INTRODUCTION

Automotive A/C systems operate on the principle of moving heat from inside to a warmer outside of the vehicle. Heat travels from a higher temperature (higher energy level) to a lower temperature (lower energy level).

- The flow of a refrigerant through the system is called the refrigeration cycle and is used to cool the interior of the vehicle.
- The heating system transfers heat from the engine's cooling system to the passenger compartment.

The refrigeration system uses evaporation of a liquid (refrigerant) and the large amount of heat required for evaporation. The refrigerant boils so that it changes from liquid to gas, but it is condensed back to gas using an engine or electrically powered compressor to move the refrigerant and to increase its pressure in the system.

Heat, from in-vehicle cabin air, causes the refrigerant to boil in the evaporator. The compressor increases the pressure and moves refrigerant vapor to the condenser, where the heat is transferred to ambient air. This also causes the vapor to return to liquid form. Figure 1.

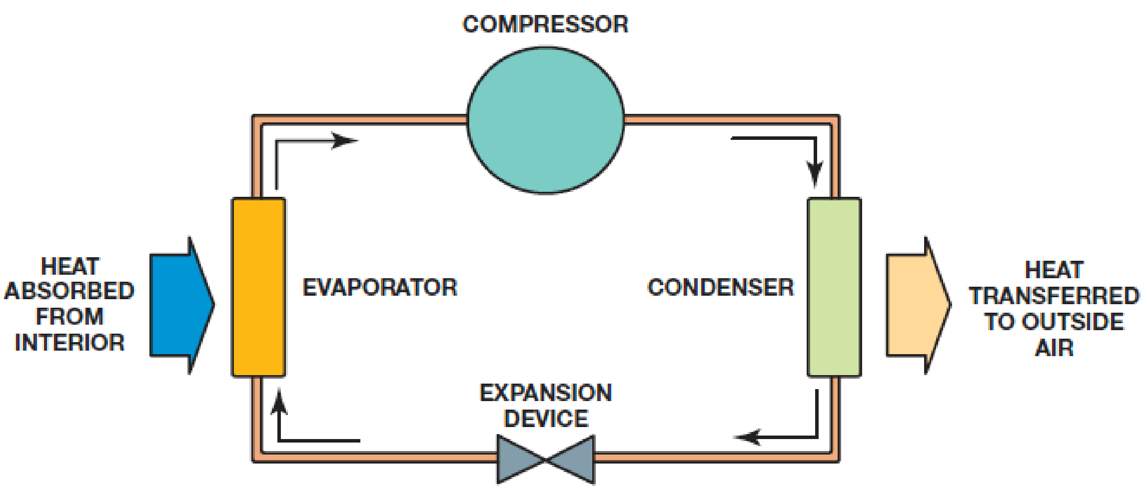


Figure 1. Refrigeration system.

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. Figure 2.

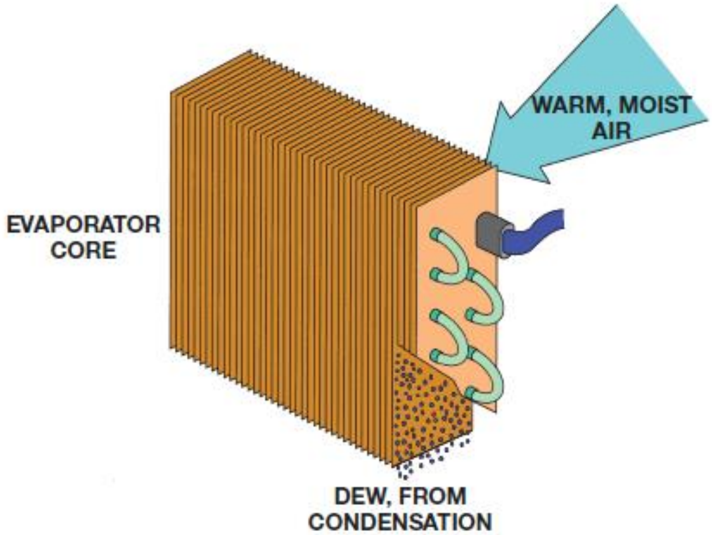


Figure 2. Evaporator core lowers the humidity in the vehicle.

The heater core, evaporator, blower fan, and air control doors are contained within a housing located behind the vehicle dashboard. Figures 3 and 4.

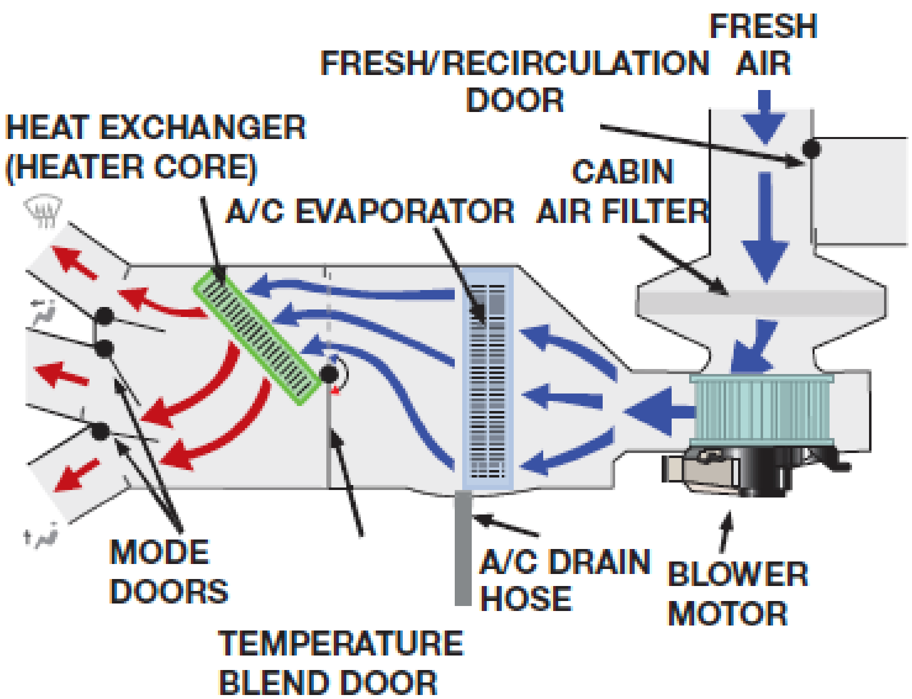


Figure 3. HVAC housing and components.

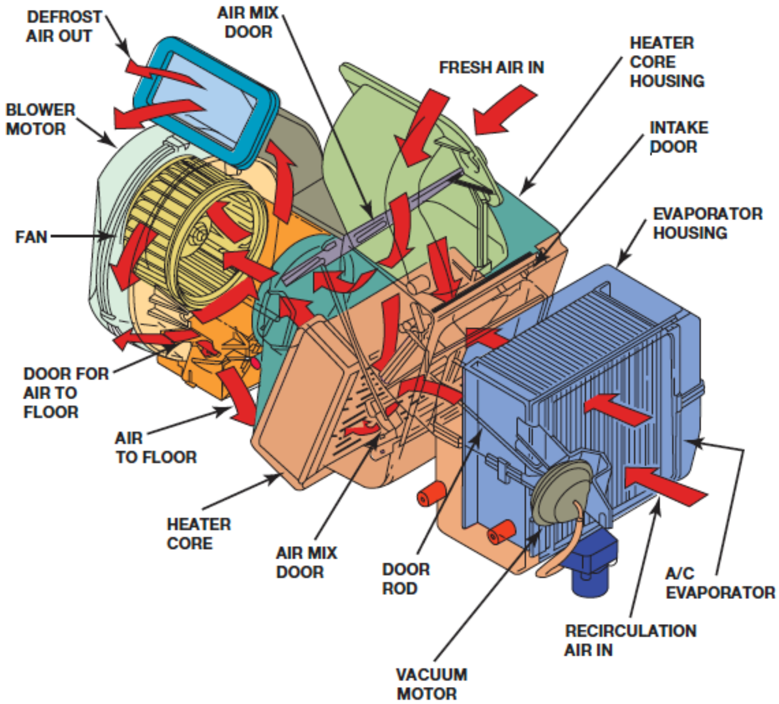


Figure 4. Airflow through the HVAC system.

Refrigerant. All automotive air-conditioning systems are closed and sealed. A refrigerant is circulated through the system by a compressor. Current model vehicles use either R-134a or R-1234yf refrigerants. These are not interchangeable.

Compressor. The air-conditioning compressor can be thought of as a pump that circulates refrigerant. Most A/C compressors are driven by a belt and pulley from the engine. The refrigerant pressure must be increased until the refrigerant temperature is above ambient air temperature so the condenser can get rid of all the heat absorbed in the evaporator. Figure 5.

Figure 5. The compressor is mounted to the engine and driven by a belt.

Condenser. 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. The condenser of most vehicles is mounted in front of the radiator. Figure 6.

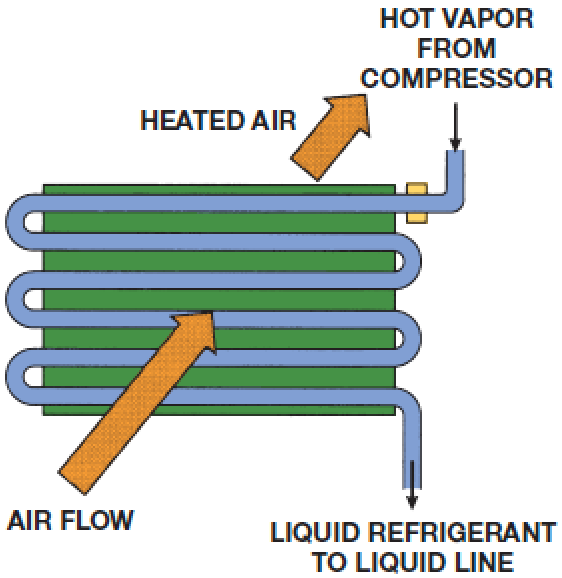


Figure 6. A condenser is a heat exchanger that transfers heat from the refrigerant to the air flowing through it.

The refrigeration system contains a restriction or orifice in the refrigerant line so the compressor can build pressure. Automotive systems use either an orifice tube or an expansion valve for this purpose.

