INTRODUCTION

The air-conditioning compressor can be thought of as a pump that circulates refrigerant. It has to work against the restriction of the thermal expansion valve (TXV) or orifice tube (OT). The pressure of the refrigerant must be increased to the point where refrigerant temperature is above ambient air temperature and there is enough heat transfer in the condenser to get rid of all the heat absorbed in the evaporator. Most A/C compressors are driven by a belt and pulley from the engine.

There are many types of A/C compressors used on vehicles, including the following:

- Piston compressors—Older automotive compressors used a crankshaft, similar to a small gasoline engine, and a reciprocating-piston type. Newer piston compressors use a swash or wobble plate.
- Scroll compressors—Scroll compressors require rather complex machining to achieve constant sealing between the fixed and movable scrolls.

A piston compressor moves the pistons up and down in a cylinder to produce pumping action and controls the refrigerant flow with two sets of reed valves. Figure 1.

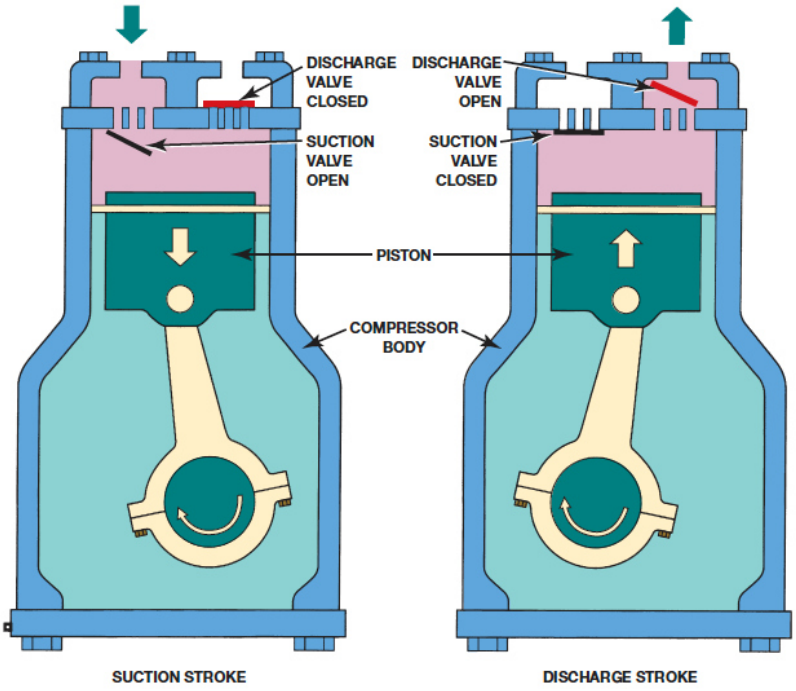

Figure 1. Piston-type compressor operation.

COAXIAL SWASH-PLATE COMPRESSORS Coaxial swash-plate compressors drive the pistons through a swash plate, which is attached to the driveshaft. The swash plate is mounted at an angle so it will wobble and cause the reciprocating action of the pistons.

The pistons are double ended so that each end can pump, and the pistons are arranged parallel to and around the driveshaft. This is called a coaxial arrangement. One driveshaft revolution causes each piston end to move through a complete pumping cycle. The most common arrangement is three double pistons making a 6- cylinder compressor and a 10-cylinder using five pistons. Figure 2.

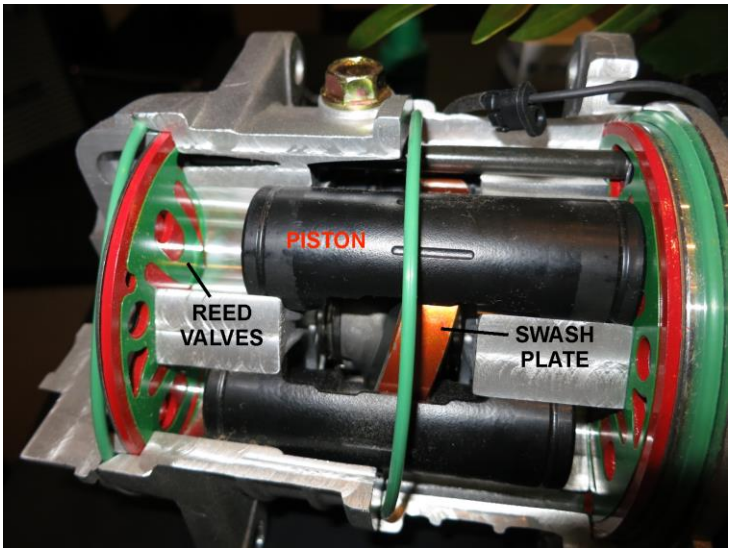

Figure 2. A swash plate compressor.

COAXIAL WOBBLE-PLATE COMPRESSORS Wobble-plate compressors drive the pistons through an angle plate that looks somewhat like a swash plate, but the wobble plate does not rotate and drives single pistons through piston rods. Wobble-plate compressors commonly use five or seven cylinders. Figure 3.

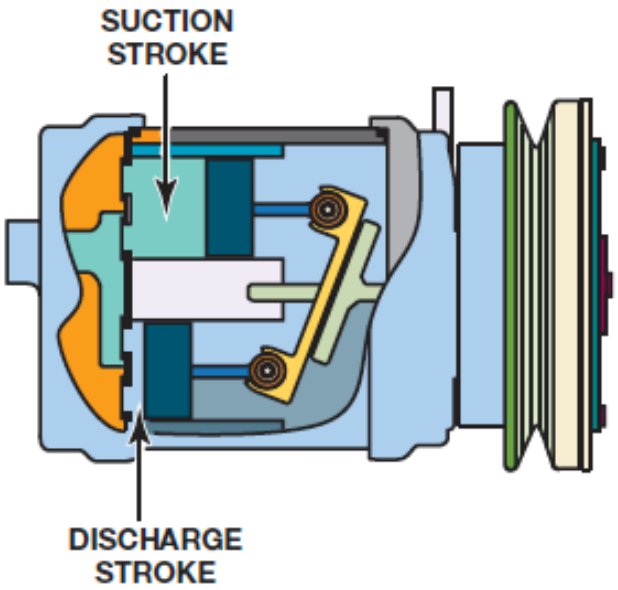

Figure 2. A wobble-plate compressor.

VARIABLE DISPLACEMENT WOBBLE- PLATE COMPRESSORS A variable displacement compressor provides smooth operation with no clutch cycling, a constant 32°F (0°C) evaporator, and the most efficiency. A variable displacement compressor can change the angle of the wobble plate and piston stroke. Figure 3.

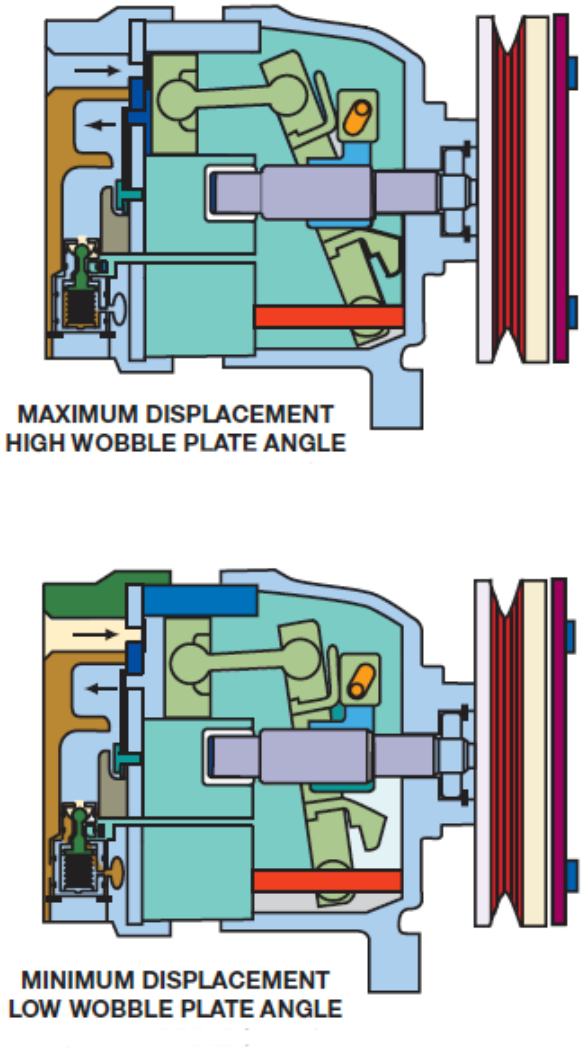

Figure 3. Variable displacement compressor.

SCROLL COMPRESSORS Scroll compressors use two major components:

1. Fixed scroll—The fixed scroll is attached to the compressor housing.

2. Movable scroll—The movable scroll is mounted over an eccentric bushing and counterweight on the crankshaft. It does not rotate, but it moves in an orbit relative to the stationary scroll.

As the scroll orbits, it forms a pumping chamber that is open at the outer end. This chamber is moved to the center by the action of the scroll as the pressure is increased. The outer ends of the scrolls are open to the suction port, and the inner ends connect to the discharge port. Figure 4.

