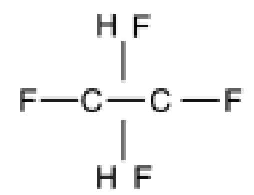


FIGURE 29. R-134 contains carbon, hydrogen, and fluoride atoms. It is used as a refrigerant in most vehicles built from 1990 to the present.

Properties of R-134a

Like R-12, R-134a has chemical properties that make it ideal for use as a refrigerant. These include:

- Low boiling point of -15° F (-26° C) at sea level.
- Ability to change temperature readily in response to changes in pressure.

R-134a provides most of the benefits of R-12 without the harmful atmospheric effects. The absence of chlorine in R-134a makes it environmentally “friendly,” but R-134a can be flammable under certain pressures and concentrations. For more information about these conditions, see “Safety Procedures” on page 57.

DIFFERENCES BETWEEN REFRIGERANTS

A/C systems that use one type of refrigerant cannot use the other type. For example, you cannot use R-134a to charge an older A/C system designed to use R-12. (Some older systems can be retrofit to use the new refrigerant, but these are special cases. See “Retrofitting” on page 56.)

Under no circumstances can you mix R-12 and R-134a in the same system. Mixing refrigerants is called *cross-contamination*, and it can seriously damage the A/C system. In addition, identifying contaminated refrigerant during normal diagnosis is difficult.

The chart below outlines the differences between the two refrigerants. Whenever you work on an A/C system, you *must* determine the refrigerant type.

	R-12	**R-134a**
Container color	White	Light blue
Container marking	R-12	R-134a
Container fitting size	7/16" - 20; 1/4" flare	1/2" - 16 ACME
Chemical name	Dichlorodifluoromethane	Tetrafluoroethane
Boiling point	-21.62° F (-29.70° C)	-15.07° F (-25.15° C)
Latent heat of vaporization	36.43 BTUs @ 32° F (0° C)	47.19 BTUs @ 32° F (0° C)

To prevent cross-contamination, always observe the following rules:

1. Refer to the tags or bands around the lines and tubes to identify the refrigerant used in the system.

2. Do not mix R-12 and R-134a service equipment.

3. Do not use adapters to cross from one refrigerant to the other.

4. You may use new R-134a rubber seals and hoses on an R-12 system. However, you may not use R-12 rubber seals and hoses on an R-134a system.

RECYCLED, RECLAIMED, AND EXTRACTED REFRIGERANT

Technicians often remove *(discharge)* refrigerants from an A/C system during service. Depending on how these refrigerants are processed after removal, they are called *recycled, reclaimed,* or *extracted.*

Recycled Refrigerant

Recycled refrigerant is cleaned to remove contaminants produced during normal operation of a mobile A/C system. Mixing recycled refrigerant from a non-mobile system — a building A/C system, for example — will contaminate recycled mobile refrigerant.

Reclaimed Refrigerant

Reclaimed refrigerant is processed to the same standards and purity as new refrigerant. This process requires expensive equipment not ordinarily found in dealership service departments.

Reclaimed and recycled refrigerant will perform equally well in all mobile A/C systems.

Extracted Refrigerant

Extracted refrigerant is simply removed and stored in an approved container, without any filtering or processing. Before you return extracted refrigerant to a vehicle A/C system, you should recycle it to remove impurities.

STORING RECYCLED REFRIGERANT

Both R-12 and R-134a are gases at normal room temperature, and they can be hazardous if stored improperly. New refrigerant stored in its original, properly filled container usually poses no safety hazard. However, recycled refrigerant can be dangerous if it is stored in the wrong type of container or in an overfilled container.

To prevent accidents when handling recycled refrigerant, always follow the rules below:

1. *Never* save disposable refrigerant containers for reuse. Remove all refrigerant and dispose of the containers properly.
2. Use only containers approved by the U.S. Department of Transportation. Approved containers are marked “DOT4BA” or DOT4BW.”
3. Never fill a container to more than 60 percent of its capacity.
4. Never store refrigerant containers in direct sun or heat. High temperature causes the gas to expand, which increases the pressure in the container. Figure 30 shows what can happen if a properly filled container reaches a temperature of 100° F (38° C).

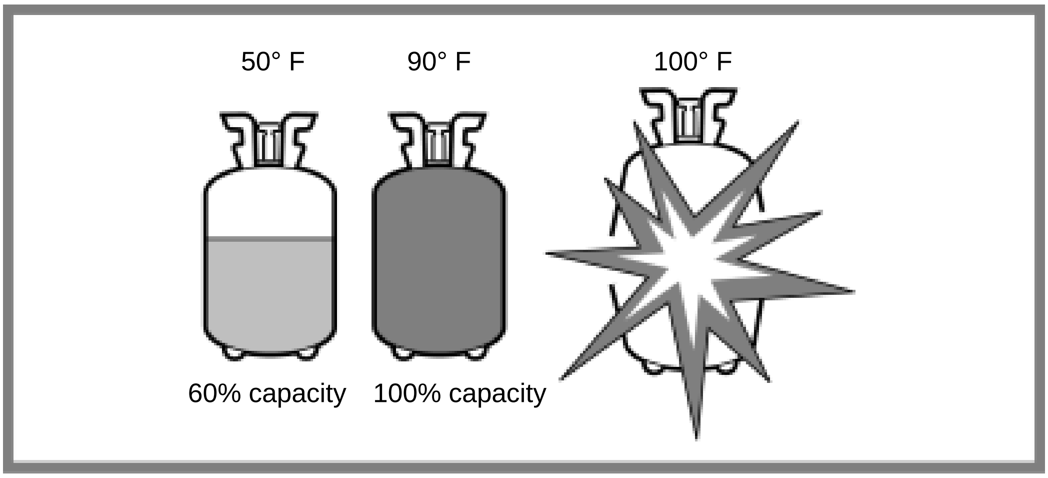


FIGURE 30. A container filled to 60 percent capacity at 50° F (10° C) poses no safety hazard. However, the same container at 90° F (32° C) reaches its maximum capacity. At 100° F (38° C), high pressure in the container can cause an explosion.

5. Before using any recycled refrigerant, always check for air in the tank. Air is a *non-condensable* gas; its volume cannot be reduced. This could create a very dangerous situation. If you have air and refrigerant in a container and you heat the container, the pressure rises. The refrigerant changes state, but the air doesn't. This creates excess pressure that can cause an explosion. In addition, under some conditions, recycled refrigerant mixed with air can be flammable.

Fortunately, there is simple rule of thumb that can help you check for non- condensable gases in recycled R-12. At temperatures between 25° F and 75° F, the pressure of R-12 (in psi) should be roughly equal to its temperature (in ° F). For example, if you have a container of R-12 refrigerant at 75° F, then the pressure should be approximately 75 psi.