Orifice tube. Most orifice tubes are a thin brass tube that is a couple of inches long and has a plastic filter screen around it. This tube is sized to flow the proper amount of refrigerant into the evaporator for maximum cooling loads. Figure 7.

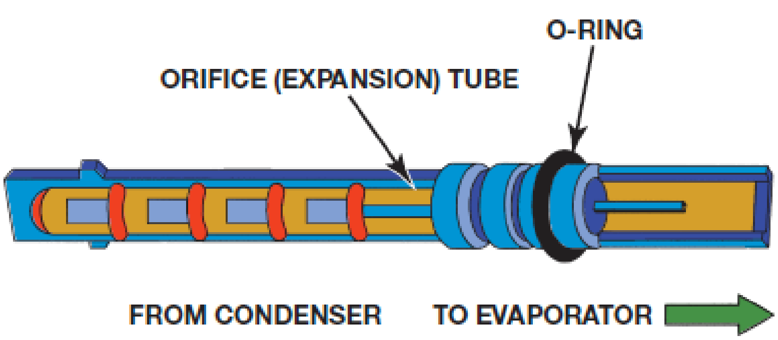


Figure 7. Orifice tube.

Expansion valve. A thermal expansion valve (TXV) senses both temperature and pressure and controls the flow of refrigerant into the evaporator. Figure 8.

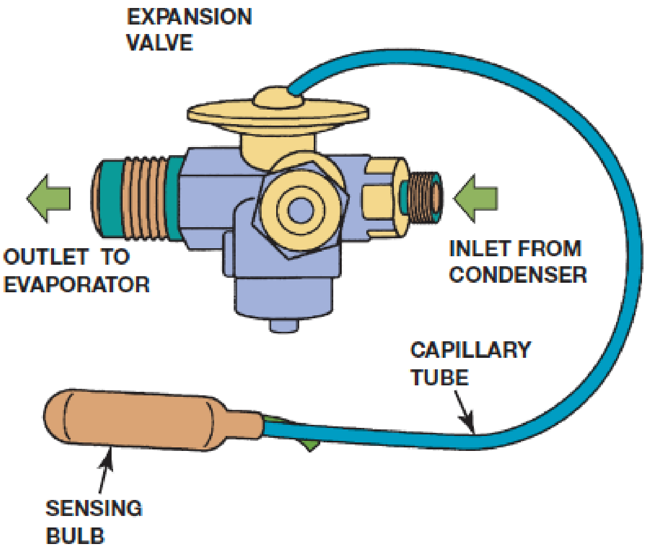


Figure 8. Thermal expansion valve (TXV).

Evaporator. 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. Figure 9.

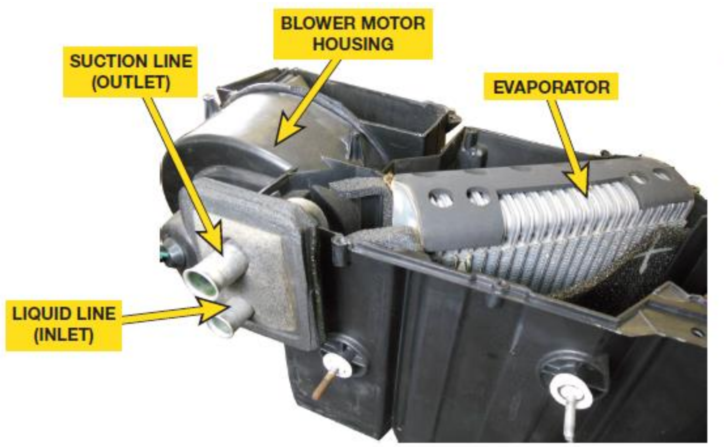


Figure 9. The evaporator is located inside the HVAC housing.

Storage device. The refrigeration system includes a receiver-drier or an accumulator that is used to store refrigerant. The purpose of refrigerant storage is to compensate for volume changes due to temperature change or refrigerant loss. A desiccant is included to remove moisture or water, which can cause corrosion. Figure 10 and 11.

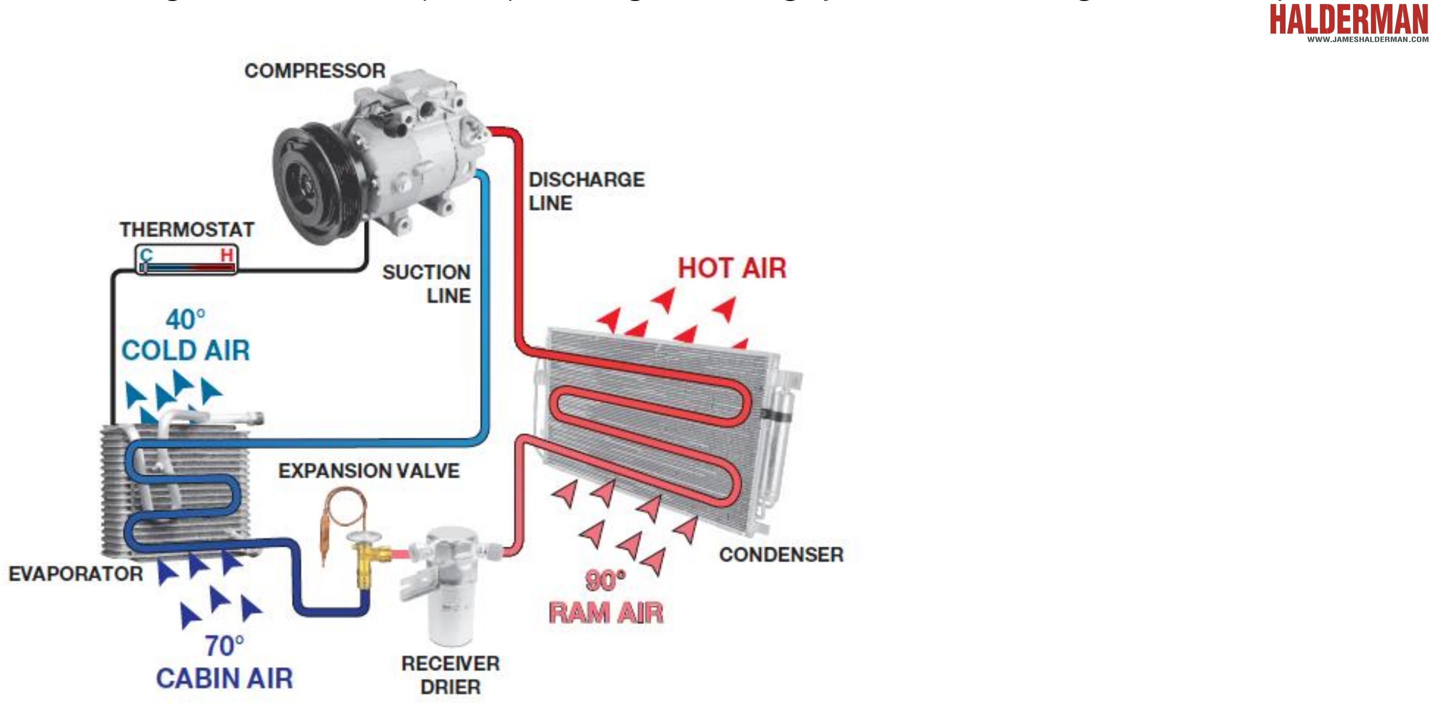


Figure 10. A receiver-drier is used with an expansion valve system.

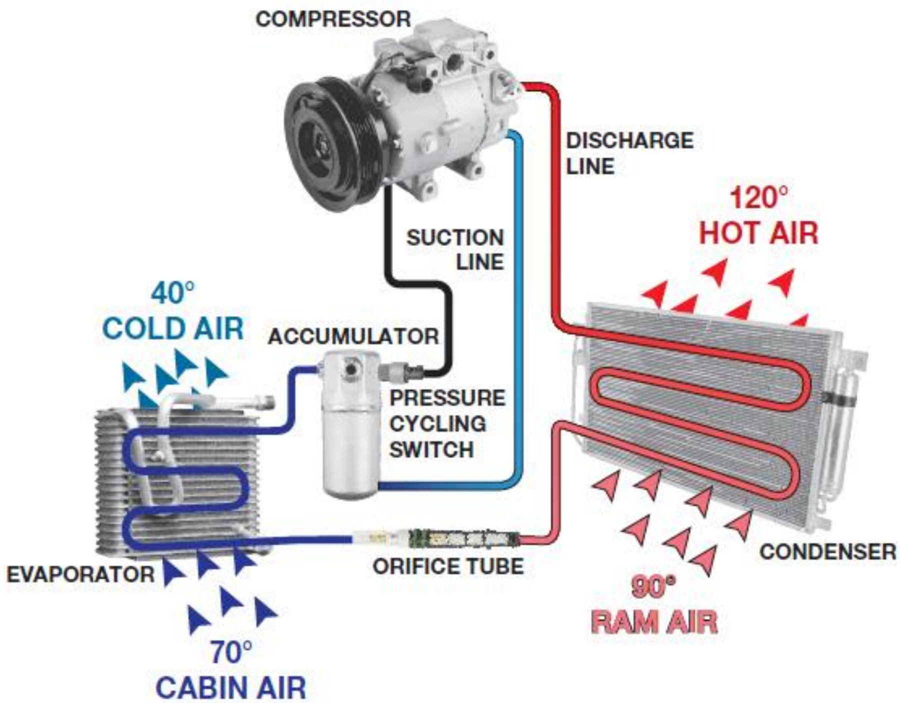


Figure 11. An accumulator is used with an orifice tube system.

ASE TEST TOPICS

1. Identify system type and conduct performance test on the HVAC system; determine needed repairs.

The HVAC system type can be determined by the presence of an accumulator or a receiver drier, as described in the introduction. If the system has an accumulator it is an orifice tube system and with a receiver-dried it is a TXV system.

The performance of the air-conditioning system can be determined by measuring the temperatures at various locations. The temperature of the air being discharged into the passenger compartment should be checked to provide adequate cooling by performing the following steps.

STEP 1 Start the engine and turn the air-conditioning system to maximum, with the engine operating between 1500 and 2000 RPM with the doors open. Operate the system for 5 to 10 minutes.