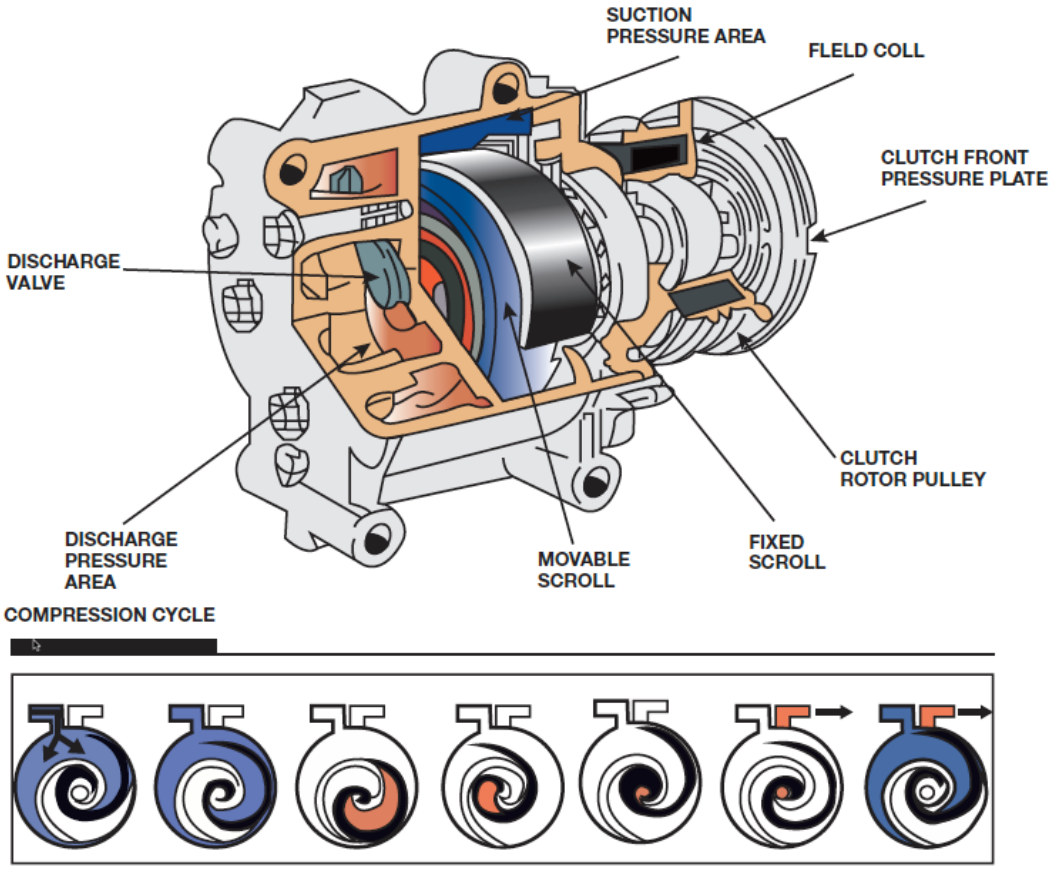

Figure 4. Basic components of a scroll compressor.

COMPRESSOR CLUTCHES Electromagnetic clutches allow the compressor to be turned on and off. The clutch uses a coil of wire where a magnetic field is generated when electrical current flows through it. The magnetic field pulls the drive plate against the rotating pulley to drive the compressor. Figure 5.

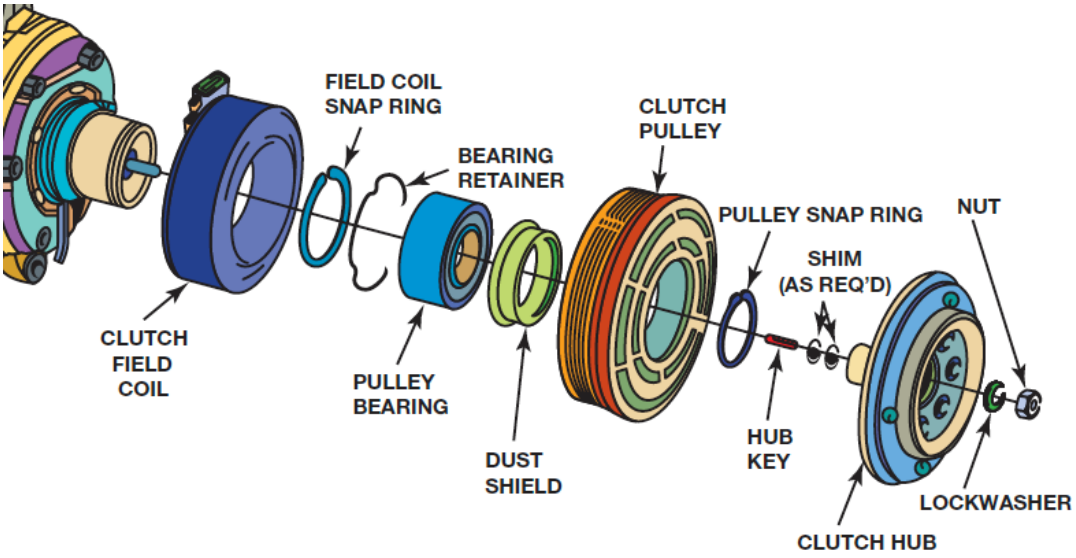

Figure 5. Electromagnetic clutch assembly. Shims are used to adjust the space between the clutch hub and the clutch pulley (air gap).

CONDENSERS The condenser is a heat exchanger that is used to get rid of the heat removed from the passenger compartment. The condenser cools the hot refrigerant vapors, which while passing through the condensing tubes condense into high pressure liquid. Figure 6.

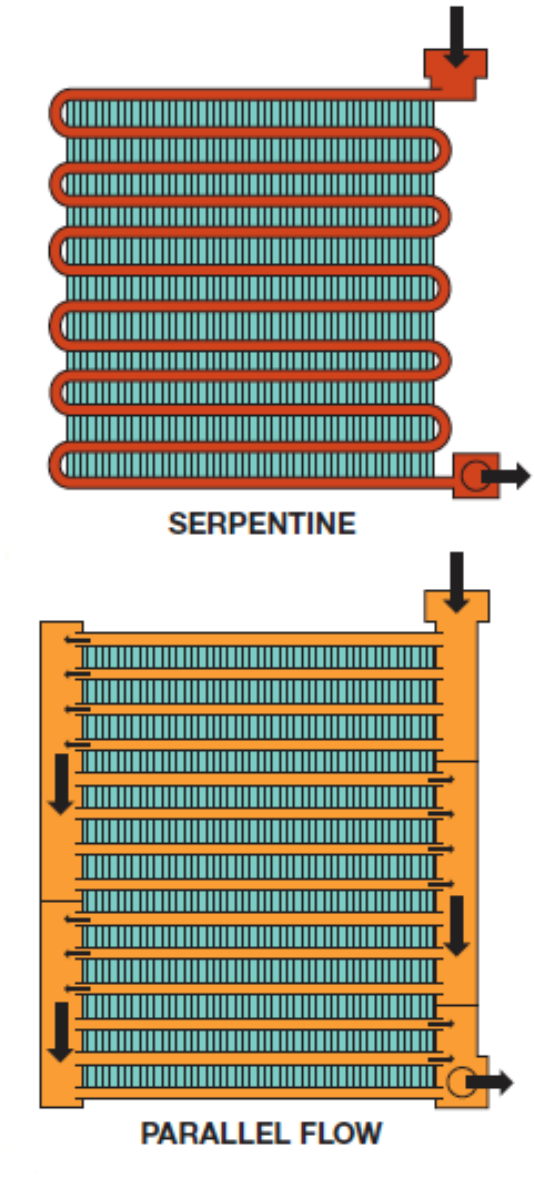

Figure 6. Two types of A/C condensers.

EVAPORATORS An evaporator, sometimes called the evaporator core, is a heat exchanger. The purpose and function of the evaporator is to remove heat from the air being forced through it to cool the inside of the vehicle. Most evaporators are a series of plates sandwiched together to form both the refrigerant and air passages. Figure 7.

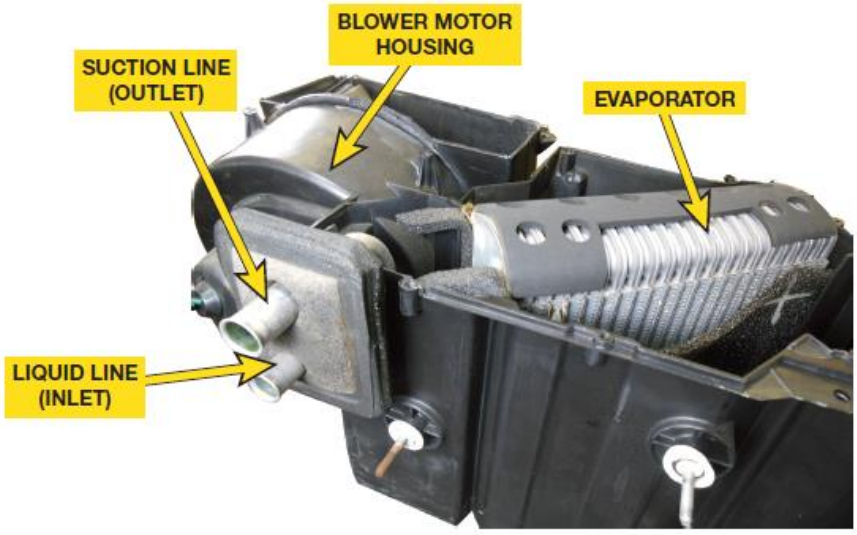

Figure 7. An evaporator in the HVAC case showing the liquid line inlet tube from the TXV or orifice tube and suction outlet line to the compressor or accumulator.