You can use the following temperature/pressure relationship chart for R-12. (Notice that the center column demonstrates the one-to-one relationship between temperature and pressure.) If the pressure is higher or lower than the listed pressure at a given temperature, then you probably have air in the tank, and you should *not* use the container.

R-12 Temperature/Pressure Relationship

° F	Pressure	° F	Pressure	° F	Pressure
-35	8.3*	25	24.6	80	84.1
-30	5.5*	30	28.5	85	91.7
-25	2.3*	32	30.1	90	99.6
-20	0.6*	35	32.6	95	108.1
-15	2.4	40	37.0	100	116.9
-10	4.5	45	41.7	105	126.2
-5	6.8	50	46.7	110	136.0
0	9.2	55	52.0	115	146.5
5	11.8	60	57.7	120	157.1
10	14.7	65	63.7	125	167.5
15	17.7	70	70.1	130	179.0
20	21.1	75	76.9	140	204.

*Inches of mercury (vacuum); all other pressures are in pounds per square inch (psi).

RETROFITTING

Many older vehicles on the road have A/C systems designed for R-12 refrigerant. As R-12 production is phased out (and completely eliminated by 2000), the auto industry is exploring ways to retrofit these vehicles so they can use more environmentally friendly refrigerants. These efforts have focused on two approaches: "drop-in" replacement refrigerants, and retrofitting system components.

"Drop-In" Replacement Refrigerants for R-12

In the past few years, several non-R-12 replacement refrigerants have appeared on the market. Supposedly, you can simply add these "drop-in" replacements to an existing R-12 system with no noticeable effects.

Unfortunately, most of these drop-in replacement refrigerants are highly combustible and hazardous to service technicians. Because of these safety problems, the Environmental Protection Agency (EPA) has banned all such refrigerants for use in passenger vehicles. However, these refrigerants are legally sold.

Currently, there is *no* satisfactory replacement for R-12, and Mazda strongly recommends that you *do not* use R-12 replacement refrigerants. Using drop-in replacements can contaminate a dealership's supply of R-12, and diagnosing this type of contamination can be very difficult. In addition, there is an ample supply of R-12 to service older vehicles.

Retrofitting System Components

The EPA and most A/C professional organizations recommend component retrofitting to meet the needs of older vehicles. As the original components — such as the compressor, condenser, and evaporator — wear out, replacing them with R-134a retrofit components makes the cost more acceptable.

SAFETY PROCEDURES

A/C service and repair is potentially dangerous. You will be dealing with refrigerant and coolant at high pressures and temperatures, and you will be working in the middle of an operating engine. In addition, the chemical properties of refrigerant make it potentially hazardous if not handled properly.

For these reasons, you must observe the following safety rules whenever you work on an A/C system.

1. *Always* wear eye protection. If refrigerant gets in your eyes, you could be blinded. Keep a supply of sterile mineral oil and a weak solution of boric acid handy to wash out your eyes in case of an accident. In addition, make sure you have a physician's phone number readily available.

2. Wear a long-sleeved shirt and rubber gloves to minimize areas of exposed skin. If you accidentally release pressurized refrigerant on your skin, the area may be frostbitten. At the very least, evaporation on the skin will cause severe drying.

3. Ventilate confined work areas. Refrigerants are about three times heavier than air so they tend to collect in confined spaces. Make sure the area is well ventilated to prevent suffocation.

4. Although refrigerant is not ordinarily combustible, it can become flammable when mixed with air. Always test for air in the storage tank before using a refrigerant.

5. Do not expose refrigerant to open flame. R-12 may produce poisonous phosgene gas, and R-134a may support combustion.

6. Refrigerants readily absorb moisture and may form hydrochloric and hydrofluoric gases if released.

7. Before starting the engine, make sure hands, clothes, cords, shop towels, and tools are clear of all belts and fans.

8. Be careful when steam-cleaning an engine near A/C lines. The high temperature of the steam can raise the internal pressure of the A/C system.

9. Always use proper tools and equipment designed for A/C system service.

REVIEW EXERCISE 7

Fill in the words that complete these sentences correctly. Check your answers with the answer key on page 60.

1. An approved refrigerant storage container will be marked with _____________ or _____________.
2. Refrigerant ____________________ causes environmental damage to the earth's ozone layer.
3. Refrigerant ____________________ has a boiling point of about -15° F (-25° C).
4. Mazda recommends ____________________ "drop-in" replacement refrigerant for R-12 A/C systems.
5. Refrigerant that is processed to the same standards and purity as new refrigerant is called ____________________.
6. Refrigerant that touches exposed skin can cause _______________________ and _______________________.
7. Refrigerant ____________________ produces hydrofluorocarbons, rather than chlorofluorcarbons.
8. Refrigerant ____________________ normally comes in a white container.

OBJECTIVES

After completing this section, you will be able to:

- Explain the purpose of refrigeration lubrication.
- Identify the differences between mineral oil and PAG oil.
- Describe the characteristics of refrigeration oil.
- Explain why you must add oil to an A/C system when you replace components.

REFRIGERATION LUBRICATION

Refrigeration oil lubricates the moving parts and seals of an A/C system. The oil flows with the refrigerant throughout the system. Refrigeration oil and motor oil are different. *Never* use motor oil in an A/C system.

Mineral Oil and PAG Oil

The type of refrigeration oil used in an A/C system depends on the type of refrigerant. In fact, when engineers develop a refrigerant, they simultaneously develop the lubrication oil used with it.

- R-12 A/C systems use mineral oil as a lubricant. Different types of compressors in R-12 systems require different types of mineral oil.
- R-134a systems use oil made of polyalkylene glycols, commonly called PAG oil.
- PAG oil and mineral oil are completely incompatible. *Never* mix them.

Characteristics of Refrigeration Oil

Refrigeration oil — either mineral or PAG — is highly refined and free of the additives and detergents found in conventional motor oil. Refrigeration oil flows freely at temperatures well below freezing, and it includes an additive to prevent foaming in the A/C system.

Refrigeration oil readily absorbs moisture. If stored improperly, the oil becomes unusable. For example, an unsealed container of PAG oil becomes saturated with two percent water if left in a humid climate for five days. If you use saturated oil in an A/C system, acids will form, damaging seals and other components. Always seal refrigerant oil properly after use, and never reuse oil removed from an operating A/C system.

Some A/C systems use a compressor with carbon seals. In these cases, the refrigeration oil may have a dark color. This color is normal.