STEP 2 Place an air-conditioning thermometer in the air-conditioning vent near the center of the vehicle. Wait several minutes to allow the system to reach maximum output and observe the temperature in the thermometer. Figure 12.

- If 35°F to 45°F (2°C to 7°C) or 30°F (–1°C) cooler than the outside air temperature, the system is functioning normally.
- If over 45°F (7°C) or over 30°F (–1°C) warmer than the outside air temperature, then further testing is needed to determine the root cause.

Figure 12. Measure the temperature at the center vents.

2. Diagnose HVAC system problems indicated by system pressures and/or temperature (contact, non-contact, thermal imaging) readings; determine needed repairs.

Pressures are measured using the A/C gauge set. To measure system pressures:

- Install pressure gauges to the service ports. Figure 13.

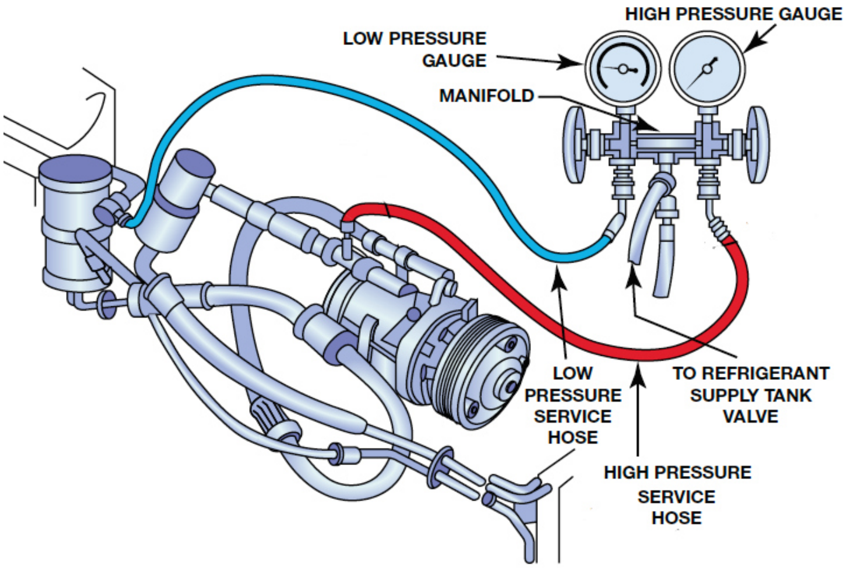


Figure 13. HVAC gauge set installation.

- Start the engine, set the parking brake, and raise the idle to 2000 RPM.
- Set the air conditioner for maximum cooling.
- Allow the system to operate for another five minutes before recording the gauge readings. Figure 14.

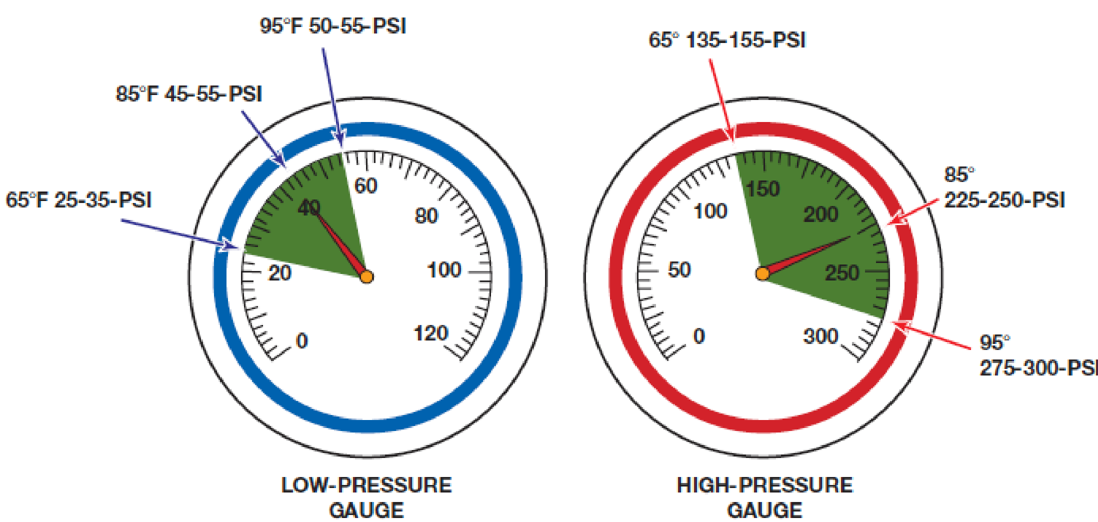


Figure 14. Normal R-134a A/C pressures shown at three different ambient air temperatures. High humidity and airflow velocity across the evaporator and condenser will affect the pressure readings.

Temperature and pressure are directly related in A/C systems. As the ambient temperature increases, the high-side pressure will also increase to have a heat transfer at the condenser. Figure 15.

- The high-side pressure is directly related to the amount of heat that needs to be removed by the heat transfer at the condenser.

- Low-side pressure indicates the boiling point of the temperature of the evaporator. If the pressure is too high, the boiling point of the refrigerant and temperature of the evaporator are too high. Low-side pressure that is too low indicates the evaporator is too cold and may ice, or that there is not enough boiling refrigerant in the evaporator to remove an adequate amount of heat.

LOW SIDE	HIGH SIDE	DUCT (VENT) TEMPERATURE	POSSIBLE CAUSE
Low	Low	Warm	Low refrigerant charge
High	High	Warm	Overcharged
High	High	Some cooling	Air in the system or overcharge
Normal	Normal	Warm	Moisture in the system
Low	Low	Warm	Expansion valve stuck closed or orifice tube clogged
Low	Low	Warm	High-side restriction
High	Low	Warm	Compressor or control valve failed

Figure 15. Diagnostic chart showing high and low refrigerant pressures and duct (vent) temperature with possible causes.

System performance can be checked using an infrared thermometer to measure temperature changes across the evaporator and condenser.

Temperature change across the evaporator. The temperature difference between the inlet and outlet of the evaporator should be the same or within 5° (−5° to +5°).

- If the temperature at the evaporator outlet is more than 6° different than the inlet temperature, the system is overcharged.
- If the temperature at the outlet of the evaporator is cooler than the inlet, the system is undercharged.

Temperature change across the condenser. The temperature difference between the inlet and outlet of the condenser should be 20°F to 50°F (–7°C to 10°C).

- If the temperature difference is higher than 50°, the system is undercharged or has a restriction.
- If the temperature difference is less than 19°, the system is overcharged.

3. Diagnose HVAC system problems indicated by sight, sound, smell, and touch procedures; determine needed repairs.

A quick test to check the state of charge of an orifice tube system is to use one hand and touch the evaporator side of the orifice tube. Touch the other hand to the inlet to the accumulator.

- Normal operation—both temperatures about the same
- Undercharged condition—accumulator temperature higher (warmer) than the orifice tube temperature

High pressure means that the temperature of the component or line will also be high (hot). Low pressure means that the temperature of the component or line will also be low (cold). For example, the inlet to the compressor (low pressure) should always be cool, whereas the outlet of the compressor (high pressure) should always be hot.

4. Leak test A/C system (dye and/or electronic); determine needed repairs.

The use of an electronic leak detector meeting SAE J1628 is the most used method that experts and vehicle manufacturers recommend to find refrigerant leaks. Before using an electronic leak detector, perform a visual inspection and check the entire refrigerant system for traces of oil which usually indicates the location of a refrigerant leak. Figure 16.

Figure 16. An electronic leak detector being used to locate a possible leak in a system. For best results, move the detector probe completely around each fitting and connection.

Ultraviolet (UV) fluorescent trace dye is sometimes added to the refrigerant to help the technician visually spot a leak in the refrigerant system. The dye circulates throughout the system with the refrigerant oil. Leaks can be viewed by the technician using the light supplied with the dye kit.

5. Identify A/C system refrigerant type (R-12/ R-134a/ R-1234yf) and existing charge amount; recover refrigerant.

A label under the hood of the vehicle specifies the type of refrigerant the system is designed for. To verify what type of refrigerant in the vehicle, a refrigerant identifier is used. Figure 17.

Figure 17. This vehicle specifies R-134a refrigerant.

A refrigerant identifier should be used on any system that is being serviced. Two service hoses (a low and high side) are connected to the system service ports. The identifier is usually built into the recovery, recycling, and recharging (RRR) machine. Figure 18.

Figure 18. Identifier printout shows 100% R-1234yf.

Recovering the refrigerant from a system usually includes the following steps:

STEP 1 Identify the refrigerant in the system.

STEP 2 Connect the recovery unit to the system following the instructions of the manufacturer.

STEP 3 Open the required valves and turn the machine on to start the recovery process, following the instructions of the machine's manufacturer.

STEP 4 Continue the recovery until the machine shuts off or the pressure reading has dropped into a vacuum.

STEP 5 Verify completion of recovery by shutting off all valves and watching the system pressure. If pressure rises above 0 PSI within 5 minutes, repeat steps 3 and 4 to recover the remaining refrigerant.

STEP 6 Drain, measure, and record the amount of oil removed.

NOTE: Newer RRR machines have steps 3, 4, and 5 built into software; the machine performs these steps automatically.

6. Evacuate A/C system.

After a system has been repaired, all of the air and moisture that might have entered must be removed. Evacuation means that a vacuum will be applied to the system to remove the air and to vaporize any moisture that may be in the system.

Most recent RRR machines use electric solenoids to control the flow inside the machine, and starting the evacuation process opens the solenoids needed for this process.

During evacuation the machine will perform a vacuum leak check by holding for 5 minutes and watching for any pressure rise. Any pressure rise indicates that the system is leaking, and further repairs are needed.

Newer RRR machines combine the evacuation, leak check, and recharge operations into a mandatory step-by-step process to prevent charging a system that is leaking. If the vacuum leak test does not pass the machine will not allow recharging.

7. Inspect and test A/C system components for contamination; flush or replace as needed.

Flushing is using a liquid or a gas to clean the inside passages of an air-conditioning system. When a compressor fails, it usually sends solid compressor particles into the high and possibly the low sides, which can plug the condenser passages and orifice tube or TXV. Flushing is done by pumping a liquid material through the passages in a reverse or normal flow direction. Note that a compressor cannot be flushed. The accumulator or receiver–drier are replaced, not flushed.