ASE TEST TOPICS

► Compressor and Clutch

1. Diagnose A/C system problems that cause the protection devices (pressure, thermal, and electronic controls) to interrupt system operation; determine needed repairs.

Most air-conditioning compressors use an electromagnetic clutch. Some systems may connect one or more switches in series with the compressor clutch so that all have to be functioning before the compressor clutch can be engaged. A low- and high-pressure switch or sensor may also be an input to the PCM or HVAC controller for use in controlling the compressor. Figure 8.

- Low-pressure switch: This pressure switch is electrically closed only if there is 8 PSI to 24 PSI (55 kPa to 165 kPa) of refrigerant pressure. This amount of pressure means that the system is sufficiently charged to provide lubrication for the compressor.
- High-pressure switch: This pressure switch is located in the high-pressure side of the A/C system. If the pressure exceeds a certain level, typically 375 PSI (2,600 kPa), the pressure switch opens, thereby preventing possible damage to the air-conditioning system due to excessively high pressure.

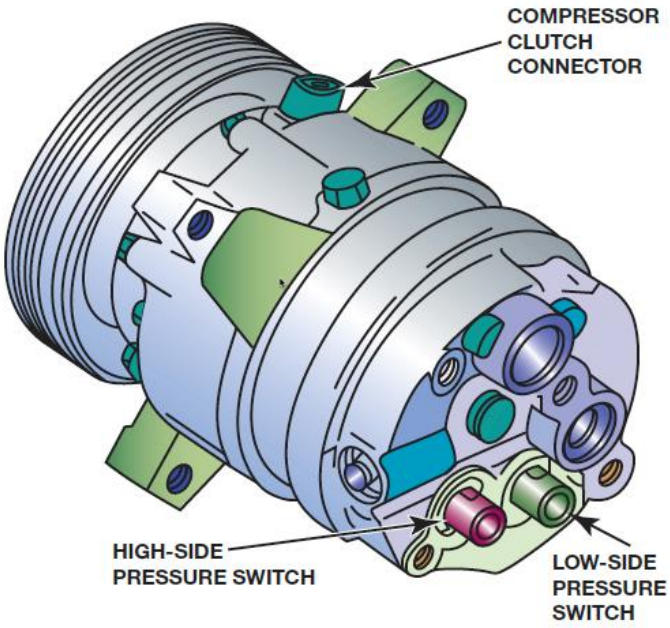

Figure 8. Pressure switches.

2. Inspect, test, and replace A/C system pressure, thermal, and electronic protection devices.

Various electrical switches and sensors are used in A/C systems to prevent evaporator icing, protect the compressor, and control fan motors. Control switches can be located anywhere in the system. Figure 9.

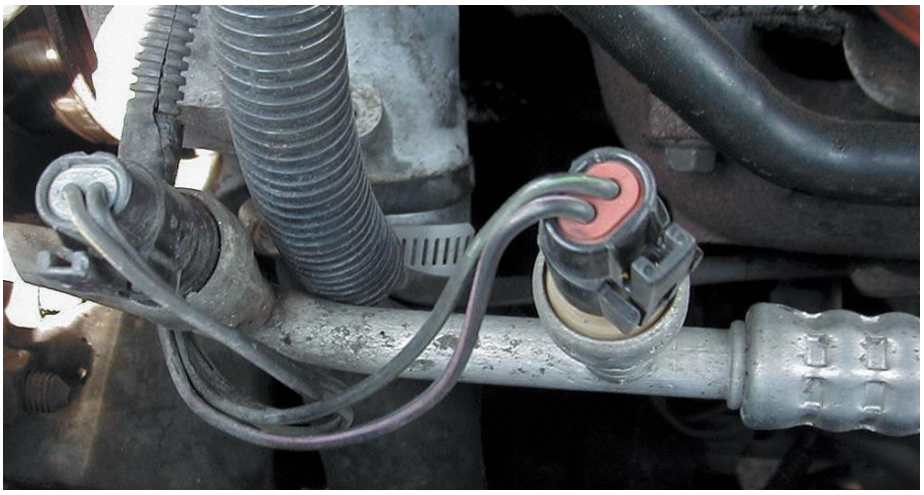

Figure 9. A switch and sensor located in the high side refrigerant line.

These switches and sensors are most often checked using a scan tool. The scan tool data may show status (on or off) or a range (system pressure in psi or kPa). Figure 10.

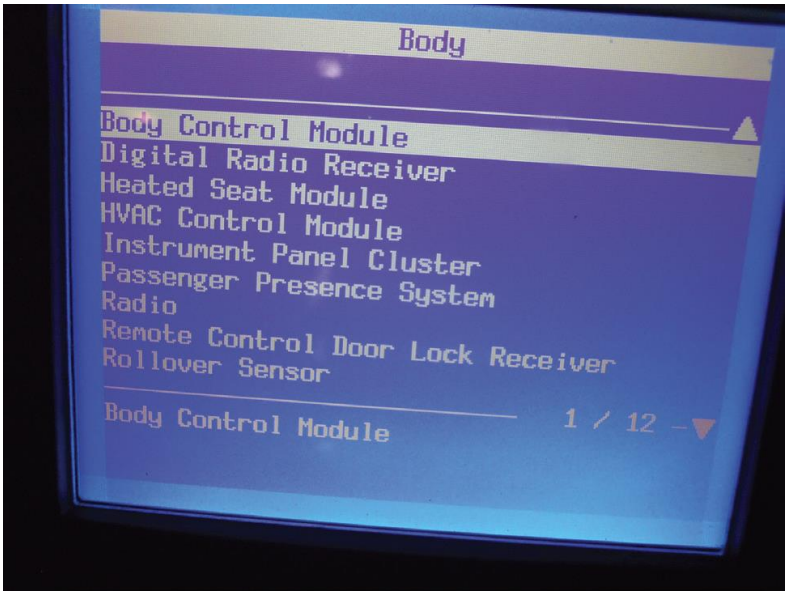

Figure 10. Under “Body” on most scan tools, select “HVAC Control Module” for access to the HVAC-related data and diagnostic trouble codes.

3. Inspect, adjust, and replace A/C compressor drive belts, pulleys, and tensioners.

It is generally recommended that all belts be inspected regularly and replaced as needed. Replace any serpentine belt that has more than three cracks in any one rib that appears in a 3 inch span. Newer belts are made from ethylene propylene diene monomer (EPDM). This rubber does not crack like older belts and may not show wear, even though the ribs do wear and can cause slippage. Figure 11.

Figure 11. A belt wear gauge should fit tightly into the belt groves. A loose fit means the belt is worn and should be replaced.

If the belt needs replacement, first make note of the belt routing. There may be a diagram under the hood. Use a tool to release the tensioner and then remove the belt. Install the new belt and release the tensioner. Figure 12.

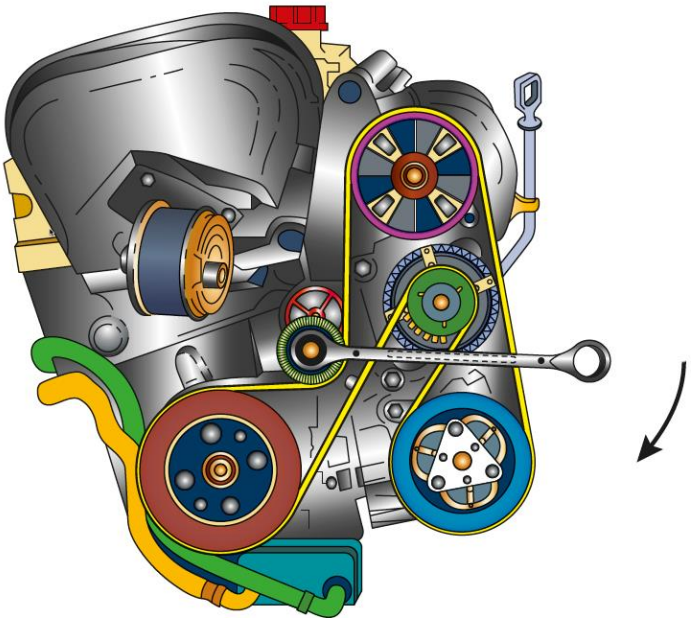

Figure 12. Turn the wrench in the direction indicated to loosen the belt tensioner.

The belt tensioner is designed to keep the belt tight enough so it does not slip but not so tight that the belt or bearings in the driven components will fail early. It must also dampen the tensioner arm to stop excess motion/bouncing and align the pulley to the belt.

With the engine running at idle speed, observe any tensioner movement, and there should be a rather gentle motion. If it appears to bounce back and forth a large amount, the dampener portion is probably worn out.

Starting in 2007, some vehicles use a stretch-fit, multi-rib belt without a tensioner. The elastic nature of the belt allows it to be stretched to install it over the pulleys, and the stretch provides the tension to keep it from slipping. A special tool or strap is required to install a stretch belt, and some manufacturers advise to cut the belt to remove it. Figure 13.