OIL QUANTITY AND COMPONENT REPLACEMENT

In a new A/C system, the compressor holds all the refrigerant oil. The compressor mixes the oil with the refrigerant and circulates it throughout the system. After the system has been used, some refrigerant oil may be stored in the evaporator or condenser.

When you replace an A/C component, you must also replace the refrigeration oil trapped in the component. Service manuals contain charts describing how much oil to add for various component replacements. For example, the chart may tell you to add 30 ml of refrigerant oil after replacing a condenser.

If an A/C system develops a leak, refrigeration oil will appear at the site of the leak. Any leaking refrigerant evaporates immediately. The amount of oil lost depends on the size of the leak and the length of time it was leaking. After you repair a leak, replace the amount of lost oil. Carefully measure the oil removed during evacuation and replace it with a slightly greater amount.

REVIEW EXERCISE 8

Mark each statement as true or false. Check your answers with the answer key on page 62.

1. True or false? When you replace an A/C component, you will usually need to add refrigeration oil as well.

2. True or false? Refrigerant is usually visible around the area where an A/C system is leaking.

3. True or false? You can reuse refrigeration oil removed from an operating A/C system.

4. True or false? PAG oil is suitable for R-134a A/C systems.

5. True or false? Refrigeration oil flows through a special set of grooves and channels drilled into A/C system components.

6. True or false? If refrigeration oil is not sealed properly, it will absorb moisture from the air.

7. True or false? You may use either mineral oil or PAG oil in R-12 systems.

OBJECTIVES

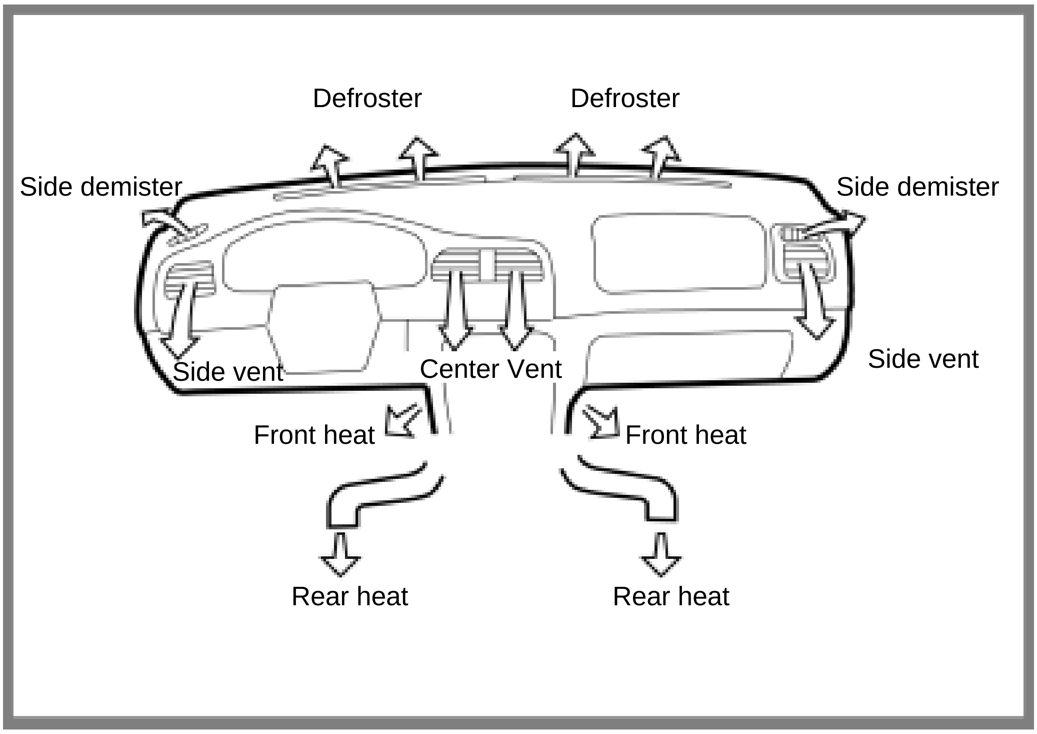
After completing this section, you will be able to describe how the following components direct airflow through the heating and A/C system:

- Fresh/re-circulated air door
- Blower fan
- Temperature blend door
- Defroster door
- Vent/face and heater doors

AIR FLOW MANAGEMENT COMPONENTS

The climate control system in Mazda vehicles provides conditioned air at the desired temperature. It is a combined heating and air conditioning unit. The operator can select heating or cooling and direct the air to specific vents on the dashboard. Figure 31 shows the location of these vents in a typical vehicle.

FIGURE 31. The Mazda climate control system allows the operator to select heating or cooling, with the conditioned air directed to various vents on the dashboard.



The heating and A/C system provides a desired comfort zone in the passenger compartment by controlling temperature and humidity. This comfort zone is subjective, varying from person to person. In addition, as weather conditions change, the system must allow changes in temperature and airflow direction.

To allow this flexibility, the system includes the following airflow management components:

- Fresh/re-circulated air door
- Blower fan
- Temperature blend door
- Defroster door
- Vent/face and heat doors

The following topics describe the operation of these components.

Fresh/Re-circulated Air Door

Air first enters the system through the fresh/re-circulated air door, as shown in Figure 32.