Adapters are used to connect a flushing unit, which pumps the flushing material through the components. Most flushing machines are fully automated, meaning that it will vacuum, flush, recover, recycle, vacuum, and purge the cleaning solvent all automatically. Figure 19.

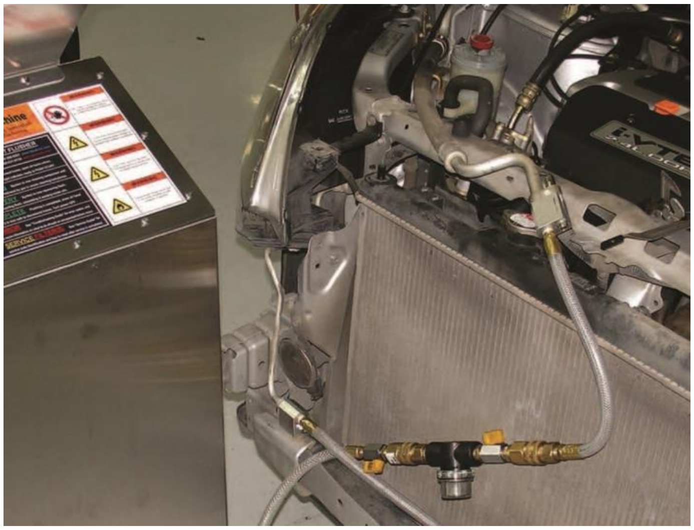


Figure 19. Flushing machine connected to a vehicle.

8. Charge A/C system with appropriate refrigerant.

Recharging with an RRR machine usually is done as soon as the system is evacuated. During evacuation the machine will perform a vacuum leak check by holding for 5 minutes and watching for any pressure rise. Any pressure rise indicates that the system is leaking, and further repairs are needed.

As standards are tightened concerning refrigerants, many of the steps for evacuating and recharging systems are built into the software of the RRR machine. This helps to prevent charging refrigerant into a leaking system.

The standard operating procedure when using the RRR machine to charge the system includes the following steps:

STEP 1 After the technician enters the correct charge amount, the machine first draws a vacuum on the system to 26.9 inches of mercury.

STEP 2 The machine monitors the applied vacuum to make sure that it does not degrade lower than 25.9 inches mercury in 5 minutes. If the vacuum drops more than allowed, the leak has to be repaired before the machine will allow refrigerant to be added to the system.

STEP 3 If the systems passed the vacuum test, the RRR machine will automatically add a small refrigerant charge to the system and then monitor the system pressure for 5 minutes. A pressure decrease of 10% or more indicates a leak is present and the machine will not add more refrigerant.

STEP 4 If the system is leak-free, the machine will proceed and fully charge the system.

9. Identify A/C system lubricant type and capacity; replenish lubricant if necessary.

The proper amount of oil can be kept in a system by adding oil to replace the amount of oil removed when a component is replaced. This is usually only a small amount. Compressor replacement requires a slightly larger amount. The amount of oil retained in a component varies with the size and design. Figure 20.

COMPONENT	TYPICAL AMOUNT OF OIL IN FLUID OUNCES (FL OZ)	TYPICAL AMOUNT OF OIL IN CUBIC CENTIMETERS (CC)
Evaporator	2.0	60
Condenser	1.0	30
Receiver–Drier	0.5	15
Accumulator	2.0	60

Figure 20. Amount of oil to be added for replaced components.

PAG (polyalkylene glycol) oils are used in most R-134a systems. POE (polyol ester) (ester) oils are used in a few R-134a systems. The refrigerant oil required for HFO-1234yf is PAG-based oil with an additive package unique to R-1234yf. Always check the under-hood decal or service information for the exact oil and viscosity to use. Figure 21.

Figure 21. This vehicle uses R-1234yf refrigerant and POE oil.

10. Inspect and replace passenger compartment (cabin air, pollen) filter.

Many newer systems include an HVAC air filter, usually called a cabin filter, in the air distribution system. Cabin filters are located outside the air inlet and are serviced under the hood, or between blower and evaporator which are serviced from under the dash. Figure 22.

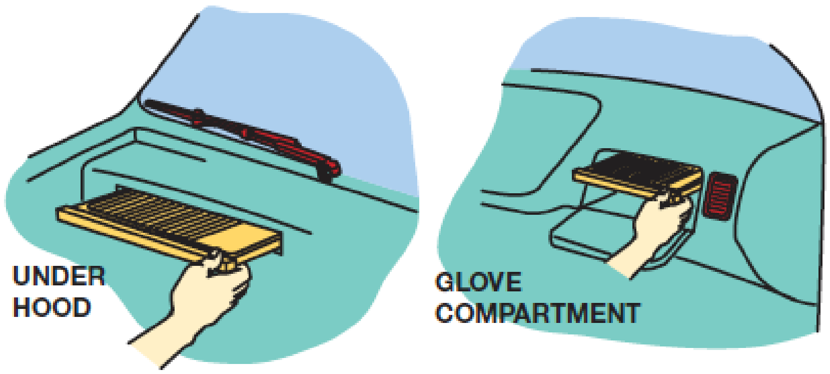


Figure 22. A cabin filter can be accessed either through the glove compartment or under the hood on most vehicles.

These filters require periodic replacement. If they are not serviced properly, they will cause an airflow reduction when plugged. Most vehicle manufacturers recommend replacing the cabin filter every 15,000 to 25,000 miles (24,000 to 40,000 km).

11. Disarm and enable the airbag system for vehicle service following manufacturers' recommended procedures.

Check service information for the exact disarming procedure, which usually includes the following steps:

STEP 1 Disconnect the negative battery cable. Once the battery is disconnected, wait as long as recommended by the manufacturer before continuing. When in doubt, wait at least 10 minutes to make sure the reserve capacitor is completely discharged.

STEP 2 Remove the airbag fuse (some vehicles)

STEP 3 Disconnect the yellow electrical connector located at the base of the steering column to disable the driver's-side airbag.

STEP 4 Disconnect the yellow electrical connector for the passenger side airbag.

12. Read diagnostic trouble codes (DTCs) and interpret scan tool data stream.

To get access to the codes set for most of the HVAC-related faults requires the use of a factory scan tool or an enhanced factory-level aftermarket scan tool. Many HVAC systems are controlled by the body control module (BCM). The air-conditioning-related diagnostic trouble codes are usually found under "Body" or "Chassis" and if set, will NOT light the "check engine" warning light. HVAC-related faults may light another warning lamp or a message on the dash.

13. Read and interpret technical literature (service publications, bulletins, recalls, and information including wiring schematics).

The most comprehensive and accurate service information is the service information from the vehicle manufacturer. This information is available for most, if not all, vehicles and can be purchased from their website.

A technical service bulletin (TSB) is issued by the vehicle manufacturer to notify service technicians of a potential problem or other critical information. The TSB may include diagnostic procedures and the necessary corrective action.

A recall can occur when either the manufacturer or the National Highway Traffic Safety Administration (NHTSA) determines there is a concern. A recall or campaign is issued by a vehicle manufacturer, and a notice is sent to all owners of record.

Service information includes wiring schematics of every electrical circuit in a vehicle. A wiring schematic, sometimes called a diagram , shows electrical components and wiring using symbols and lines to represent components and wires.

Wire size is shown on all schematics. Figure 23 illustrates a rear side marker bulb circuit diagram where “0.8” indicates the metric wire gauge size in square millimeters (mm2) and “PPL” indicates a solid purple wire.

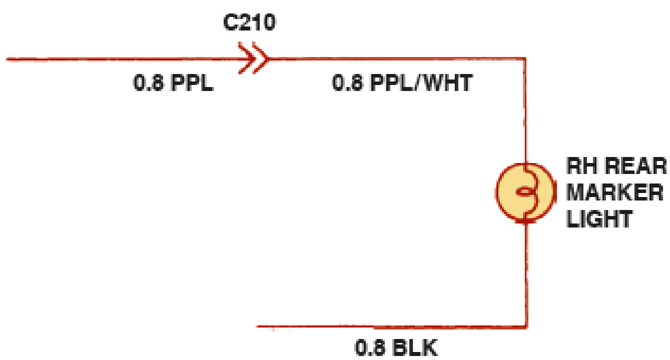


Figure 23. Typical section of a wiring diagram. Notice that the wire color changes at connection S210.

Electrical and electronic symbols are used in automotive wiring and circuit diagrams. Both the conventional and the global symbols are shown side by side to make reading schematics easier. The global symbols are used by many vehicle manufacturers. Figure 24.