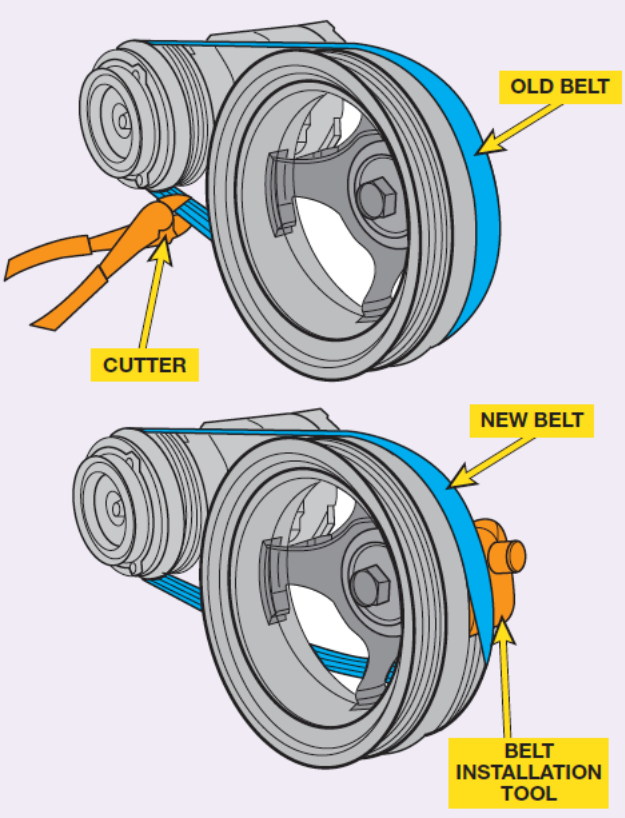

Figure 13. The belt is removed by cutting. Install the new belt using the plastic tool supplied with the new belt.

4. Identify compressor drive type (clutch/clutchless). Inspect, test, service, and replace A/C compressor clutch components, assemblies, or breakaway hubs.

Air conditioning compressors that are belt driven usually have a magnetic clutch-type drive pulley so the compressor can be engaged or disengaged by the HVAC control system. Figure 14.

Figure 14. An electromagnetic compressor clutch.

Some recent vehicles use a clutchless damper drive, with an electronically controlled variable displacement compressor. The pulley always drives the compressor through a rubber portion that dampens rotating engine pulsations. The pulley drive plate includes a metal or rubber shear portion that can break to protect the drive belt in case the compressor should fail and lock up.

A variable displacement compressor that uses a damper drive is electronically controlled to go to minimum displacement of 2% output when A/C is not used. This displacement requires very little power and is enough to circulate oil through the moving parts. Figure 15.

Figure 15. A damper drive is a one-piece pulley and hub.

Most A/C compressor clutches are three-part assemblies with a separate drive hub (armature), rotor pulley, and coil. To remove a clutch assembly, check service information for the exact procedure to follow. Special tools are usually needed when replacing a compressor clutch assembly. Figure 16.

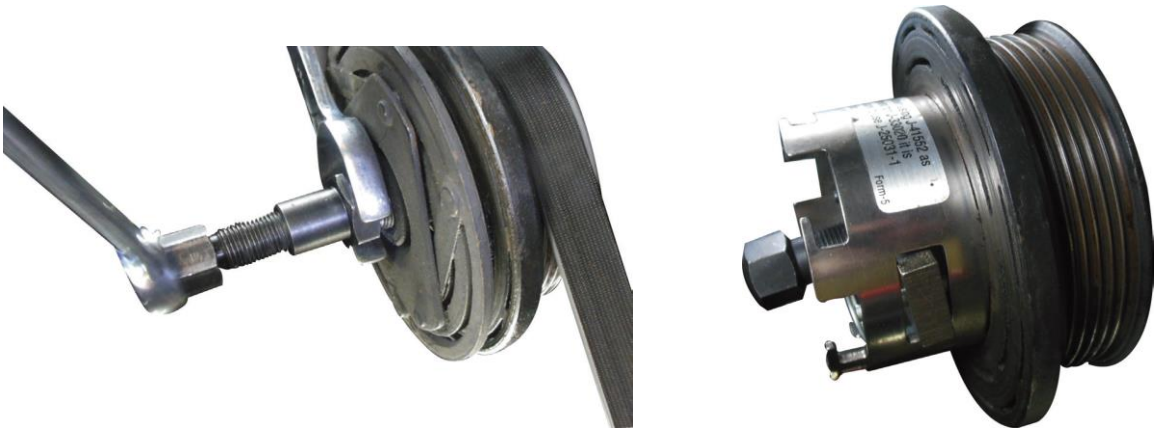

Figure 16. Special tools are often needed when replacing a clutch assembly.

5. Identify required lubricant type; inspect and correct level in A/C compressor.

The type of oil for the system being serviced is identified on the label under the hood. Mineral oil is used in R-12 systems. PAG oils are used in most R-134a systems. The refrigerant oil required for HFO-1234yf is PAG-based oil with an additive package unique to R-1234yf.

Compressors normally contain a certain amount of oil (often just 2 oz. to 8 oz.). The oil level can only be checked by removing the compressor and draining all of the oil, then measuring how much oil came out. This is normally only done when a compressor is replaced or when major service is performed on the system. Figure 17.

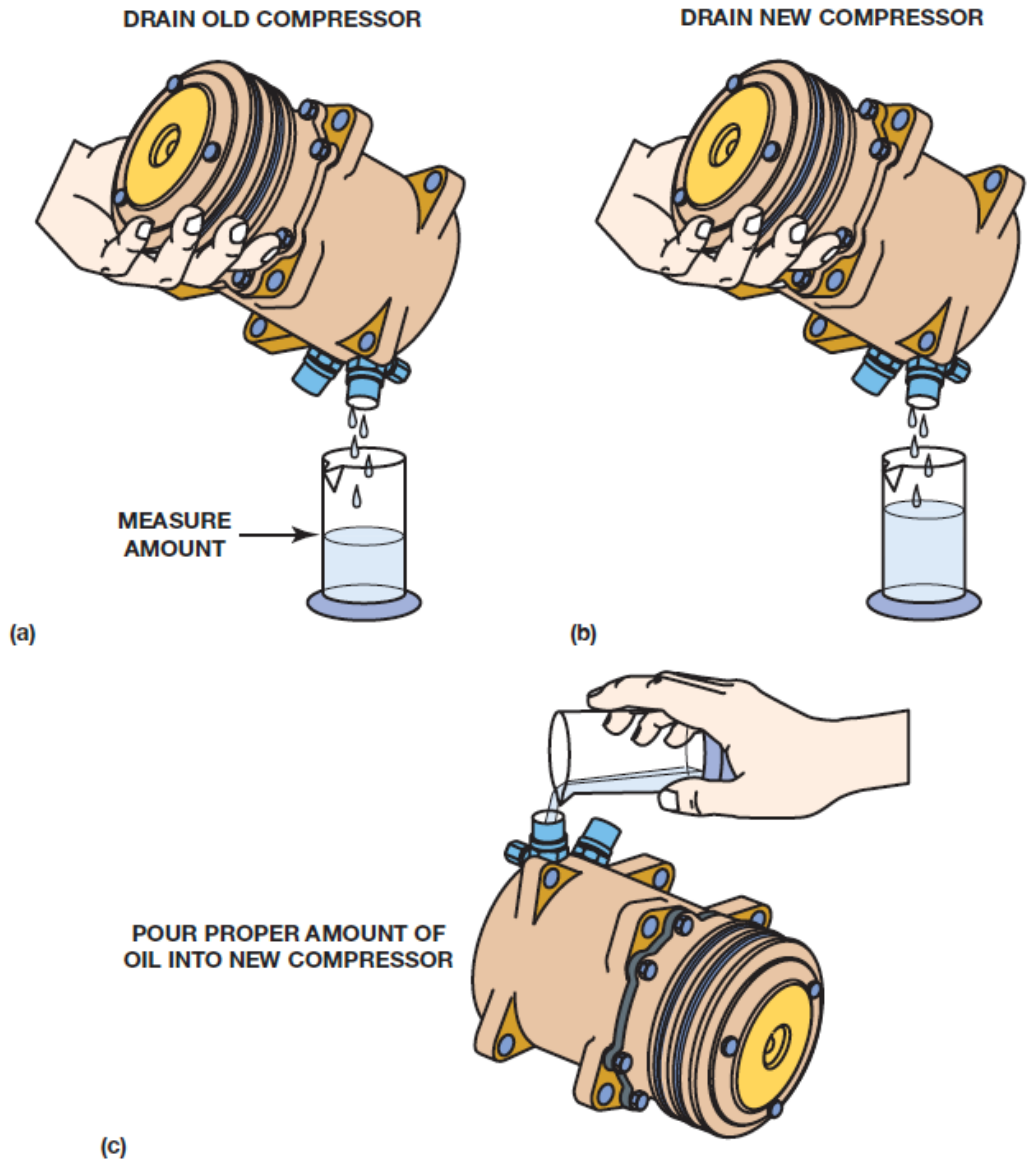

Figure 17. (a) The oil should be drained from the old compressor (top left); rotate the compressor shaft and the compressor to help the draining. (b) Drain the oil from the new compressor (top right). (c) Pour the same amount of oil drained from the old compressor or the amount specified by the compressor manufacturer of the proper oil into the new compressor.

