Figure 62-1  Water is a substance that can be found naturally in solid, liquid, and vapor states.

FREQUENTLY ASKED QUESTION:

Why Is Liquid Sprayed from a Can Cold?

If you spray a can of liquid continuously, the can becomes cold, and the liquid being sprayed becomes cold. The can becomes cold because the pressure in the can is reduced while spraying, allowing the liquid propellant inside the can to boil and absorb heat. The liquid being sprayed has also been cooled by the liquid propellant. The propellant vapor is further cooled as it decompresses when it hits the open air. Rapid decompression results in a rapid temperature drop.
**Figure 62-2** The extra heat required to change a standard amount of water at its boiling point to a vapor is called the latent heat of vaporization.

1 Gram Water = 540 Calories = 1 Gram Vapor
1 Pound Water = 970 BTUs = 1 Pound Vapor

**Figure 62-3** The latent heat of vaporization that water vapor stores is given off when the vapor condenses to a liquid. The temperature stays the same.

1 Gram Vapor = 540 Calories = 1 Gram Water
1 Pound Vapor = 970 BTUs = 1 Pound Water

**Figure 62-4** A sling psychrometer is used to measure relative humidity.
FREQUENTLY ASKED QUESTION

What Is an Auxiliary Electric Water Pump?

Some vehicles are equipped with an auxiliary electric water pump. The purpose and function of this pump is to help warm the interior of the vehicle by circulating coolant from the engine through the heater core when the engine is at idle speed. At idle speed, the water pump does not circulate a sufficient quantity of coolant through the heater core to warm the interior in freezing weather.
Figure 62-7 The evaporator removes heat from the air that enters a vehicle by transferring it to the evaporating refrigerant.

The underlying principle involved in air-conditioning or refrigeration is that “cold attracts heat.” Therefore, a cool evaporator attracts the hot air inside the vehicle. Heat always travels toward cold and when the hot air passes through the cold evaporator, the heat is absorbed by the cold evaporator, which lowers the temperature of the air. The cooled air is then forced into the passenger compartment by the blower through the air-conditioning vents.

Figure 62-8 The compressor provides the mechanical force needed to pressurize the refrigerant.
Figure 62-9  The condenser changes the refrigerant vapor into a liquid by transferring heat from the refrigerant to the air stream that flows between the condenser fins.

Figure 62-10  A typical air-conditioning system that uses an expansion valve. A temperature sensor bulb is attached to the outlet of the evaporator to control the amount of refrigerant allowed to flow into the evaporator.

Figure 62-11  A typical automotive air-conditioning system that uses a cycling clutch and an orifice tube.
Figure 62-12  Typical orifice tube.

Figure 62-13  A cutaway of an air-conditioning compressor electromagnetic clutch.

Figure 62-14  R-134a is available in 12 oz cans as well as larger 30-lb containers.
A depletion of the ozone layer allows more ultraviolet radiation from the sun to reach Earth’s surface.

Chlorofluorocarbon molecules break apart in the atmosphere.

Frequently Asked Question:
Is Carbon Dioxide the Next Refrigerant?
Not likely. While carbon dioxide (CO₂) (R744) is being used in prototype vehicles, such as the Toyota Fuel Cell Hybrid Vehicle (FCHV), it requires extremely high pressures, up to 2000 psi and is not as efficient as a refrigerant as R-134a. SEE FIGURE 62–17.
Figure 62-17: The label on a Toyota Fuel Cell Hybrid Vehicle (FCHV) showing that CO\(_2\) is being used as the refrigerant.

Figure 62-18: PAG oil used in Chrysler vehicles equipped with HFC-134a refrigerant. Notice that different oils are used for different systems depending primarily on the manufacturer of the compressor. Also notice that both PAG oils are in metal cans. PAG oil absorbs moisture so readily that it can even absorb moisture that is in the air through plastic—that is why metal containers are used.

Figure 62-19: Ester refrigerant oils are often specified for use when retro-fitting an R-12 system to an R-134a system by companies who supply retrofit kits. Ester refrigerant oil is not recommended by many vehicle or air-conditioning compressor manufacturers. Always use the recommended refrigerant oil for the vehicle and system being serviced.
Figure 62-20  The condenser serves the same function for both the orifice-tube and the expansion valve–type air-conditioning system, and that is to remove the heat from the refrigerant and cause the hot refrigerant vapors to condense into a hot liquid.

TECH TIP: Broken Condenser Line? Check the Engine Mounts!

Most air-conditioning systems use aluminum and flexible rubber lines between the compressor and the condenser. Because the compressor is mounted on and driven by the engine and the condenser is mounted to the body, these lines can break if the engine mounts are defective. The metal lines attached between the aluminum fittings of the compressor and condenser are designed to absorb normal engine movement. Worn engine mounts would allow the engine to move too much. Aluminum lines cannot stand to be flexed without crushing and breaking. Therefore, the wise technician will carefully inspect and replace any and all worn engine mounts. A broken aluminum condenser line is designed to prevent a premature failure of a replacement condenser. SEE FIGURE 62-21.