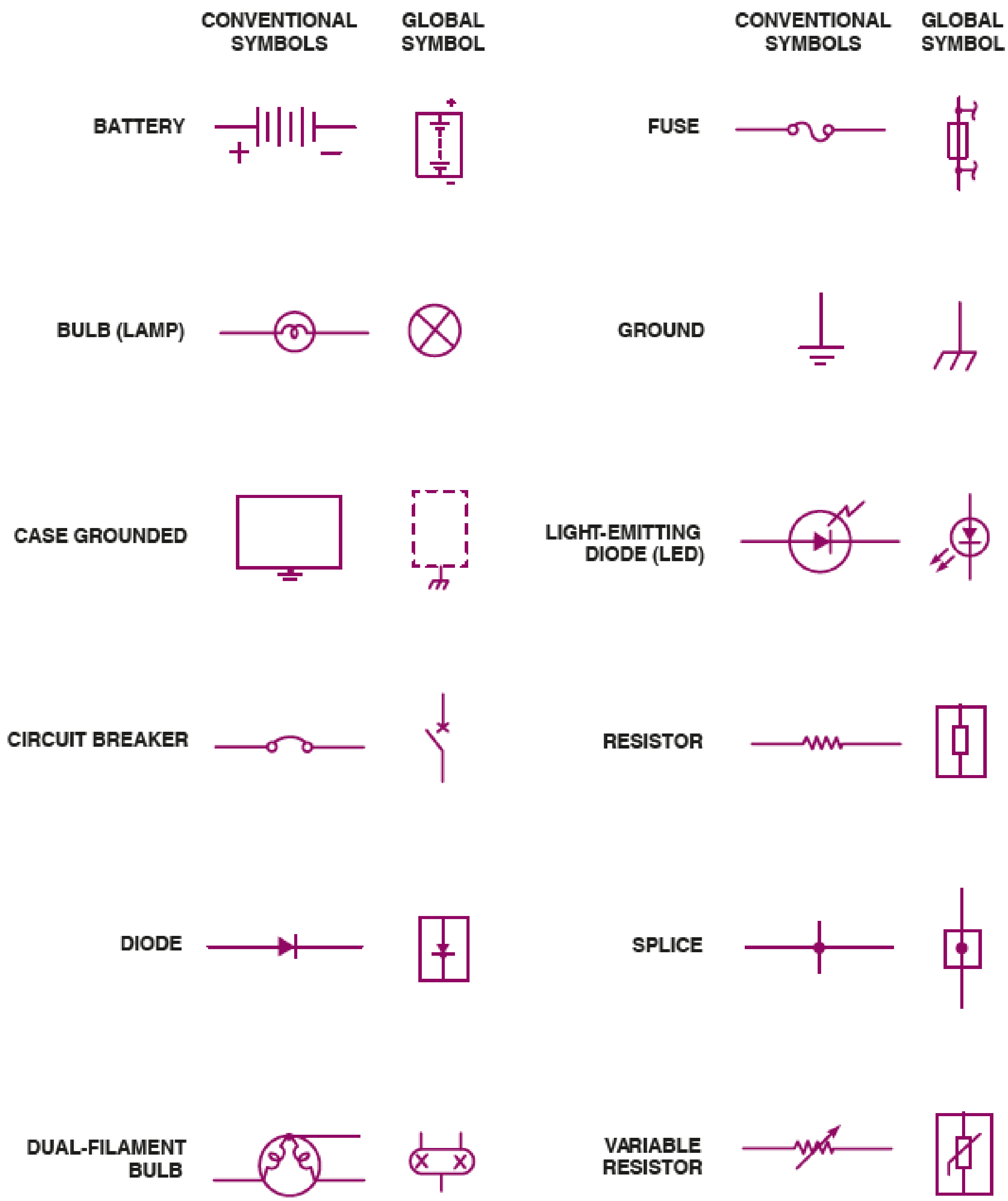


Figure 24. Typical schematic symbols.

14. Use a scan tool, digital multimeter (DMM), or digital storage oscilloscope (DSO) to test HVAC system sensors, actuators, circuits, and control modules; determine needed repairs.

Use a factory scan tool or a factory level aftermarket scan tool and check for diagnostic trouble codes (DTCs). If there are stored diagnostic trouble codes, follow service information instructions for diagnosing the system. If there are no stored diagnostic trouble codes, check scan tool data for possible fault areas in the system. Figure 25.

SENSOR	TYPICAL VALUE
Inside air temperature sensor	–40°F to 120°F (–40°C to 49°C)
Ambient air temperature sensor	–40°F to 120°F (–40°C to 49°C)
Engine coolant temperature (ECT) sensor	40°F to 250°F (–40°C to 121°C)
Sun load Sensor	0.3 volts (dark) 3.0 volts (bright)
Evaporator temperature sensor	Usually 34°F to 44°F (1°C to 7°C)
Relative Humidity sensor	0% to 100%

Figure 25. Typical scan tool sensor data.

Most recent vehicles use electrical function switches at the HVAC control head. These switches are usually inputs to an HVAC controller that then uses actuators to position the air distribution and temperature-blend doors.

A five-wire actuator uses two wires to power the motor (power and ground) and three wires for a potentiometer that is used to signal the HVAC control module of the position of the motor. Figure 26.

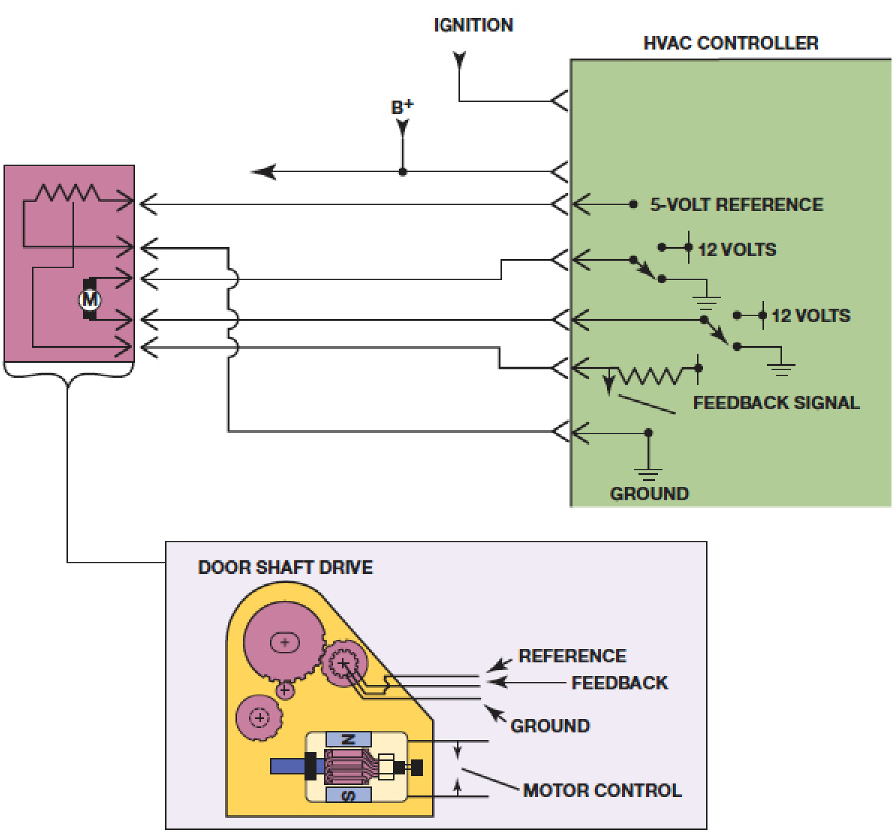


Figure 26. An electric HVAC door actuator with feed position sensor.

All factory scan tools are designed to provide bidirectional capability, which allows the service technician the opportunity to operate components using the scan tool, thereby confirming that the component is able to work when commanded.

15. Verify proper operation of certified equipment.

SAE (formally the Society of Automotive Engineers) has established guidelines and specifications. Each document has a "J" prefix and a number that makes searching for the details on the Internet easier. Before purchasing or using automotive air-conditioning test or service equipment, make sure that it meets the current standards for the vehicle being serviced. Some examples are:

- J2842—This SAE Standard establishes design criteria and certification for mobile air-conditioning evaporator and service replacements for R-1234yf and R744.
- J2843—This SAE Standard establishes R-1234yf (HFO- 1234yf) recovery/recycling/recharging equipment.
- J2927—This SAE standard applies to refrigerant identification equipment to be used for identifying an acceptable level of R-1234yf purity in a refrigerant tank or vehicle system labeled as containing R-1234yf and not misidentify other refrigerants.

Newer RRR machines will prompt the user for required maintenance needs. Some required service items are the filter and oxygen sensor.

To meet the SAE standards for adequate moisture and contaminant removal, the filter must be replaced after 150 lb. (68 kg) of refrigerant has been filtered. The latest RRR machines give a warning when 125 lb. (57 kg) of the filter capacity has been used. When the 150 lb. (68 kg) filter capacity has been reached, the machine will lock down and cannot be used until the filter is changed. For this reason, always keep a new filter in stock.

Another user check is a calibration check. This function is used to ensure the machine's internal scale is always calibrated. During this test, the calibration weight that is provided with the machine is attached when prompted and the machine checks its internal scale.

16. Recycle or properly dispose of refrigerant.

RRR equipment performs the recycling process automatically, as the refrigerant is recovered from the system. During recycling the recovered refrigerant is pumped through a very fine filter to remove foreign particles, past a desiccant to remove water, and through an oil separator to remove any excess oil. Air is removed by venting it, using the non-condensable purge, from the top of the liquid refrigerant.

If an unknown refrigerant is detected, it is considered to be the best practice to recover the refrigerant using a dedicated recovery only unit. Contamination from a foreign refrigerant requires that the refrigerant be sent off for reclaiming or disposal. Check with local waste-processing companies for the proper and legal way the contaminated refrigerant can be handled.

17. Label and store refrigerant.

Refrigerant containers are color coded:

- R-12 containers are white.
- R- 22 containers are green.
- R-134a containers are light blue. Figure 27.
- R-1234yf are white with a red stripe. Figure 28.

Refrigerant containers are usually disposable. These containers should be evacuated into a recovery unit, marked empty, and properly disposed of when they are emptied.

Figure 27. R-134a container.

Figure 28. R-1234yf container.

18. Test refrigerant cylinders for non-condensable gases; identify refrigerant.

Any gas that does not condense (change from vapor to liquid) under the normal compression refrigeration conditions is called a non-condensable gas (NCG). Any refrigerant that contains NCG, usually air, is considered contaminated.

Check for non-condensable gases (air) in the refrigerant by looking at the pressure–temperature (PT) relationship of the refrigerant. This is best done after the temperature of the refrigerant has stabilized for 12 hours.

- Read the pressure in the container using a calibrated pressure gauge with 1 PSI increments.
- Read the temperature of the air next to the container.
- Compare the pressure and temperature readings to the chart. Figure 29.

TEMPERATURE °F	PRESSURE (PSIG) R-12	PRESSURE (PSIG) R-134A
77	90	85
78	92	88
79	94	90
80	96	91
81	98	93
82	99	95
83	100	96
84	101	98
85	102	100
86	103	102
87	105	103
88	107	105
89	108	107
90	110	109
91	111	111
[illegible]	[illegible]	[illegible]

Figure 29. Partial chart showing pressure-temperature relationship of R-12 and R-134a refrigerants.

A refrigerant identifier displays the percentage by weight of R-134a, R-1234yf, R-22, hydrocarbons, and air (displayed as NCG). If the contaminant is air, the refrigerant can be safely recovered and recycled for reuse. If the contaminant is another refrigerant or a hydrocarbon, then a special recovery procedure is required, and the recovered mixture needs to be sent off for disposal or recycling.

19. Identify the procedures and equipment necessary to service, diagnose, and repair A/C systems in hybrid/ electric vehicles.