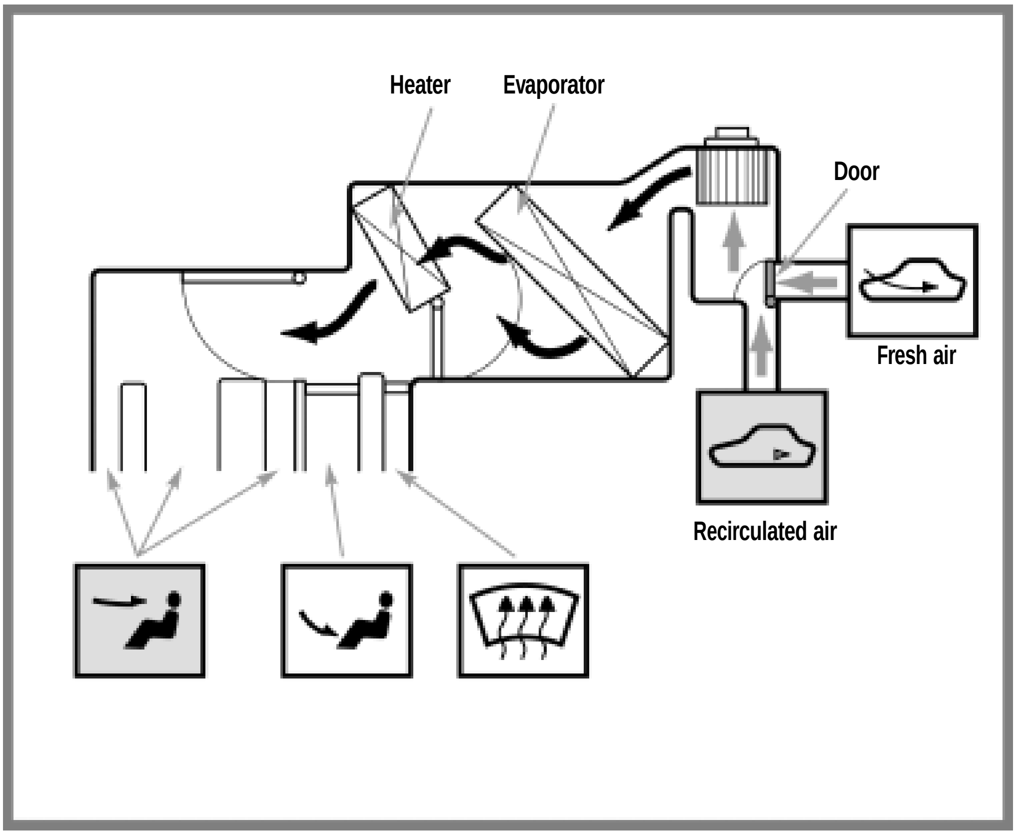


FIGURE 32. The fresh/re- circulated air door allows either outside air or re-circulated air from the vehicle interior into the heating and A/C system.

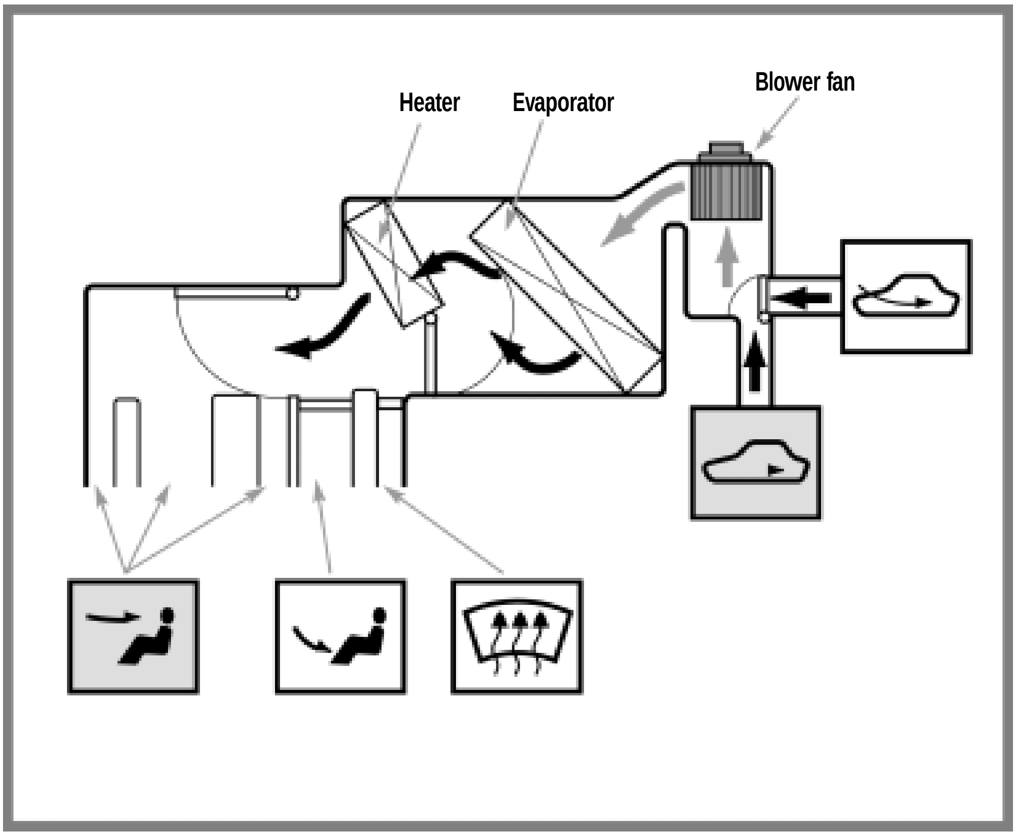
If the operator selects the fresh air option, the system draws outside air into the unit either by the force of the forward motion of the vehicle or with the assistance of a fan. During normal operation, the fresh air option provides the best results.

The re-circulated air option closes off the outside air passage and re-circulates cool, dehumidified air from the passenger cabin. This option provides maximum cooling.

Blower Fan

The blower fan, highlighted in Figure 33, draws air in through the fresh/ re- circulated air door. Depending on the system settings, the blower draws air through the evaporator (for cooling), the heater unit, or a combination of both.

FIGURE 33. The blower fan draws air through the fresh/re-circulated air door for cooling and/or heating.



If the fresh air door is open, a certain amount of “ram” air enters as the vehicle moves down the road. In most cases, this is not enough to provide noticeable airflow in the passenger compartment. The blower fan ensures that plenty of airflow is available for cooling and heating.

Temperature Blend Door

The temperature blend door, highlighted in Figure 34, controls airflow to the evaporator and heater.