Figure 62-21  A repaired condenser refrigerant line.
The evaporator serves the same function for both the orifice-tube and the expansion-valve-type air-conditioning systems, and that is to allow the liquid refrigerant to evaporate and absorb heat from inside the passenger compartment.

Expansion-valve systems store excess refrigerant in a receiver-drier, which is located in the high-side liquid section of the system, whereas orifice-tube systems store excess refrigerant in an accumulator located in the low-side vapor section of the system.

A typical accumulator used on a cycling clutch orifice-tube (CCOT) system.
Figure 62-25  Rigid lines and flexible hoses are used throughout the air-conditioning system. The line to and from the compressor must be flexible because it is attached to the engine, which moves on its mounts during normal vehicle operation.

Figure 62-26  A typical expansion valve which uses an inlet and outlet attachment for the evaporator, and a temperature-sensing bulb that is attached to the evaporator outlet tube.

Figure 62-27  A slot cut in the ball seat inside the expansion valve permits a small amount of refrigerant and oil to pass through at all times, even when the valve is closed. This flow of oil through the system is necessary to make sure that the compressor receives the oil it needs for lubrication.
Figure 62-28 The sensing bulb is attached to the evaporator outlet tube. Refrigerant inside the bulb expands or contracts in response to the evaporator temperature.

Figure 62-29 Pressure from the capillary tube pushes on the spring-loaded diaphragm to open the expansion valve. As the pressure in the capillary tube contracts, the reduced pressure on the diaphragm allows the valve to close.

Figure 62-30 An H-valve (H-block) combines the temperature-sensing and pressure-regulating functions into a single assembly.
Figure 62-31  An H-valve as used on a Chrysler minivan.

Figure 62-32  In this Chrysler system, a low-pressure cutoff switch and a cycling-clutch switch are mounted on the H-valve.

Figure 62-33  The orifice tube is usually located at the inlet tube to the evaporator.
In a positive-displacement compressor, the descending piston creates a drop in pressure inside the cylinder. The resulting pressure differential allows low-side pressure to force the suction valve open. Refrigerant then flows into the cylinder. On the piston’s discharge stroke, the pressure caused by the ascending piston closes the intake valve and forces the refrigerant out the discharge valve.

**Figure 62-34**

A reed valve is a one-way check valve that flaps away from the valve plate to open, and toward the valve plate to close.

**Figure 62-35**

**TECH TIP: The Radio POP Trick**

Most air-conditioning compressor clutch circuits contain a diode that is used to suppress the high-voltage spike that is generated when the air-conditioning compressor clutch is turned off. If this diode were to fail, a high voltage (up to 400 volts!) could damage sensitive electronic components in the vehicle, including the electronic air-conditioning compressor clutch control unit (if so equipped).

Another thing that can occur is that the radio will often turn off and then back on whenever the electronics inside the radio detect a high-voltage spike. This can create a pop in the radio that is very intermittent because it only occurs when the air-conditioning compressor cycles off. To check this diode, simply tune the radio to a weak AM station near 1400 Hz and cycle the air-conditioning compressor on and off. If a pop is heard from the radio speaker(s), then the diode is defective and must be replaced.

NOTE: While some A/C compressor diodes can be replaced separately, some of these air-conditioning compressor clutch diodes are part of an entire wiring harness assembly.
Figure 62-36 The swash plate, attached to the crankshaft at an angle, converts the pulley’s rotary motion to axial motion, which drives the pistons in a reciprocating motion.

Figure 62-37 A V-5 variable displacement compressor. Internal pressures act on the swash plate, which changes the stroke of the piston and, therefore, displacement based on the pressures in the system.

REAL WORLD FIX: What Throttle Switch?

A service technician was tracing the cause of an inoperative air compressor on a Saab. The service manual showed a schematic of the air-conditioning compressor that included a number of switches that had to be closed for the compressor clutch to be supplied with battery voltage. Besides the low pressure switch (to assure that the system is charged so as not to damage the compressor), a throttle switch was shown on the schematic. Obviously, someone else had worked on the vehicle because the throttle switch was missing entirely—just two wires remained to indicate that anything had been installed. Connecting the two wires together provided enough voltage to the air-conditioning compressor clutch. The customer decided not to replace the throttle switch, stating that the engine was at wide open throttle (WOT) and that anything that had been installed was still in place. The technician was able to determine that the throttle switch was intended to disconnect (open circuit) the air-conditioning compressor when the throttle was at wide open positive to allow the maximum power for passing.
Figure 62-38  Typical air-conditioning pressure switches. A service manual would be needed to determine the function of each switch. One switch could be the low-pressure switch and the other a high-pressure switch.