6. Inspect, test, service or replace A/C compressor, mounting, and fasteners.

Replacement compressors are available as new or rebuilt units, and proper identification is made from the vehicle make, model, and engine size. Then, if needed, proper identification is made by the old compressor make and model. At times, a failed compressor is replaced with a different compressor make and model if the mounting points, clutch diameter and belt position, and line fittings are the same.

7. Inspect, test, service, and replace compressor displacement control components.

A variable displacement compressor can be internally controlled or externally controlled. An internally controlled compressor has a control valve with a pressure-responsive bellows that opens or closes passages into the compressor crankcase to change the angle of the wobble plate. Figure 18.

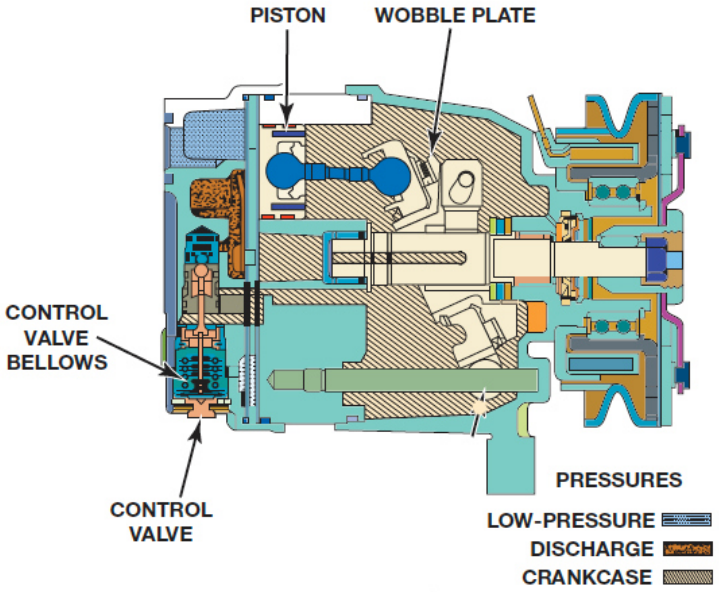

Figure 18. An internally controlled variable displacement compressor.

The externally controlled variable displacement a/c compressor is controlled by a pulse-width modulated solenoid mounted in the compressor. The variable voltage to the control solenoid on the back of the compressor can be checked with a DVOM, if accessible.

- If the variable voltage is close to 12 to 13V (95%) then the compressor is being commanded to produce full pressure.
- If the variable voltage signal to the compressor is close to 0V (10%) then the compressor is being commanded to produce minimum pressure.
- A voltage of between 6 to 7V means the compressor is commanded to 50% on time or midrange.

If the control solenoid is not accessible, some systems will display the compressor voltage/amperage applied on a scan tool. For example, 0A = full off and .99A = full on for some vehicles.

Either type of control valve is installed in the compressor housing with a snap ring or bolt, sealed with O-rings. The system must be evacuated before replacing the control valve.

► **Evaporator, Condenser, and Related Components**

8. Inspect, repair, or replace A/C system mufflers, hoses, lines, filters, fittings, and seals.

The various system components must be interconnected so that refrigerant can circulate through the system. The components are connected using hoses and tubing (also called pipes). Both flexible rubber and rigid metal tubing are used to link the components. The connections to the compressor must be flexible to allow for engine and compressor movement. Figure 19.

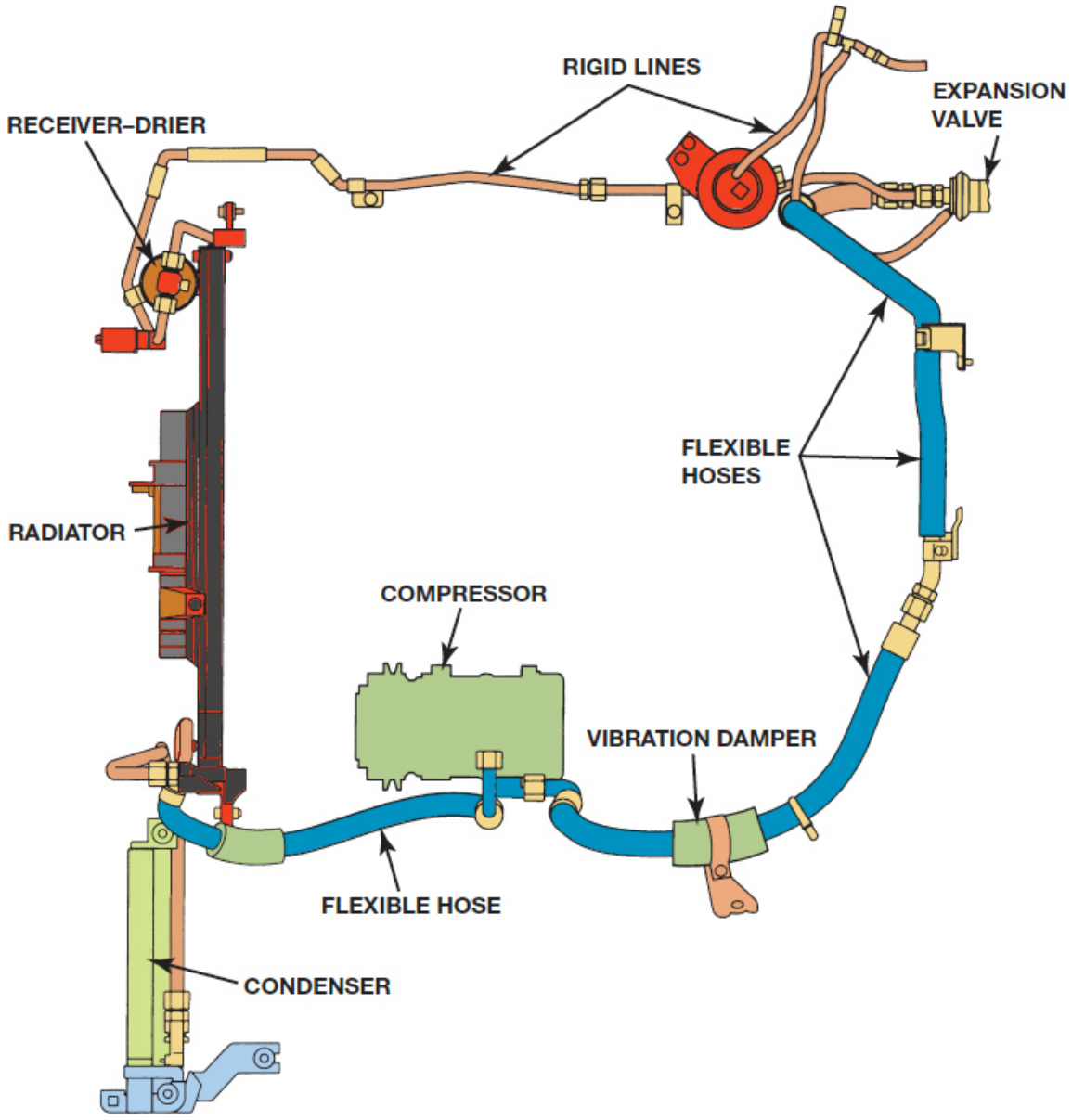

Figure 19. Rigid lines and flexible hoses. The outlet of the condenser is connected to the receiver-drier by a rigid line under the radiator (not shown).

Refrigerant hoses designed for R-134a are made with one or two nonpermeable inner layers with internal reinforcement and an outer layer for protection. The nonpermeable nylon layer forms a leak-proof barrier and are commonly called barrier hoses.

The lines in a system are named for their function or what they contain. Starting at the compressor, the discharge line, sometimes called the hot gas line, connects the compressor to the condenser inlet. The liquid line connects the condenser outlet to the receiver–drier and TXV or OT. A TXV system can have two liquid lines, one on each side of the receiver–drier. The suction line connects the evaporator outlet to the accumulator or compressor and has the largest diameter because it transfers a low-pressure vapor. Figure 20.