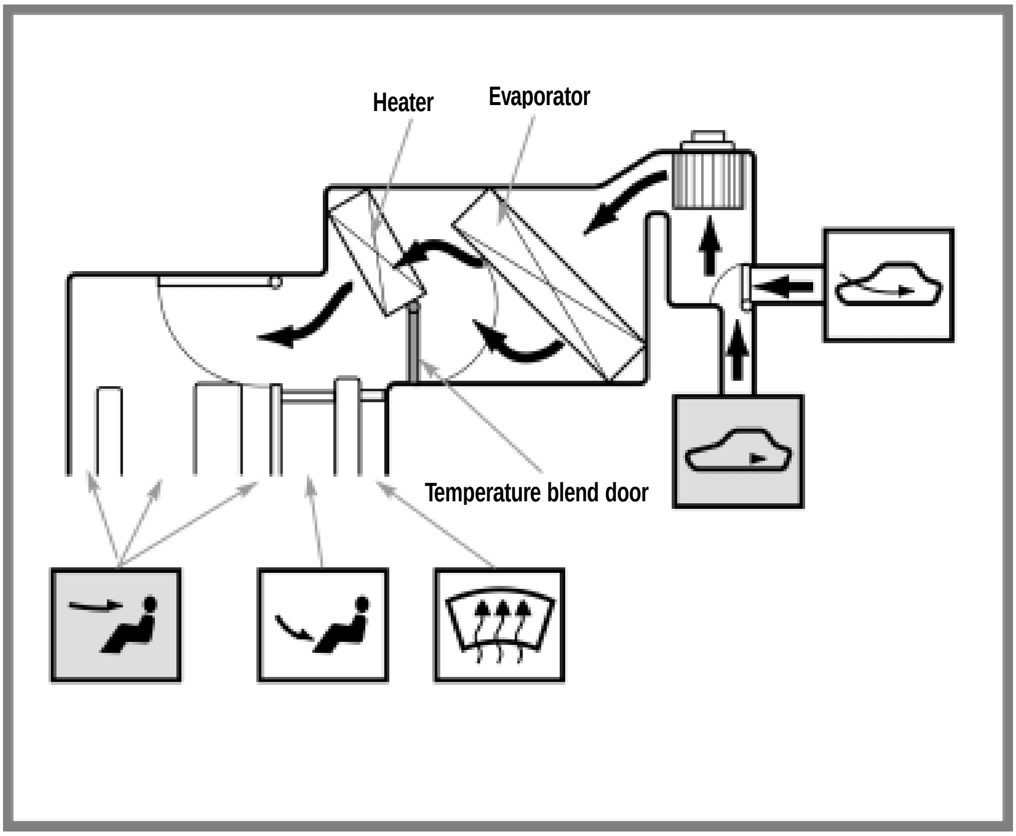


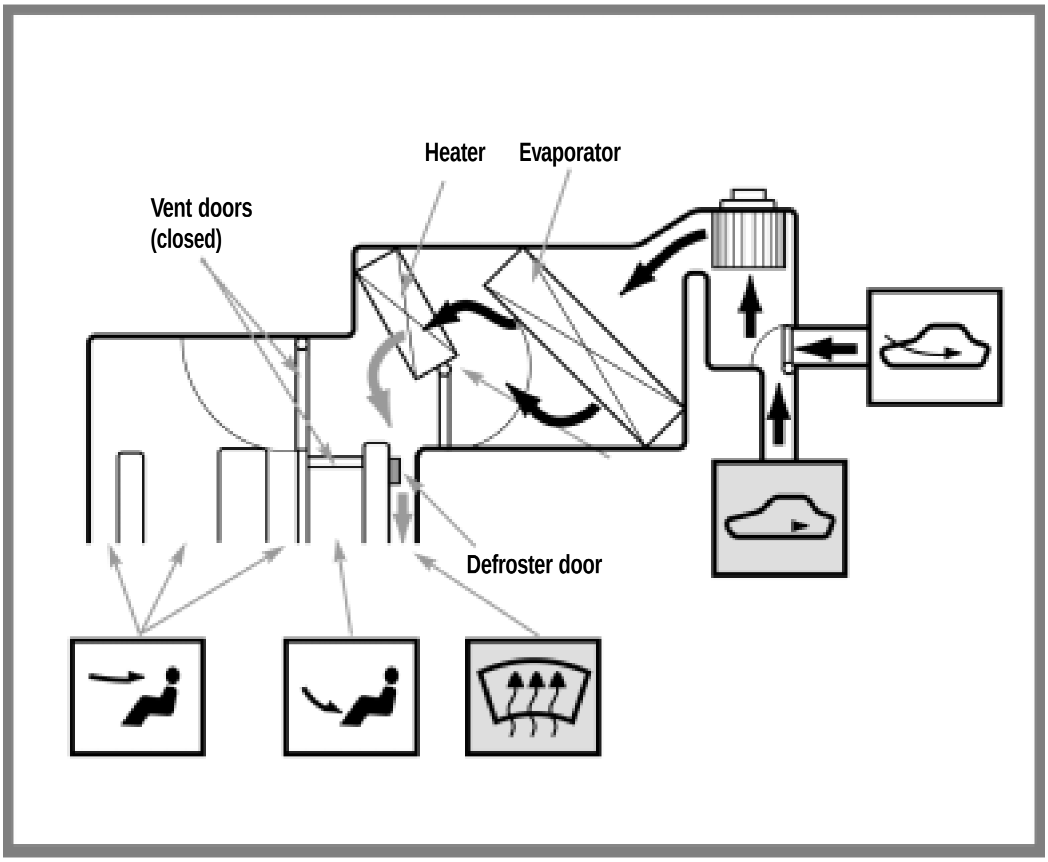
FIGURE 34. The temperature blend door directs airflow to the evaporator, the heater, or to both units.

The temperature blend door can be set to any position along the arc of its travel. With the system set to the “cool” position, the temperature blend door blocks all airflow to the heater. When the door is partially open, the air discharged into the passenger compartment is a combination of heated air, unheated air, and cooled air. Proper adjustment of the temperature blend door is critical to system performance.

Defroster Door

The defroster door redirects all airflow to the windshield. Figure 35 shows the defroster door.

FIGURE 35. The defroster door opens to let airflow on the windshield. At the same time, doors to the floor and upper vents close.



When the operator selects the defrost position, a door blocking the defroster passages opens, and other doors for the floor and upper vents close. This arrangement provides maximum airflow to the windshield area.

System operation depends on the correct adjustment of the defroster door. If incorrectly adjusted, the defroster door may open, allowing unintended airflow to the windshield.

Vent/Face and Heater Doors

The vent/face and heater doors (Figure 36) direct air either to the floor vents or the upper vents. If the operator selects the “bi-level” position, air will flow to both sets of vents.

