Air Conditioning - Part 1 (AIR02e)

Textbook

I-CAR®

Version: 2.2

AIR02e-STMAN1-E

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Contents

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Introduction

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Obligations To The Customer And Liability

The collision repair industry has an obligation to correctly repair the customer's vehicle. Collision repairs must be performed using:

- recommended or tested procedures from vehicle makers, I-CAR, and other research and testing organizations.
- quality replacement parts and materials.
- repair processes and parts as written and agreed upon in the repair order. If items on the repair agreement are not consistent with the repair order, it can be considered fraud.

Performing proper collision repairs requires using parts and procedures that keep remaining warranties intact.

Collision repairs must restore:

- safety.
- structural integrity.
- durability.
- performance.
- fit.
- finish.

Throughout the damage analysis and repair process the repairer and insurer must:

- communicate with each other.
- maintain constant communication with the customer.
- be in agreement with each other and the customer on how repairs will be performed.
- inform the customer of any changes in the repair plan from the original repair agreement, and explain the changes and why they have to be made.

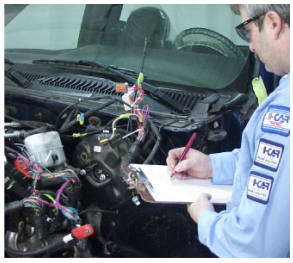
To reduce liability:

- make sure that all repairs are performed thoroughly, correctly and as listed in the damage report.
- follow proper procedures.
- have documentation of required repairs with detailed record keeping available for customers.

Technicians are considered the experts and are expected to be knowledgeable on how to perform a quality repair.

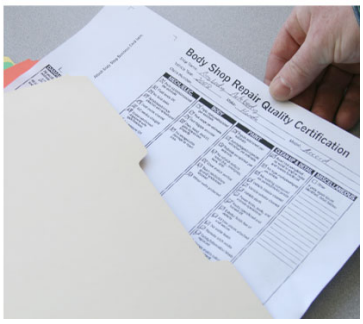
Liability insurance that covers the repair facility may not always cover all damages. For example:

- the policy may not cover faulty repairs, leaving liability responsibility completely on the facility.
- a shop owner may find that repair facility liability coverage may not cover the full amount awarded in a lawsuit. The shop owner would have to pay the difference.



It is difficult to reduce the risk of liability exposure. The part that the repairer can control is the chance of being found at fault. Chances can be minimized by:

- using recommended or tested procedures from the vehicle makers, I-CAR, or other research and testing organizations.
- using quality replacement parts and materials that restore fit, finish, durability, and perform at least as well as the original.
- keeping thorough records.



Keeping thorough records includes more than recording the date, mileage, and pre-existing damage. Record keeping also includes:

- making sure all notes are legible.
- verifying the repairs that were made or not made.
- having the customer sign a waiver for repairs that they do not want performed. Repairers must determine their liability on not repairing safety systems such as restraint and anti-lock brake systems.
- keeping computer printouts or worksheets on file showing wheel alignment readings or vehicle dimensions before and after repairs.
- keeping scan tool printouts and records of computer codes for airbag, anti-lock brake, emission, and powertrain control module (PCM) systems.

- attaching the OEM or other tested procedure printout to the vehicle repair order.
- keeping receipts for all sublet work performed.

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Module 1 - System Operation

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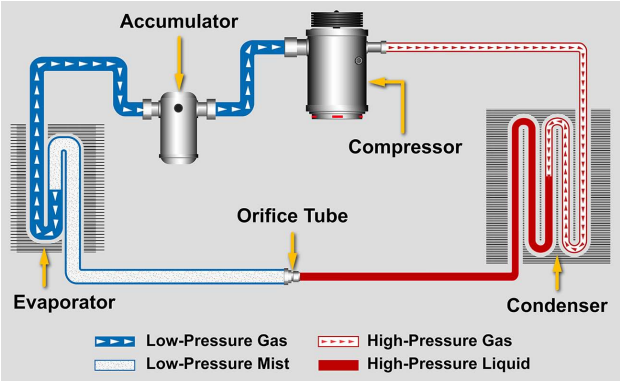
Basics Of Refrigerant Flow

Learning objectives for this module include:

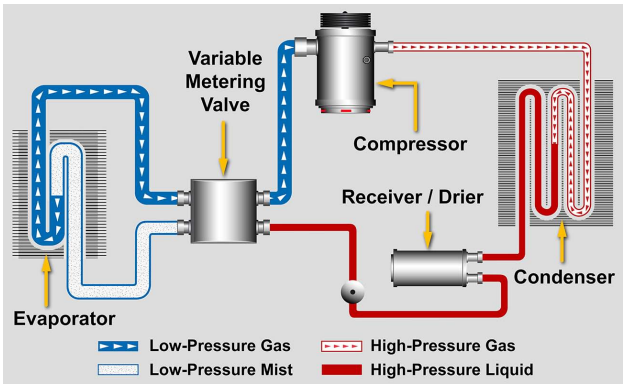
- identifying air conditioning system designs.
- explaining air conditioning system operation.
- identifying air conditioning system parts terminology, function, and location.



These are the parts of an A/C system using an accumulator.

In order to effectively work on air conditioning (A/C) systems, it is important to have a clear understanding of how the various parts of the system work. There are two types of A/C systems used in automotive applications. One type of system uses an accumulator and orifice tube.

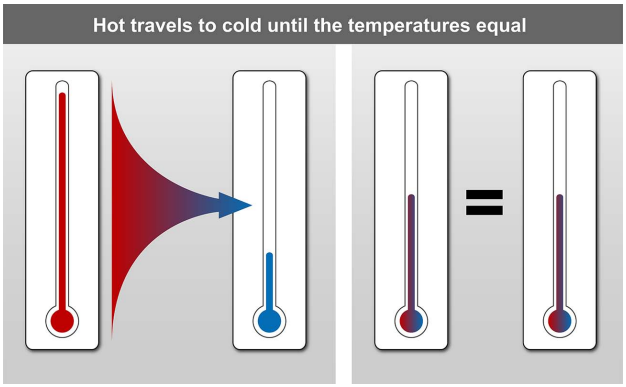
Refer to Video: Refrigerant Flow - Accumulator, for a video showing the flow of refrigerant through an air conditioning system using an accumulator and an orifice tube.



These are the parts of an A/C system using a receiver / drier.

Another type of A/C system uses a receiver / drier and variable metering valve.

Refer to Video: Refrigerant Flow - Receiver / Drier, for a video showing the flow of refrigerant through an air conditioning system using a receiver / drier and a variable metering valve.

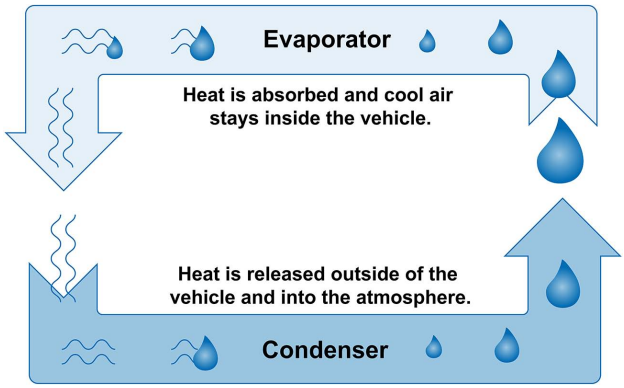


This illustration shows how the second law of thermodynamics works.

The laws of thermodynamics are used to move refrigerant through an air conditioning system. The first law of thermodynamics states that:

- heat is energy. A thermometer measures the intensity of this energy.
- everything contains heat including things we consider cold such as ice. This statement is true for temperatures above -450°F. This temperature is called absolute zero and cannot be found in nature.
- the best definition of "cold" is lack of heat. This is similar to the definition of "darkness" being the lack of light. Therefore, the temperature change inside the passenger compartment is obtained by removing the heat, not adding "cold."

The second law of thermodynamics states that heat travels from hot to cold until temperatures equal.



A change of state takes place in the evaporator and the condenser.

An A/C system uses evaporation and condensation to remove the heat from the passenger compartment and transfer it to the outside of the vehicle. Evaporation occurs during a change of state. Factors involved during this change of state are:

- a liquid changing to a gas.
- during evaporation, heat is absorbed by the liquid to change it into a gas.
- an A/C evaporator uses the evaporation process to remove

heat from the passenger compartment.