Hybrid vehicle A/C systems that use electrically driven compressors must use POE (polyol ester) oil. PAG (polyalkylene glycol) oil, which is used in non-hybrid vehicles, is slightly conductive and can cause electrical leakage between the windings and the compressor housing. This may set DTCs.

Many manufacturers specify the separate or different air-conditioning service equipment for hybrid and electric vehicles that use an electric air-conditioning compressor. To avoid cross contamination between

PAG and POE oil, which might lead to an electric motor winding failure or a loss of isolation, separate air-conditioning recovery stations are specified.

20. Diagnose the cause of temperature control problems in the heater/ventilation system; determine needed repairs.

The diagnosis of a heater problem or concern should start with a visual inspection. The following items should be checked or tested:

1. Coolant level and condition—Low coolant level can cause a lack of heat from the heater. Low coolant level can also cause occasional loss of heat.

2. Water pump drive belt condition and proper tension— Drive belt condition and proper installation are important for the proper operation of the cooling system.

3. Check the radiator or condenser for possible clogged or restricted areas—Carefully touch the outside of the unit with your hand or use an infrared thermometer. Any cool spots indicate that the radiator or condenser is clogged in that cool area.

4. Check the temperature of the heater hoses—Both should be hot to the touch. If the supply hose is hotter than the return hose, this indicates that the heater core could be partially clogged.

5. Check for proper airflow across the heater core—If the airflow is blocked by leaves or debris, this can reduce the amount of heat being delivered to the passenger compartment. Check that the cabin filter is clean and not restricted.

Using a factory or factory-level aftermarket scan tool, perform the following:

- Use a scan tool and check for any stored or pending diagnostic trouble codes, especially those that pertain to the HVAC controls.
- Check that the coolant temperature as measured by the engine coolant temperature (ECT) sensor is correct, usually 180°F to 200°F (82°C to 103°C).
- Perform a bidirectional control of the blend door and blower motor speed, if possible, to confirm that these are operating correctly.

21. Diagnose window fogging problems; determine needed repairs.

The Federal Motor Vehicle Safety Standard (FMVSS) 103 requires that every vehicle sold in the United States must be able to defrost or defog certain areas of the windshield in a specified amount of time. Most HVAC systems will default to defrost if there is a failure in the control part of the system. The defrost/defog system in most vehicles uses the heater/AC system and diverts the airflow to the base of the windshield.

Factors that contribute to fogged glass in a vehicle are:

- Temperature differences between the interior and exterior environment. When warm, moist air inside the car meets cold glass, condensation forms, causing the fog.

- Excess moisture in the car. Sources of moisture inside your vehicle, such as breathing, perspiration, wet clothes, or damp floor mats,
- Faulty vents or AC system. Clogged vents or a dirty cabin air filter can also reduce airflow and hinder the defroster's effectiveness.
- Cracks or gaps in the weather stripping around doors and windows. Damaged or worn-out seals around windows, doors, or sunroofs can allow external moisture to seep into the vehicle interior.

22. Perform engine cooling system tests (flow, pressure, electrolysis, concentration, and contamination); determine needed repairs.

A coolant hydrometer measures the density of the coolant. The higher the density, the more concentration of antifreeze in the water. For best results, the coolant should have a freezing point lower than −20°F (−29°C) and a boiling point above 234°F (112°). Figure 30.

Figure 30. Checking the freezing temperature of the coolant using a hydrometer.

Galvanic activity is the flow of an electrical current as a result of two different metals in a liquid, which acts like a battery The two different metals, usually iron and aluminum, become the plates of the battery and the coolant is the electrolyte. The higher the electrical conductivity of the coolant, the greater is the amount of corrosion.

Electrolysis requires an outside voltage source. The source is usually due to a poor electrical ground connection. Electrical flow through the cooling system may cause metal to flow into the coolant. This metal transfer can eat holes in a heater core or radiator.

A voltmeter set to read DC volts is used to test for galvanic activity and electrolysis. To check for excessive voltage caused by galvanic activity or electrolysis, perform the following steps:

STEP 1 Allow the engine to cool and then carefully remove the pressure cap from the radiator.

STEP 2 Set the voltmeter to DC volts and connect the black meter lead to a good engine ground.

STEP 3 Place the red meter lead into the coolant.

STEP 4 Read the meter. If the voltage is above 0.5 volt, this indicates excessive galvanic activity. Normal readings should be less than 0.2 volt (200 mV). Flush and refill the cooling system.

STEP 5 To test for excessive electrolysis, start the engine and turn on all electrical accessories, including the headlights on high beam.

STEP 6 Read the voltmeter. If the reading is higher than 0.5 volt, check for improper body ground wires or connections. Normal readings should be less than 0.3 volt (300 mV).

23. Inspect and replace engine coolant hoses and pipes.

Coolant system hoses are critical to engine cooling. As the hoses get old, they become either soft or brittle and sometimes swell in diameter. Their condition depends on their material and on the engine service conditions. Any hose that soft or brittle is suspect and should be replaced. Figure 31.

Figure 31. Use a hose clamp tool and replace hoses as needed.

24. Inspect, test, and replace radiator, pressure cap, coolant recovery system, and water/coolant pump (conventional/electronically controlled).

Pressure testing. Pressure testing using a hand operated pressure tester is a quick and easy cooling system test. The radiator cap is removed (engine cold!) and the tester is attached in the place of the radiator cap. By operating the plunger on the pump, the entire cooling system is pressurized. If the cooling system is free from leaks, the pressure should stay and not drop. If the pressure drops, look for evidence of leaks anywhere in the cooling system. Figure 32.

Figure 32. Cooling system pressure test.

The pressure tester can also be used to test the radiator cap. An adapter is used to connect the pressure tester to the radiator cap. Replace any cap that will not hold pressure. Figure 33.

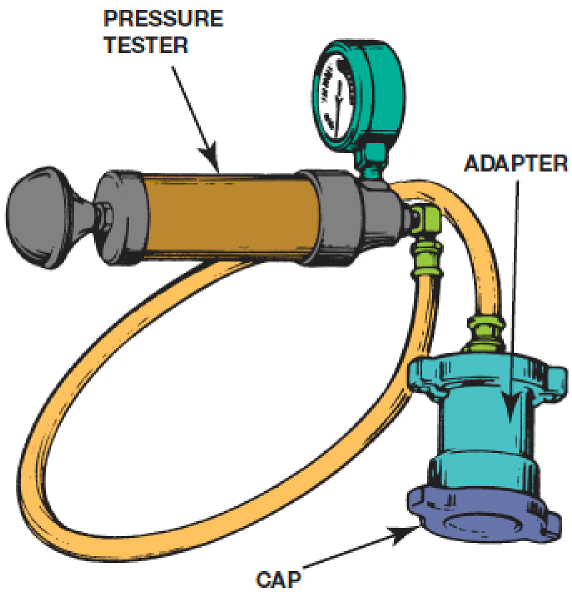


Figure 33. Testing the radiator cap.

Coolant recovery system. Most cooling systems connect radiator overflow to a plastic reservoir that holds excess coolant while the system is hot. When the system cools, the pressure in the cooling system is reduced and a partial vacuum forms, which pulls the coolant from the plastic container back into the cooling system, keeping the system full. If the container is always empty there is a leak in the system. Figure 34.

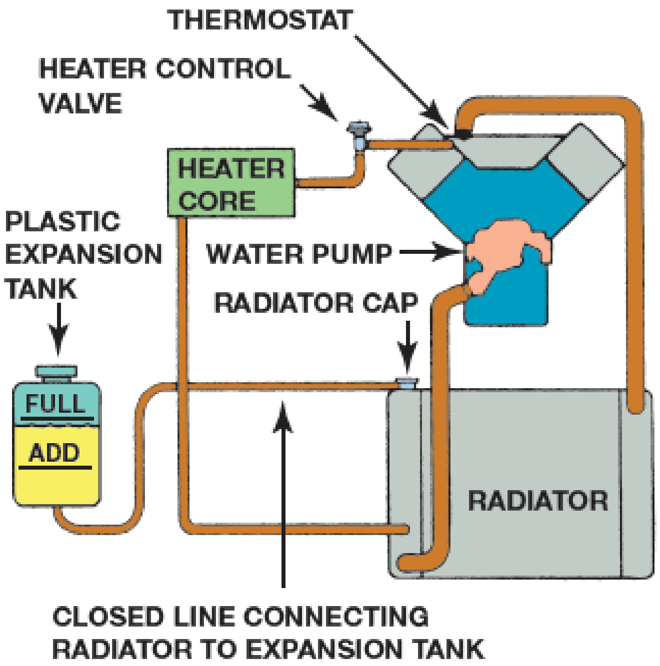


Figure 34. Coolant recovery system.

Newer vehicles use a surge tank which is located at the highest level of the cooling system and holds about 1 quart (1 liter) of coolant. The system pressure cap is located on the surge tank instead of on the radiator. Figure 35.

Figure 35. Surge tank and pressure cap.

The water pump (also called a coolant pump) is driven by one of three methods.

- Crankshaft belt
- Camshaft timing belt
- Electric motor

Coolant recirculates from the radiator to the engine and back to the radiator. Low-temperature coolant leaves the radiator by the bottom outlet. It is pumped into the warm engine block, where it picks up some heat. From the block, the warm coolant flows to the hot cylinder head, where it picks up more heat. The pump pulls coolant in at the center of the impeller. Centrifugal force throws the coolant outward so that it is discharged at the impeller tips. Fig 36.

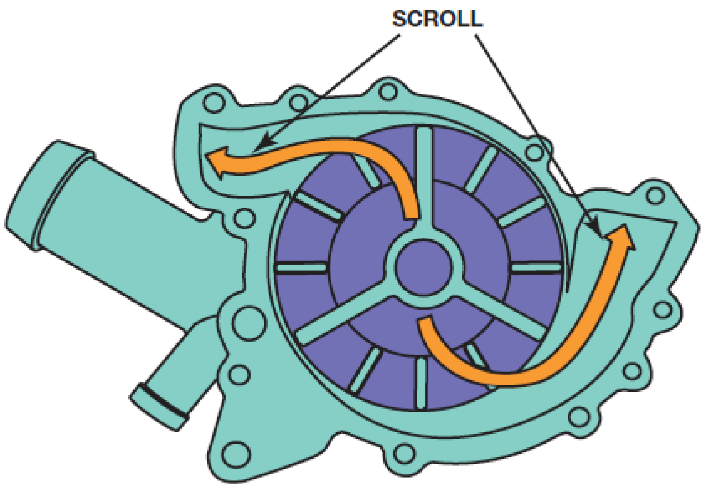


Figure 36. Water pump.