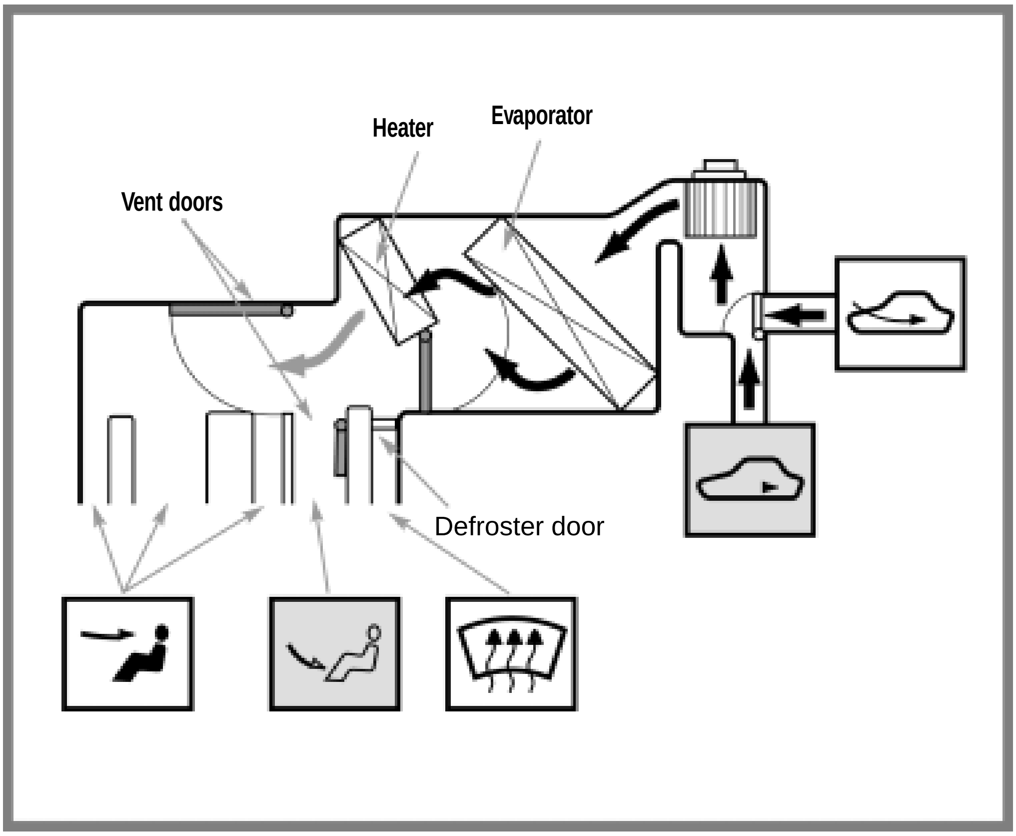


FIGURE 36. The vent/face and heater doors direct airflow to the upper or lower vents. In “bi-level” position, air flows to both sets of vents.

REVIEW EXERCISE 9

Match each component on the left to one of the descriptions on the right. Check your answers with the answer on page 72.

1. Vent/face and heater doors
2. Defroster door
3. Fresh/re-circulated air door
4. Temperature blend door
5. Blower fan

A. In bi-level position, allows air flow to upper and lower vents

B. Draws air over evaporator and/or heater

C. Directs air flow to evaporator, heater, or both

D. Opens to allow maximum air flow to windshield

E. Allows outside air into heating and A/C system

OBJECTIVES

After completing this section, you will be able to describe how to:

- Use a manifold gauge
- Recover refrigerant
- Evacuate an A/C system
- Test for a leak
- Charge a system using liquid or vapor refrigerant.

OVERVIEW

An automotive A/C system is under pressure and contains potentially lethal materials. Recharging an A/C system is not simply a matter of opening the system and adding refrigerant. You must take special precautions to prevent accidents.

Follow these five steps to ensure a safe and accurate recharge:

1. Air conditioners have both a high-pressure and a low-pressure side. Use a manifold gauge to check the system's pressures. If either side's pressure is too high or low, the A/C system will not perform correctly, and might explode.
2. Recover the refrigerant.
3. Evacuate the trapped moisture in the system. If moisture remains, the system will not perform properly and dangerous chemical compounds may form.
4. Check the system for leaks and repair any you find.
5. Recharge the system with the correct type and amount of refrigerant.

The remainder of this section, discuses each step in detail.

CHECK THE PRESSURE

Servicing an A/C system starts with using a manifold gauge set to check the pressure.

The Manifold Gauge

A manifold gauge is a calibrated device used to measure air conditioning system pressure. This device allows the technician to perform four important tasks:

1. Monitor the pressure inside the operating system.

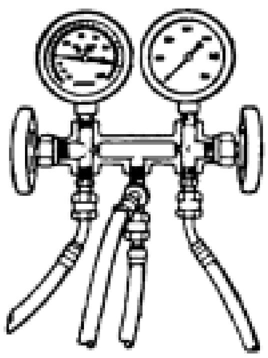
2. Monitor the flow of refrigerant into the system during charging.

3. Control the flow of refrigerant into the system during charging.

4. Access the system for discharging

A typical manifold gauge set, shown in Figure 37, consists of a center manifold and two (or sometimes three) gauges.

FIGURE 37. A manifold gauge is a calibrated device used for measuring A/C system pressure.



Manifold gauges help determine where and at what pressure to deliver refrigerant. The valves open and close passageways to the center port and its service hose.

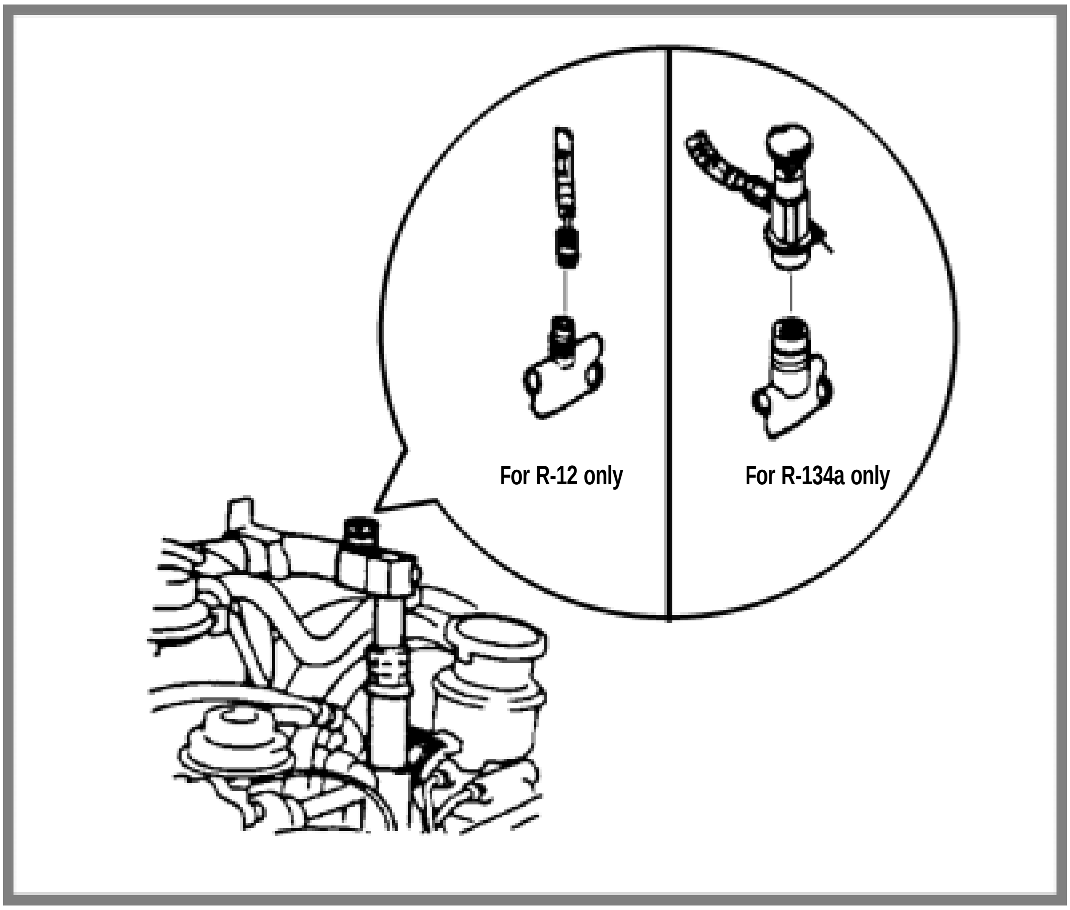
The gauges on either end of the manifold select which system to apply to the center manifold area. Although the low pressure gauge appears on the left in this drawing, and the high pressure gauge appears on the right, not all manifold gauge sets will be oriented this way.