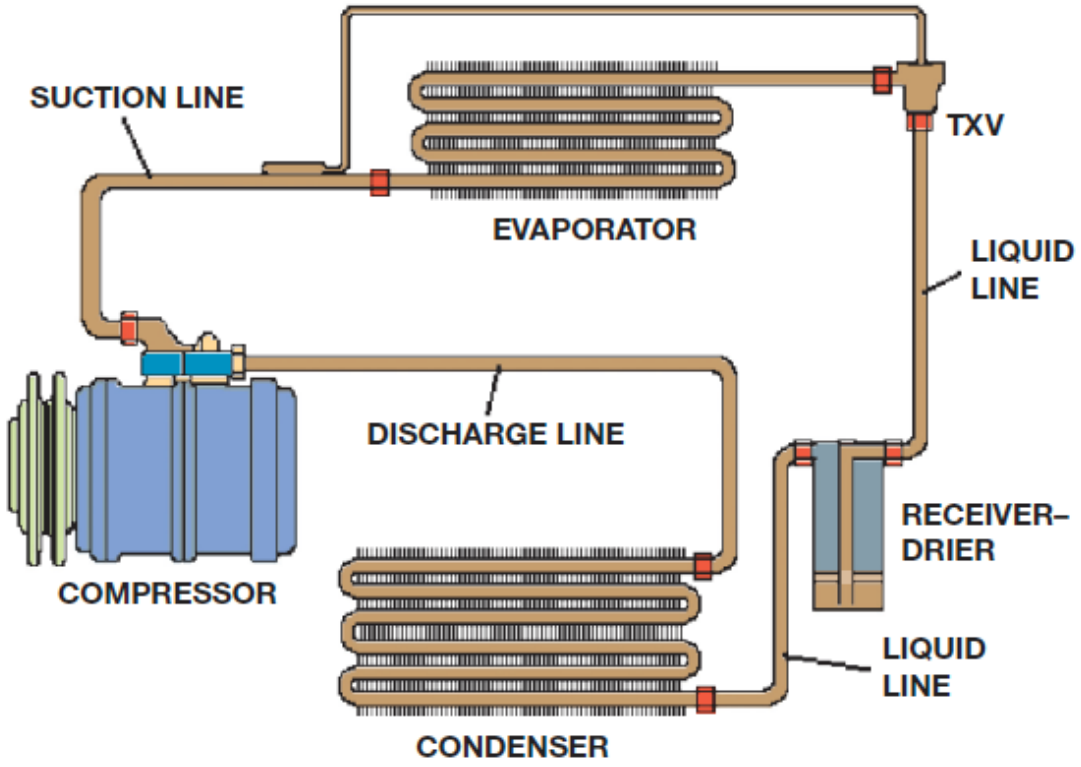

Figure 20. Refrigerant lines are named by their function.

The lines and hoses are connected to the major components using fittings of several different styles. These fittings allow the lines to be disconnected and are designed to keep refrigerant leakage to a minimum. Figures 21 and 22.

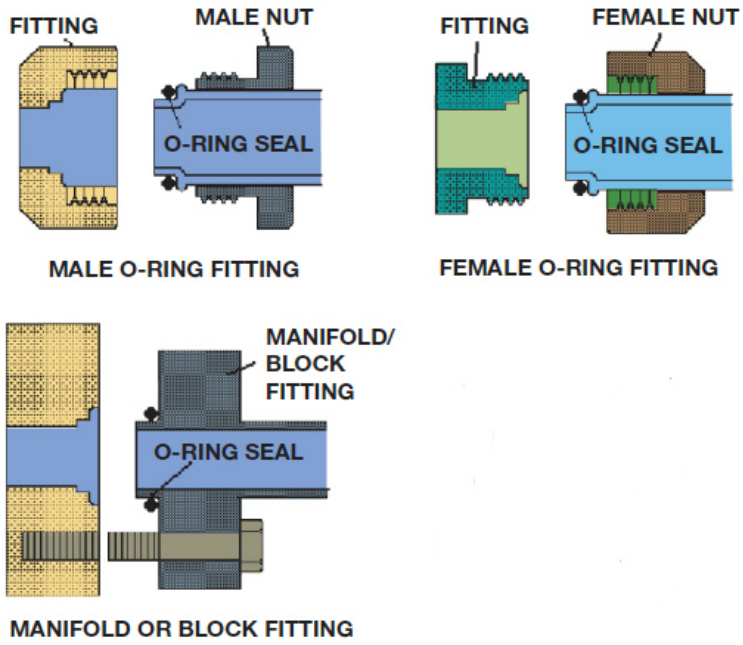

Figure 21. Threaded couplers.

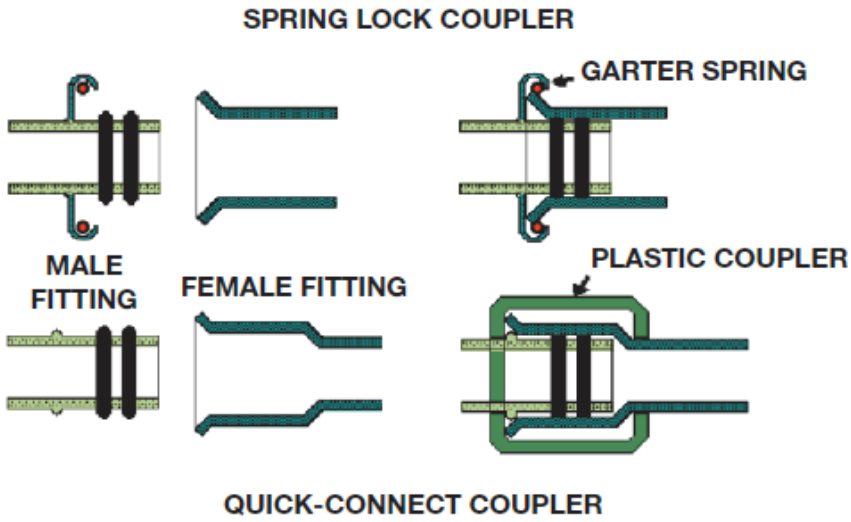

Figure 22. Spring-lock and quick-connect couplers are pushed together, and a garter spring or plastic coupler holds them together.

9. Inspect A/C condenser for proper air flow.

A common cause of poor heat transfer at the condenser is lack of airflow across the condenser. Insufficient heat transfer at the condenser will cause high-side pressure that is too high and poor cooling in the cabin. Check engine cooling fan operation with the A/C turned on. The electric fan(s) should be running, with good airflow.

Inspect the condenser for airflow restriction and clean as needed. The condenser should be carefully cleaned using water to wash off road dirt and debris from the cooling fins.

10. Inspect, test, externally clean, or replace A/C system condenser; check mountings and air seals/dams/ shutters.

A visual inspection of the underhood items should include an inspection of the condenser and fan shrouds.

- Check the faces of the condenser and radiator core for restriction to airflow caused by debris and clean as needed. The lower air dam in the front of the vehicle is used to help direct the air through the radiator. If this air dam is broken or missing, A/C operation may be affected or the engine may overheat, especially during highway driving, due to the reduced airflow through the condenser and radiator.
- Check that the fan shroud is in place and is not broken or partially missing. A fan shroud forces the fan to draw air through the radiator and condenser.

11. Inspect and replace receiver/drier (including integral receiver/drier), accumulator/drier, or desiccant.

A receiver–drier is used in the high side of a thermal expansion valve (TXV) system. It contains a desiccant to remove moisture and provides a storage chamber for liquid refrigerant. Most receiver–driers also contain a filter to trap debris that might plug the TXV. Figure 23.

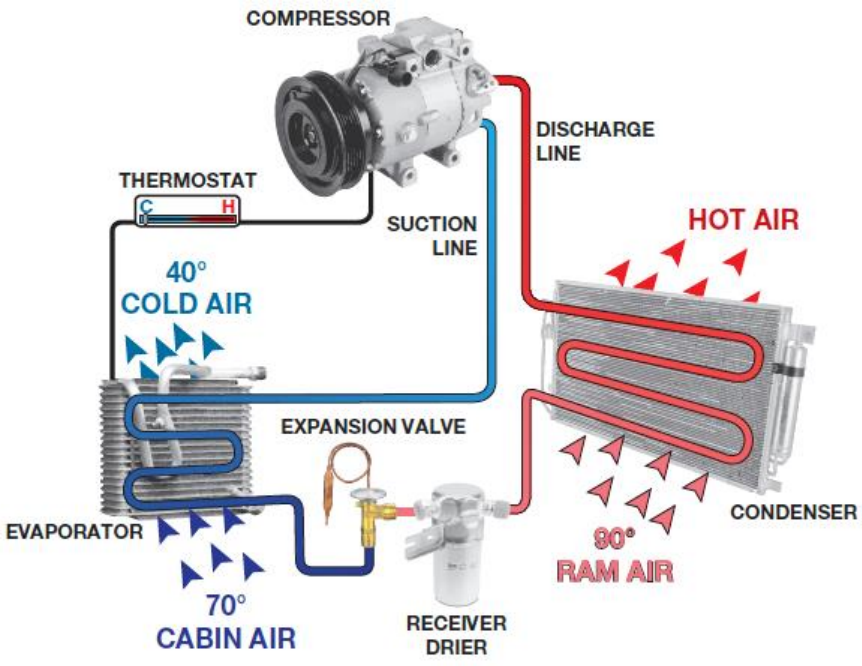

Figure 23. A TXV-type refrigeration system.

An accumulator is located in the low side of an orifice tube (OT) system. It prevents liquid refrigerant from passing to the compressor and contains a desiccant, which helps remove moisture from the system. It also holds a reserve of refrigerant. Figure 24.