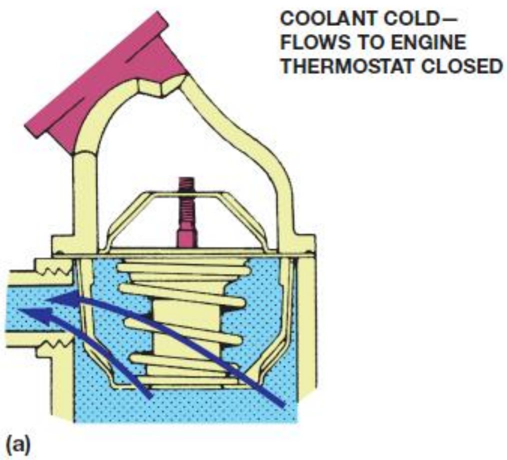
An electric water pump uses a DC motor to power the impeller and is used on most hybrid electric vehicles and some internal combustion engines. The electric water pump usually is attached to the engine and is controlled by the powertrain control module (PCM).

25. Inspect, test, and replace thermostat(s) (conventional/electronically controlled), engine temperature control valve, thermostat bypass, and housings.

There is a normal operating temperature range between low-temperature and high-temperature extremes. The thermostat controls the minimum normal temperature.

A scan tool can be used on most vehicles to read the actual temperature of the coolant as detected by the engine coolant temperature (ECT) sensor. As the engine warms up the scan tool can see the point where the thermostat opens as a slight decrease in temperature as cooler coolant flows from the radiator.

The thermostat is a temperature-controlled valve placed at the engine coolant outlet on most engines. Some thermostats are electrically heated. Fig. 37 and 38.



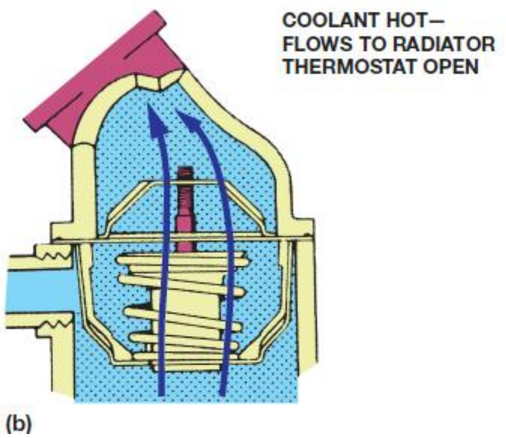


Figure 37. (a) When the engine is cold, the coolant flows through the bypass. (b) When the thermostat opens, the coolant can flow to the radiator.

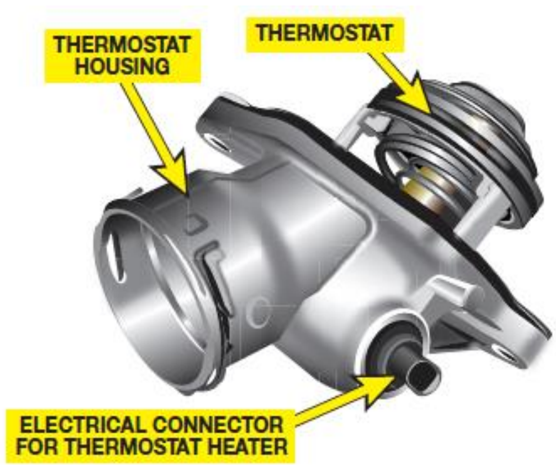


Figure 38. An electrically heated thermostat.

To replace the thermostat, coolant will have to be drained from the radiator drain petcock to lower the coolant level below the thermostat. It is not necessary to completely drain the system. The hose should be removed from the thermostat housing neck and then the housing removed to expose the thermostat.

Some thermostats are an integral part of the housing. This thermostat and radiator hose housing is serviced as an assembly. Figure 39.

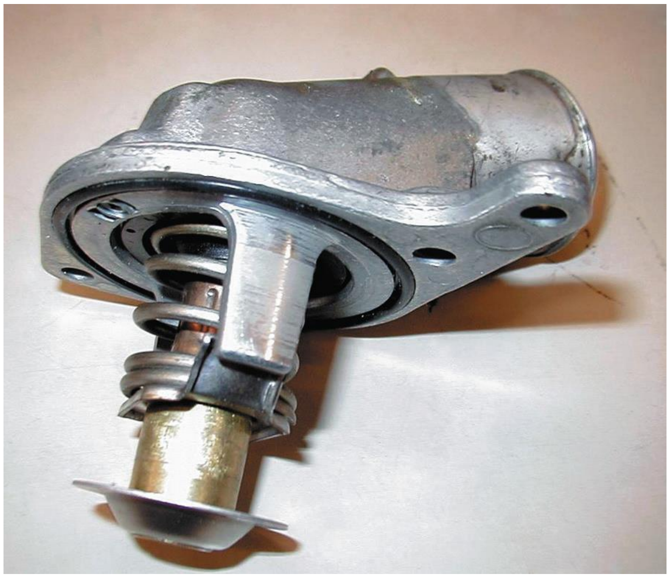


Figure 39. This thermostat seals with an O-ring instead of a gasket.

26. Identify, inspect, recover coolant; flush and refill system with proper coolant; bleed system as necessary.

Antifreeze is a concentrated, glycol-based liquid that must be diluted with water before using. When mixed with water, it is referred to as coolant. Engine coolant is usually a mixture of 50% antifreeze and 50% water.

Coolant can be checked using a coolant hydrometer. The hydrometer measures the density of the coolant. The higher the density, the more concentration of antifreeze in the water. Most coolant hydrometers read the freezing and boiling points of the coolant.

Coolant should be replaced according to the vehicle manufacturer's recommended interval. For most vehicles this interval may be every five years or 150,000 miles (241,000 km), whichever occurs first.

The cooling system can be manually flushed using clean water and a flushing/cleaning chemical. After adding the chemical and water the engine is run until operating temperature is reached. The system is drained and refilled repeatedly until the water drained out is clear.

A coolant exchange machine is able to perform one or more of the following operations:

- Exchange old coolant with new coolant
- Flush the cooling system
- Pressure or vacuum check the cooling system for leaks

Using a coolant exchange machine helps eliminate the problem of air getting into the system which can cause overheating or lack of heat due to air pockets getting trapped in the system. Figure 40.

Figure 40. A coolant exchange machine takes care of flushing and refilling the cooling system.

Many vehicle manufacturers recommend that the bleeder valve be opened whenever refilling the cooling system. Bleeding the air out of the cooling system is important because air can prevent proper operation of the heater and can cause the engine to overheat. Figure 41.

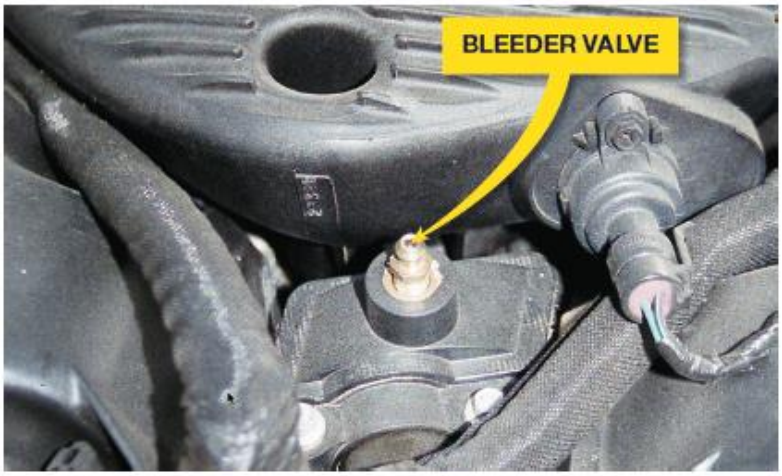


Figure 41. Open the bleeder valve when refilling the cooling system.

27. Inspect, test, and replace fan (electrical/mechanical/viscous/hydraulic), fan clutch, fan belts, fan shroud, active grille shutters, and air dams.

Many rear-wheel-drive vehicles and all transverse engines drive the fan with an electric motor. Most electric cooling fans are computer controlled. To save energy, most cooling fans are turned off whenever the vehicle is traveling faster than 35 mph (55 km/h). Two types of electric cooling fans used, a one two-speed cooling fan, or two cooling fans (one for normal cooling and one for high heat conditions).

On some rear-wheel-drive vehicles, a thermostatic cooling fan is driven by a belt from the crankshaft. The thermostatic fan is designed so that it uses little power at high engine speeds and minimizes noise. Fig. 42.

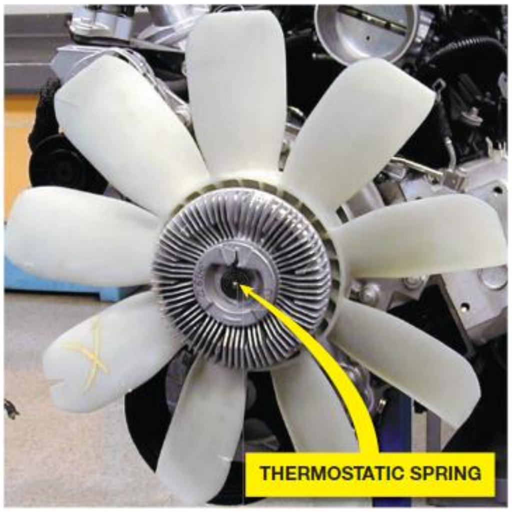


Figure 42. The thermostatic system engages the fan as engine temperatures increase.

Active Grille Shutters (AGS), also called a Radiator Shutter Assembly, are located between the front grille and the condenser. The plastic shutters open or close to control the airflow going under the hood. The primary function of the active grille shutters is to reduce the aerodynamic drag of the vehicle when closed. Unnecessary air entering the engine bay can create aerodynamic drag, decreasing fuel economy.