Making the Connection

Use one of the following methods to ensure that you connect the manifold gauge correctly.

- Identify the high and low side of the system by tracing the hose from the condenser back to the compressor. The compressor connects to the high- pressure side of the system.
- Both R-12 and R-134a systems use connectors of different sizes to help prevent connecting the gauges to the wrong sides. Furthermore, R-12 and R-134a system have different-sized valves, to prevent accidental mixing of refrigerants.
- The threaded Schrader valve is the most commonly used service valve, or port, for the R-12 system. R-134a systems use larger, metric-thread, quick- connect service valves.

FIGURE 38. R-12 and R-134a systems use different connections to the manifold gauge.



The manifold gauge connects to the air conditioning system as shown in Figure 38.

1. The low pressure gauge connects to the service valve between the evaporator and compressor suction port.

2. The high pressure gauge connects to the service valve between the compressor and the condenser.

3. The center port is used to add and remove refrigerant. This port can be connected to refrigerant supply tank, evacuation pump, or refrigeration oil canister.

Using Manifold Gauges

The following table describes the connections required for various A/C tests and servicing tasks.

	Low-Side Valve	Center Port	High-Side Valve
System Testing	Closed	Closed	Closed
Discharging	Open	Connect to a refrigerant recovery/ recycling system.	Open
Leak-testing	Closed	Connect to a refrigerant supply.	Open
Vapor charging	Open	Connect to a refrigerant supply.	Closed

Guidelines

- Close the shutoff valves before removing them from the service ports.
- Keep the gauge shutoff valves closed when not in use.
- Connect the gauge hoses to a recovery unit and remove any refrigerant from them after every use.
- Make sure that the shutoff valves are within 12 inches of the service valve.
- Never vent R-12 or R-134a into the air. Always use a recovery system.

Evaluating Gauge Readings

Temperature and humidity affect the pressures you record with the manifold gauge. Pressure on a hot day will be higher than on a cold day. Check the manufacturers' specifications for normal pressures at various temperatures.

Refrigerant Stations

Since refrigerant can never be released into the air, you must use special equipment to recover and store the refrigerant. Figure 39 shows a typical refrigerant recycling / recharging station, often called a charging station.

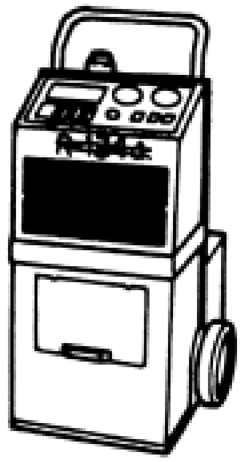


FIGURE 39. To safely and properly repair an A/C system, you must use a refrigerant recovery and recycling station.

This type of station performs several tasks, including:

- Recovering (or discharging) refrigerant from the system
- Recycling refrigerant
- Evacuating the system of moisture
- Vacuum testing the system for leaks
- Charging the system with refrigerant

Recovery

The first step in repairing an A/C system is to remove the refrigerant from the vehicle and store it in the refrigerant tank. This operation is known as recovery. During the recovery process, both refrigerant and oil are collected from the system. The oil must be drained and measured for replacement with new oil later.

Note: In an orifice tube system, the accumulator may store liquid refrigerant, which may be difficult to recover. The recovery process can be improved by making sure the engine is at normal operating temperature. Keeping the system temperature up helps prevent liquid refrigerant from being released suddenly from the accumulator.

Once refrigerant has been recovered, the station will display the weight of the refrigerant that was removed. Note the weight or quantity of the refrigerant removed because this can indicate leaks or overcharging. Open the vehicle's A/C system only after recovering the refrigerant.

Recycling

Many recharging stations also recycle refrigerant. As the refrigerant is collected, it is run through a filter-dryer unit that traps particles, acid, and moisture. This ensures the stored refrigerant is of the best quality.

Evacuation

After repairs have been performed, or if a system has been open for a long period of time, the system must be evacuated to remove moisture and ensure that it will hold a vacuum. **The minimum time any system should be evacuated is 15 minutes.** The longer the system has been open, the longer it should be evacuated.

The A/C system is evacuated by creating a vacuum within it. Negative pressure reduces the boiling point of any water in the system, causing it to turn from a liquid to a vapor. When the water turns to vapor, it can be drawn out from the system. All water must be removed from the system, because if water mixes with the refrigerant, hydrochloric acid forms. Hydrochloric acid is very corrosive and will damage the A/C system components.

REVIEW EXERCISE 10

Fill in the words that complete these sentences correctly. Check your answers with the answer key on page 80.

1. When repairing an air conditioning system, you must first _________________ the refrigerant.
2. Evacuating an A/C system forces any _________________ in the system to boil and turn to _________________ .
3. When R-12 contacts _________________ , it turns into hydrochloric acid, a very dangerous substance.
4. Never evacuate a system until removing the _________________ .
5. Recycling removes _________________ , _________________ , and _________________ from the refrigerant.
6. Pressure readings on a manifold gauge are affected by _________________ and _________________ .

LEAK TESTING

Low refrigerant level is the most common problem you will encounter in an air conditioning system, so you should always perform leak testing whenever you service an A/C system.

Some symptoms of low refrigerant level are:

- Both manifold gauges read low, and the air from the vent is cool to warm.
- The compressor cycles on and off quickly (cycling clutch systems only).

If the system has a sight glass, check for bubbles or foam. If the refrigerant level is low, it is probably the result of a leak. If the leak is as much as a pound per year, you should be able to find it in one of several ways.

Large Leaks

You can usually find large leaks by visually inspecting the system:

1. Look for oil stains and caked-on dirt.
2. Look for bubbles.
3. Check for cracked pipes or hoses.
4. Listen for a hissing sound.