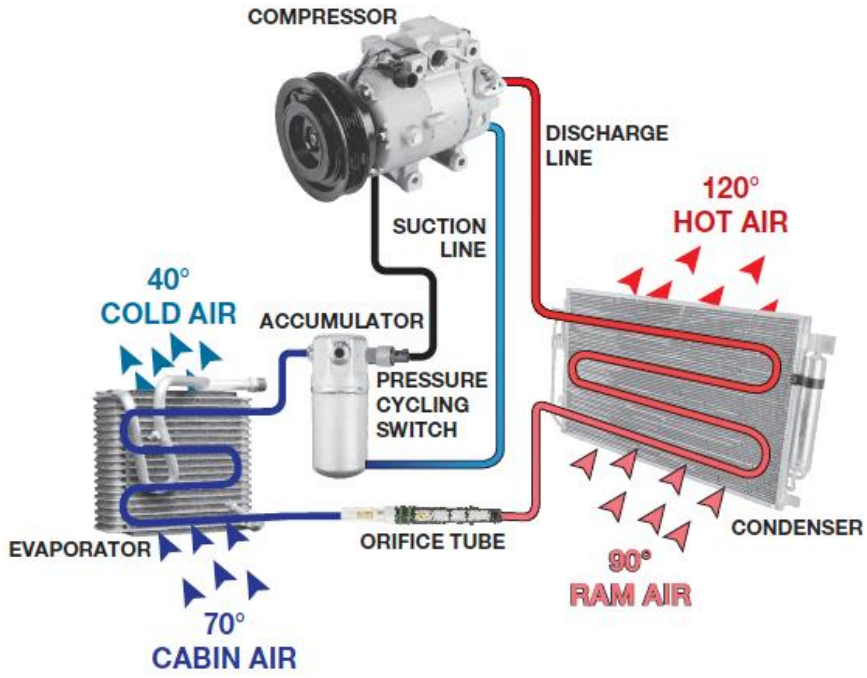

Figure 24. An OT-type refrigeration system.

It is standard practice to replace the accumulator or receiver–drier whenever major service work is done on a system, especially if the compressor is replaced.

Condenser sub-cooling makes sure that there is a liquid seal at the bottom of the condenser so the liquid line or receiver will not have any vapors. A sub-cool condenser has the drier built into the condenser itself. A condenser that includes a drier is called an integral receiver–driver (IRD). The receiver-drier may be called a modulator, and some have a plug so the desiccant can be changed. Figure 25.

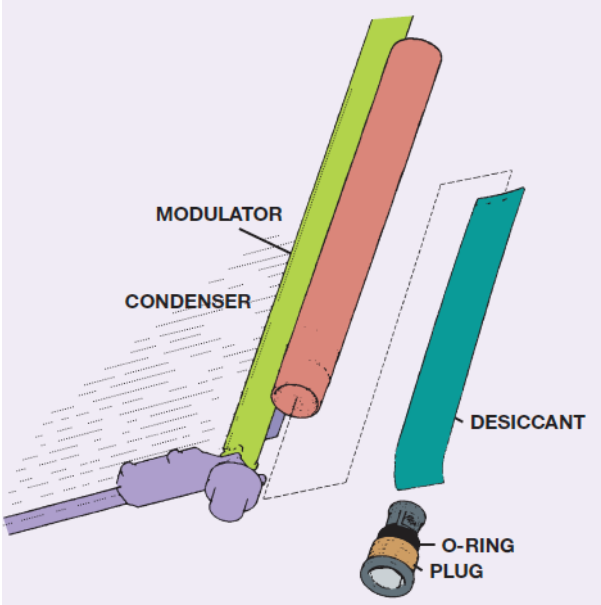

Figure 25. The modulator is built as part of the condenser and often includes a removable plug that allows desiccant replacement.

12. Inspect, test, and replace expansion valve(s) (mechanical and electronic).

A thermal expansion valve (TXV) senses both temperature and pressure and controls the flow of refrigerant into the evaporator. A typical expansion valve uses an inlet and outlet attachment for the evaporator, and a temperature sensing bulb that is attached to the outside of the evaporator outlet tube. Figure 26.

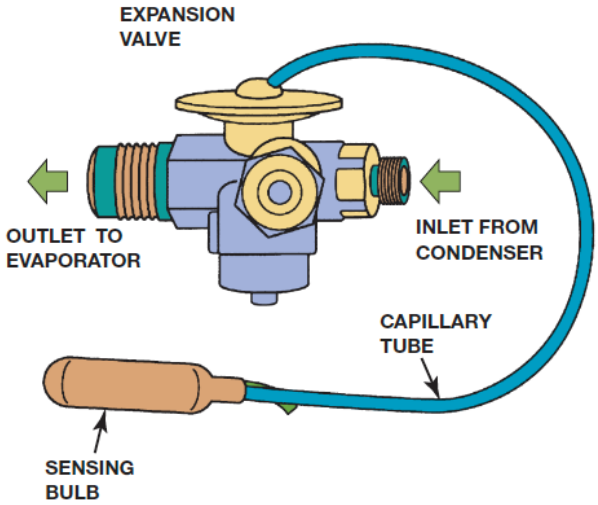

Figure 26. A thermal expansion valve.

An electronic expansion valve (EXV) has a solenoid and plunger in place of the sensing bulb and diaphragm assembly. Sensors input pressure and temperature data to the HVAC controller, then the controller can control the EXV using pulse width modulation. The EXV can be tested with a scan tool or by measuring resistance with a DVOM.

The thermal expansion block valve is another type of TXV. It is called an H-block or an H-valve. The H-block design uses four passages and controls the refrigerant flow using opposing pressures. Figure 27.

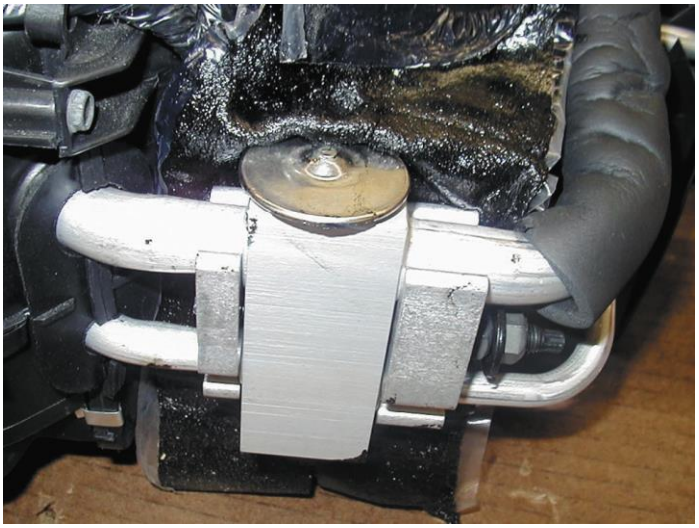

Figure 27. An H-valve (H-block) combines the temperature sensing and pressure-regulating functions into a single assembly.

To check for a possible restriction in both TXV and OT systems, follow these steps:

STEP 1 Connect the A/C pressure gauge to both low and high-side pressure fittings.

STEP 2 Operate the A/C system for 5 minutes to 10 minutes.

STEP 3 Shut off the A/C system and watch the pressure gauges. Normal time needed to equalize is often 15 seconds to 30 seconds, depending on the amount of refrigerant. If the pressures do not equalize quickly, there is a restriction in the system.

- Thermal expansion valve stuck closed.
- Orifice tube clogged with debris.

13. Inspect and replace orifice tube(s).

An orifice tube (OT), also called an expansion tube, is a fixed-diameter orifice that the refrigerant must flow through. The diameter varies between systems and is about 1/16 inch (0.065 inch or 1.6 mm). Figures 28 and 29.

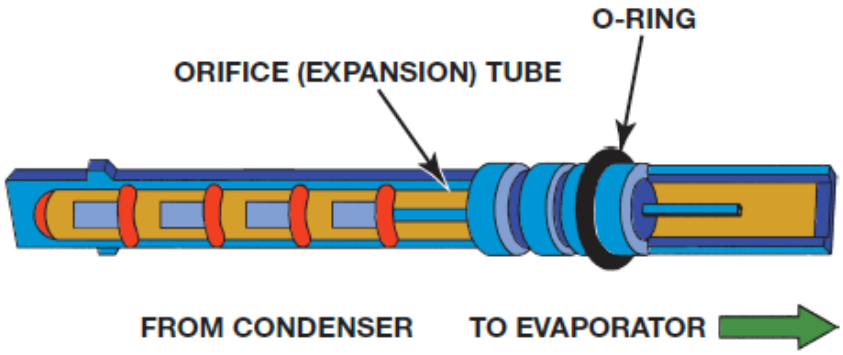

Figure 28. The orifice tube is placed in the liquid line before the evaporator.

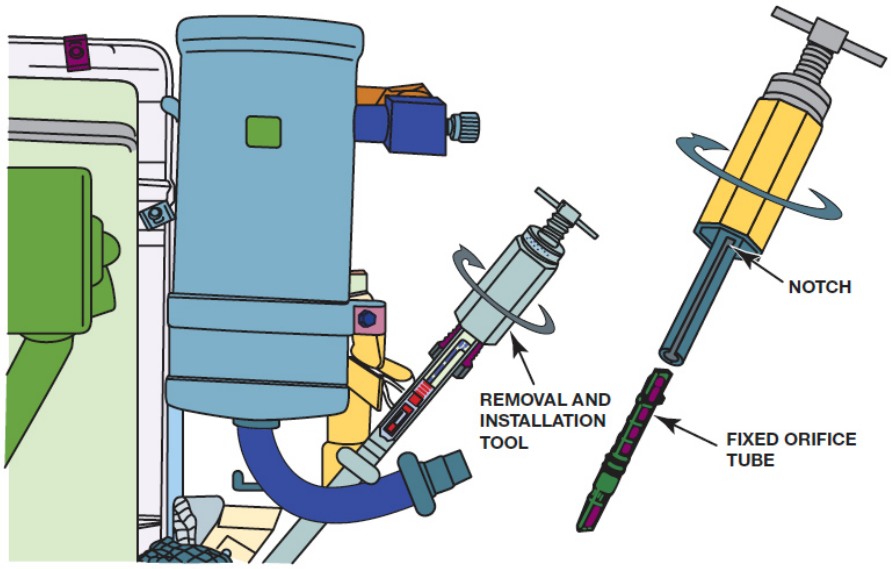

Figure 29. A special puller that attaches to the orifice tube is normally used to remove it.