28. Inspect, test, and replace heater coolant control valve (manual, vacuum, and electrical types) and auxiliary coolant pump.

The heating system uses heat that would normally be wasted (removed by the radiator) to warm the interior of the vehicle. The heating system is made up of the heater core, hoses, engine and/or electric water pump, and a blower motor to create the needed airflow into the passenger compartment. Some vehicles have a control valve in the heater inlet hose that allows coolant flow to be shut off when MAX AC is selected to keep hot coolant from flowing through the heater core. Figure 43.

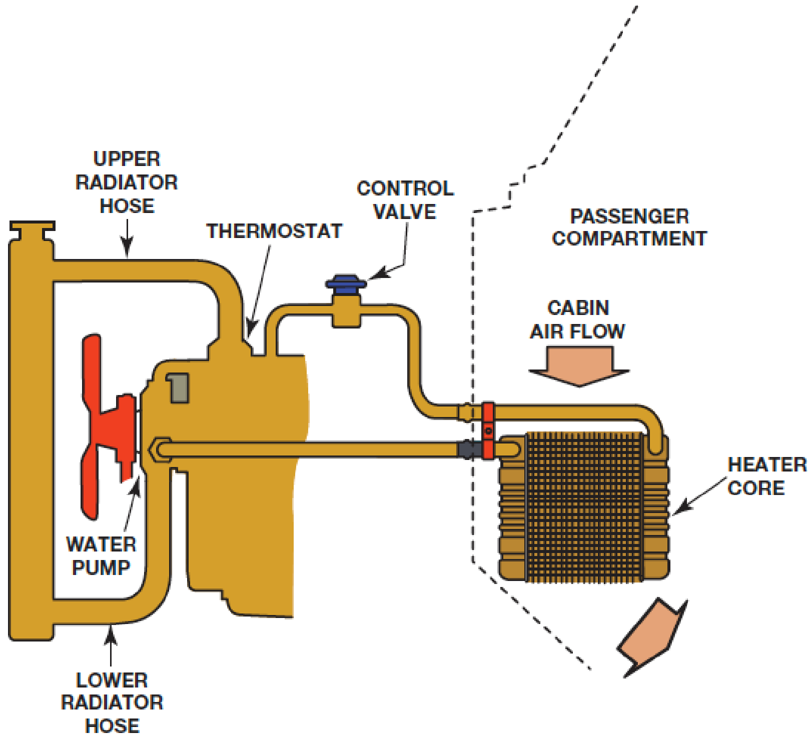


Figure 43. Heating system major components.

An auxiliary water (coolant) pump is a DC motor-operated water pump that is used to circulate coolant to the heater core to help keep the cabin warm on many hybrid and electric vehicles. Figure 44.

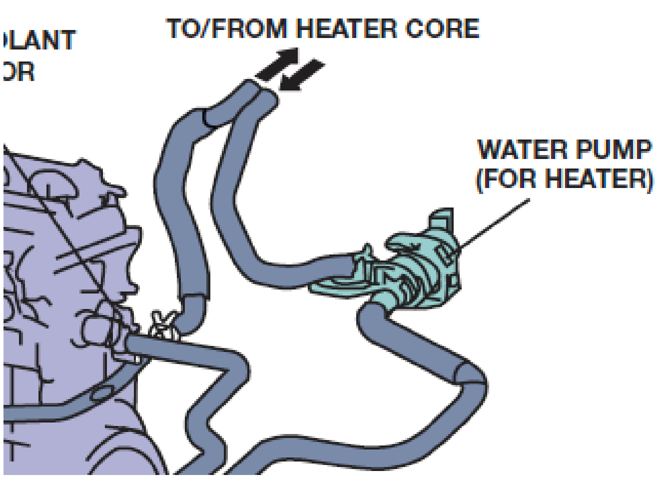


Figure 44. Auxiliary coolant pump.

29. Inspect, flush, and replace heater core.

When diagnosis the heater core, both should be hot to the touch. If the supply hose is hotter than the return hose, this indicates that the heater core could be partially clogged. The core should be flushed to see if any debris can be removed. Figure 45.

Figure 45. Flushing the heater core.

Replacing a heater core is a major repair job often involving Recovering the refrigerant, then disconnecting the refrigerant lines and heater hoses, then removing the HVAC housing assembly from behind the dash. Figure 46.

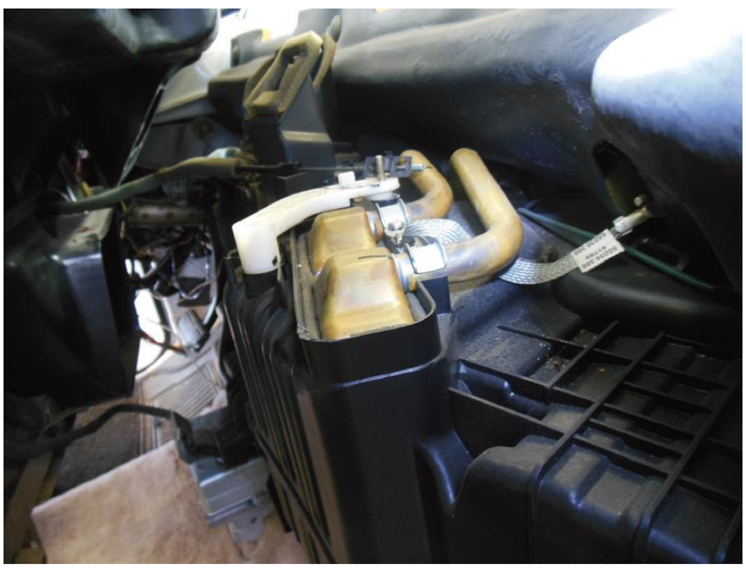


Figure 46. After partially disassembling the HVAC housing, the heater core can be removed.

30. Inspect, test, and replace alternate thermoelectric heating/cooling sources (including positive temperature coefficient (PTC) devices, duct heaters, steering wheel heaters, seat heaters/coolers, etc.).

In some vehicles, the electrical system is used to boost the heat to the passenger compartment when engine coolant temperature is low. One approach is to use PTC heaters built into the heater core itself. Positive temperature coefficient (PTC) refers to the tendency of a conductor to increase its electrical resistance as its temperature increases. PTC heaters convert electrical energy into heat, and this is used to boost heat to the passenger compartment. Figure 47.

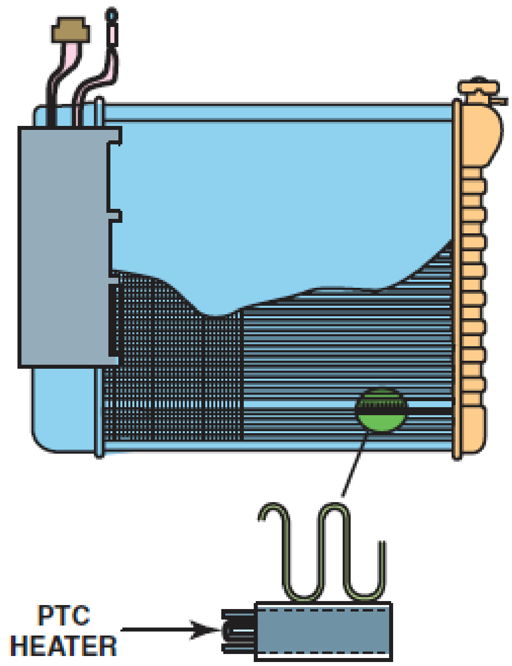


Figure 47. PTC heaters can be located on the heater core itself to help boost heat to the passenger compartment when coolant temperature is low.

PTC heaters can also be located in the air ducts in the form of a honeycomb-shaped grid. Air that is leaving the plenum chamber passes through these heaters before it enters the passenger compartment. Figure 48.

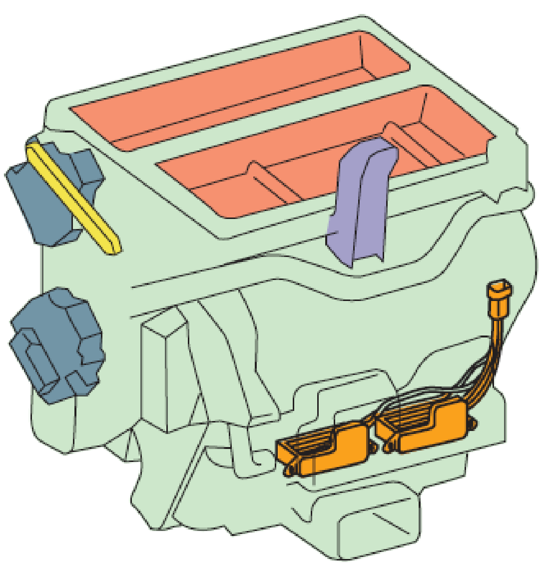


Figure 48. PTC heaters located in the air ducts.

Most electrically heated and cooled seats use a thermoelectric device (TED) located under the seat cushion and seat back. When electrical current flows through the module, one side is heated, and the other side is cooled. Reversing the polarity of the current changes the side being heated.

Each thermoelectric device has a temperature sensor, called a thermistor. The control module uses sensors to determine the temperature of the fins in the thermoelectric device so the controller can maintain the set temperature. Figure 49.

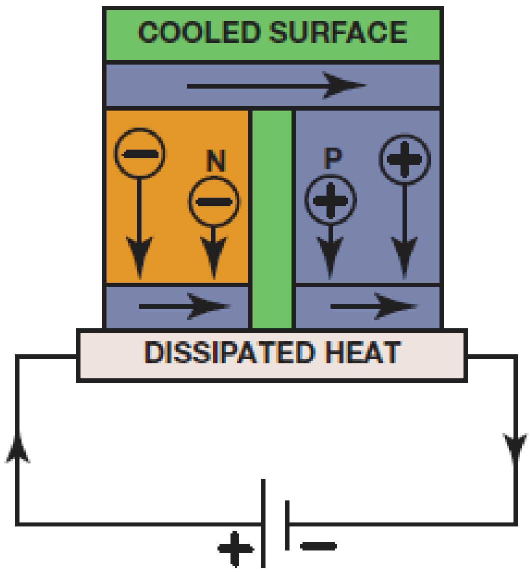


Figure 49. A thermoelectric device can provide heating or cooling, depending on the polarity of the applied current.