If the system is completely empty, add about a pound of refrigerant to test for leaks. Once the leaks have been found, recover this refrigerant.

Small Leaks

To find smaller leaks, use an electronic leak detector or a black-light-sensitive dye.

Electronic Leak Detector

Electronic leak detectors (Figure 40) are the most accurate way to detect leaks. When an electronic leak detector is passed near a leak, a beep sounds, letting you know the location of the leak.

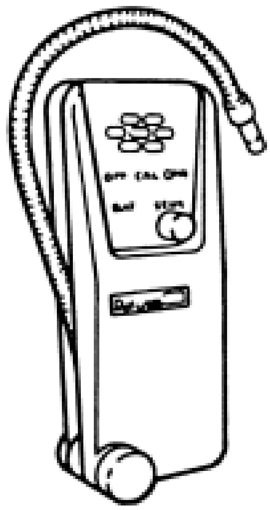


FIGURE 40. Using an electronic leak detector is the most accurate method of detecting leaks.

When you use an electronic leak detector, always remember to:

- Place the leak detector at the bottom of the hoses and fittings since refrigerant is heavier than air
- Shut the engine off and wait until the cooling fan turns off.

Dye Test

When conducting a dye test, the technician adds a luminous dye to the A/C system through a container attached to the charging system hoses. Turning the A/C on then circulates the dye through the system. A black light is then shone on all system component connections, lines, fittings, and hoses. If there is a leak present, it will glow when the luminous dye is lit by the black light.

Harder to Spot Leaks

Always check the service fittings for leaks after removing your gauges. Don't forget to install the thread caps; it's the law.

Obvious damage doesn't always accompany hose leaks. If a hose appears to be oily, wipe it down and observe it for a few seconds. If an oily stain begins spreading on the hose, there is a very good chance it has become porous. Replace the hose.

After Detection

After the leak has been located, make the necessary repairs. Then recheck, re- evacuate, and recharge system.

REVIEW EXERCISE 11

Fill in the words that complete these sentences correctly. Check your answers with the answer key on page 82.

1. The most common problem you will encounter in an air conditioning system is__________________________.
2. You can usually find large leaks by _______________ _______________ the system.
3. Use an __________________ leak detector or a __________-___________-__________ dye to find smaller leaks.

CHARGING THE SYSTEM

After all repairs are complete and the system holds a steady vacuum, add refrigerant. Adding refrigerant to an A/C system is known as *charging* the system.

The first step is to determine how much refrigerant needs to be added. Consult the service manual or underhood label for the proper refrigerant charge amount. Then program the refrigerant amount — usually measured in ounces — into the charging station.

There are two methods for charging an A/C system:

1. Liquid charging — This method adds liquid refrigerant through the high-side service valve with the compressor off. The engine must also be off during liquid charging. This is a fast method of charging the system. Since liquid refrigerant will damage a running compressor, make sure the compressor is off. In addition, pressure from the compressor could enter the storage tank and cause it to burst. Most charging stations use the liquid charging method.

2. Vapor charging — This method adds gaseous refrigerant through the low-side service valve while the compressor is running. This method is usually used with a gauge set and a refrigerant tank resting on a scale. The scale measures the amount of refrigerant added.

REVIEW EXERCISE 12

Fill in the words that complete these sentences correctly. Check your answers with the answer key on page 84.

1. Add liquid refrigerant through the ________________-side service valve.

2. ________________ charging is quicker.

3. Add ________________ refrigerant with the compressor off.

4. Add ________________refrigerant while running the compressor.

COURSE SUMMARY

The following pages, contain a brief summary of the important points covered in this Guide. Before taking the final examination, review this summary to verify your understanding of the material.

SAFETY PRECAUTIONS

Refrigerant can cause severe drying and frostbite if it comes in contact with exposed skin. It is extremely important to follow safety precautions when working with A/C systems. To help prevent injury, always wear goggles and gloves.

PHYSICAL LAWS

Air conditioning systems are based on the following fundamental physical laws:

- Heat flow
- Heat absorption
- Pressure
- Boiling points

Air conditioning systems cool the vehicle interior by absorbing heat into the evaporator. Heat travels to cold until the temperatures equalize.

A/C SYSTEM COMPONENTS

The basic components of the A/C system are:

- Compressor
- Condenser
- Receiver/dryer or accumulator
- Expansion valve or orifice tube
- Evaporator

Compressor

The compressor draws in low-pressure vapor from the evaporator and compresses it into hot, high-pressure vapor and then sends it to the condenser. The compressor also pumps the refrigerant throughout the A/C system.

Condenser

The condenser is located in front of the radiator. It removes heat from the refrigerant, causing it to condense it into a high-pressure liquid.

Receiver / Dryer

The receiver / dryer, located at the outlet to the condenser, is a storage tank for liquid refrigerant. It also contains a desiccant that removes moisture and a filter to trap contamination. A receiver/dryer is used in AC systems that have an expansion valve.

Accumulator

The accumulator is used with a fixed orifice system. The accumulator is located at the outlet of the evaporator and prevents liquid refrigerant from reaching the compressor. It also filters out particles and removes moisture from the refrigerant.

Expansion Valve / Orifice Tube

The expansion valve or orifice tube regulates refrigerant flow into the evaporator to allow maximum cooling and ensure complete evaporation of the refrigerant.

Evaporator

The evaporator, located under the vehicle dash, evaporates the refrigerant that allows it to absorb interior heat. During evaporation, any moisture (humidity) in the air condenses on the outside of the evaporator and is drained away.

REFRIGERANTS

R-12 and R-134A are refrigerants used in automotive A/C systems. They are not interchangeable. R-12 uses mineral-based lubricating oil, while R-134A uses synthetic PAG oil. The oils are not interchangeable and must never be mixed in the same system.

Most systems produced today use R-134A refrigerant. Federal law requires that R-12 refrigerant production be stopped by the year 2000.

A/C SERVICING

Moisture in an A/C system is very destructive. It can freeze in the expansion valve, preventing refrigerant flow and cooling. Water, when combined with R-12, forms hydrochloric acid, which is very corrosive and can damage A/C components and create leaks.

Proper refrigerant recovery and charging equipment must be used to prevent refrigerant from entering the atmosphere, where it can damage the ozone layer. Refrigerant equipment includes a manifold gauge set, service valves, vacuum pump, charging station, charging cylinder, recovery / recycling system, and leak detection devices.

Whenever the A/C system is open, it must be properly evacuated to remove moisture and prevent the formation of hydrochloric acid in R-12 systems.

Masters

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