14. Inspect A/C evaporator for proper air flow.

Most HVAC systems include a cabin filter to remove small dust or pollen particles from the incoming airstream. If they are not serviced properly, they will cause an airflow reduction when plugged. Figure 30.

Figure 30. A dirty cabin filter will reduce evaporator airflow.

15. Inspect, test, externally clean, or replace evaporator(s).

Some systems develop a musty, moldy smell which is most common in areas with high relative humidity, and it is caused by mildew-type fungus growth on the evaporator and in the evaporator plenum. Several companies market chemicals, essentially fungicides, to kill the bacterial growth, or detergents to clean the evaporator core. These chemicals are sprayed into the ductwork or onto the evaporator fins.

Removal of an accumulator, condenser, evaporator, or receiver–drier also removes a certain amount of oil from the system, and new oil should be added to the new part. The actual amount is usually specified in service information. Figure 31.

COMPONENT	FLUID OZ.	CC
Accumulator	2	60
Condenser	1	30
Evaporator	2	60
Each hose	0.3	10
Receiver–drier	0.5	15

Figure 31. Typical oil amounts.

If faulty, a major A/C component (the accumulator, condenser, evaporator, OT, receiver–drier, or TXV) is repaired by replacing it with a new one. In most cases, getting the evaporator case out of the vehicle is tedious and time consuming, sometimes requiring the vehicle or evaporator case to be cut. Many

technicians will not change an evaporator without consulting service information for the exact procedure to follow.

16. Inspect, clean, and repair evaporator housing and water drain.

As the air-conditioning system operates, it dehumidifies (removes moisture) from the air. Water vapor condenses on the cold evaporator fins just as it would on a glass holding a cold drink. This condensed water then drops off the evaporator and runs out the drain at the bottom of the evaporator case.

If the evaporator water drain tube becomes clogged with mud, leaves, or debris, water will build up inside the evaporator housing and spill out onto the carpet on the passenger side. Figure 32.

Figure 32. Check the condensate drain to be sure it is open if there is water on the carpet on the passenger side.

17. Inspect, test, and replace evaporator pressure/temperature control systems and devices.

The minimum temperature for an evaporator is 32°F, the point at which water freezes and ice and frost form. There are several ways of preventing evaporator icing, including the following:

- Cycling the compressor clutch
- Controlling evaporator pressure so it does not drop below 30 PSI
- Reducing the displacement of the compressor by using a variable displacement compressor.

Evaporator temperature in a cycling clutch system is sometimes controlled by either a thermostatic (thermal) switch or pressure switch. Both of these switch styles are calibrated so they are closed at temperatures above 32°F (0°C) and open at temperatures below 32°F (0°C). When the switch opens, the compressor clutch is turned off. Figure 33.

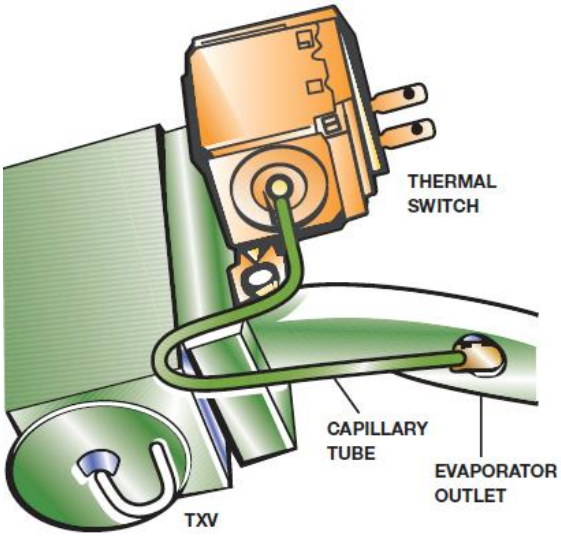

Figure 33. Older TXV systems use a thermal switch to cycle the compressor out when the evaporator gets too cold.

A pressure cycling switch is mounted to sense low-side pressure, usually on the accumulator. As the switch senses the pressure dropping below a certain point (about 30 PSI), it opens to stop the compressor. The pressure switch closes when the pressure increases, with the cut-in pressure being about 42 PSI to 49 PSI, depending on the vehicle. Figure 34.

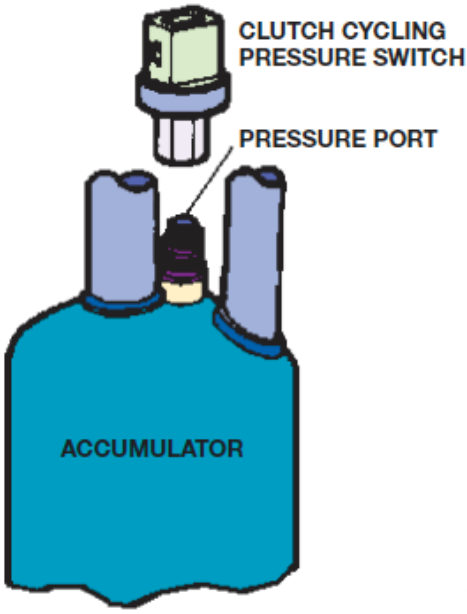

Figure 34. Orifice tube systems often use a pressure switch to cycle the compressor out when the low-side pressure drops too low.

Recent systems use solid-state sensors that do not use switch contacts. The most common sensors are thermistors and transducers. These provide a variable output instead of just being on or off like a switch. Sensors provide an electrical signal to the HVAC control module or BCM that, in turn, controls compressor clutch or condenser fan operation.

18. Identify, inspect, and replace A/C system service valves and valve caps.

The caps over the service ports include an internal O-ring. The seal is used to prevent refrigerant loss and is the primary seal. The caps used on a R-1234yf system are tethered to prevent loss according to SAE J639 standard. Service ports are found almost anywhere on the system. Service ports may be located on the receiver–drier, accumulator, compressor, muffler, or on the lines themselves. Figure 35.

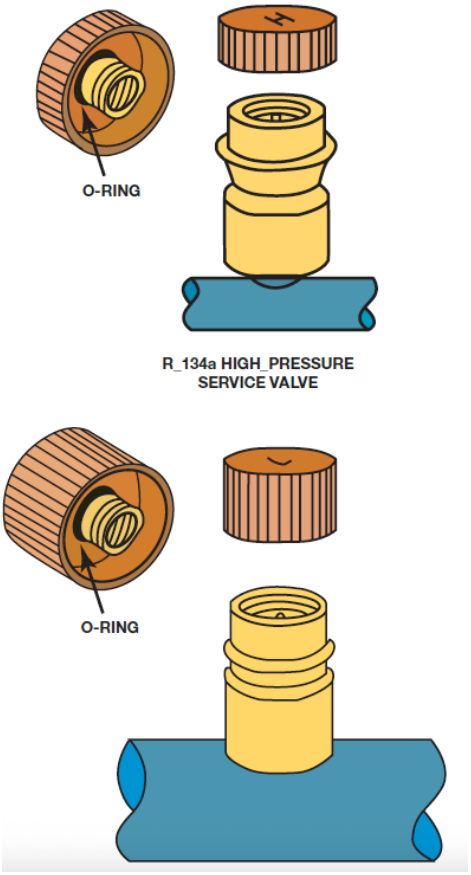

Figure 35. R-134a service ports. Vehicles with R-1234yf have different service fittings from R-134a vehicles to prevent cross-contamination.

19. Inspect and replace A/C system high pressure relief device.

Excessive high-side pressure can produce compressor damage and a potential safety hazard if the system should rupture. Many systems contain a high-pressure relief or release valve, or release valve which is mounted on the compressor. A relief valve is spring-loaded so excessive pressure will open the valve, and as soon as the excess pressure is released, the valve will reclose. Figure 36.

Figure 36. A high-pressure relief valve contains a strong spring that keeps the valve closed unless high-side pressure (from the left) forces it open.

Newer systems are designed to release the clutch and shut the system off if pressures get too high to avoid venting refrigerant into the atmosphere.

20. Identify, inspect, test, and replace internal heat exchanger (IHX).

In order to increase the performance level of a R1234yf system to that of a R134a, an internal heat exchanger (IHX) is used. An internal heat exchanger (IHX) is used to transfer heat between the low side pressure and the high pressure flow circuits. The IHX is essentially a tube within a tube. Its function is to improve system performance by further sub-cooling the refrigerant being supplied to the evaporator from the refrigerant control device. Figure 37.

Figure 37. An internal heat exchanger (IHX) is recognized by the combined refrigerant lines (circled).