Condensation occurs during a change of state. Factors involved during this change of state are:

- a gas changing to a liquid.
- during condensation, heat is released by the gas to change it into a liquid.
- an A/C condenser uses the condensation process to release the heat that was removed from the passenger compartment.

Change In Pressure = Change In Temperature
Lower Pressure = Lower Boiling Point (Vacuum)
Higher Pressure = Higher Boiling Point (Elevation)
Temperature + Pressure = State

There are four equations defining pressure / temperature relationship.

There are four equations that define the relationship between pressure and temperature:

- Change in Pressure = Change in Temperature
- Lower Pressure = Lower Boiling Point (Vacuum)
- Higher Pressure = Higher Boiling Point (Elevation)
- Temperature + Pressure = State

R-134a Temperature-Pressure Chart

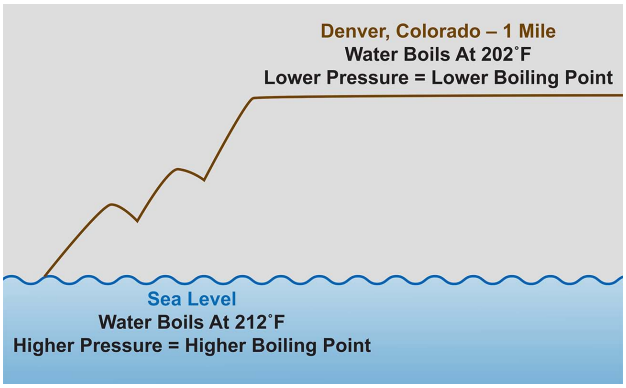
Temperature °F	Pressure kPa (PSI)	Temperature °F	Pressure kPa (PSI)	Temperature °F	Pressure kPa (PSI)
16	106 (15)	60	392 (57)	116	1114 (162)
18	115 (17)	65	438 (64)	118	1149 (167)
20	124 (18)	70	487 (71)	120	1185 (172)
22	134 (19)	75	540 (78)	122	1222 (177)
24	144 (21)	80	609 (88)	124	1260 (183)
26	155 (22)	85	655 (95)	126	1298 (188)
28	166 (24)	90	718 (104)	128	1337 (194)
30	177 (26)	95	786 (114)	130	1377 (200)
32	188 (27)	100	857 (124)	135	1481 (215)
34	200 (29)	102	887 (129)	140	1590 (231)
36	212 (31)	104	917 (133)	145	1704 (247)
38	225 (33)	106	948 (137)	150	1823 (264)
40	238 (35)	108	980 (142)	155	1948 (283)
45	272 (40)	110	1012 (147)	160	2079 (301)
50	310 (45)	112	1045 (152)	165	2215 (321)
55	350 (51)	114	1079 (157)	170	2358 (342)

Evaporator Range

Condenser Range

This chart shows pressure to temperature relationships that are used to change pressure and state in an A/C system.

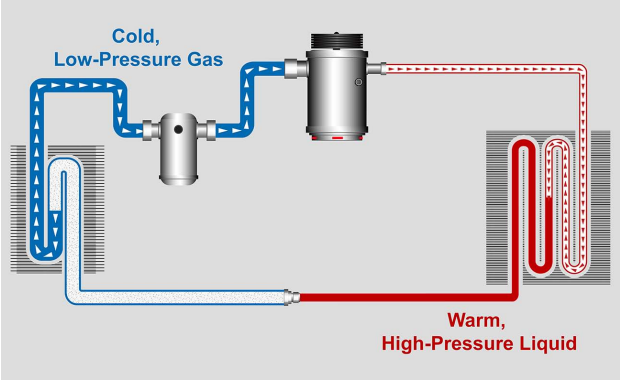
Changes in temperature are directly related to changes in pressure. In an A/C system, the high-side line temperature increases and decreases as the pressure increases and decreases. This is why A/C system high-side lines feel warm and the low-side lines feel cool.



Lower pressures cause lower boiling points, such as going from sea level to the elevation of Denver, Colorado.

Higher pressures cause higher boiling points. Water boils at 212°F only at sea level. Atmospheric pressures are higher below sea level, therefore the boiling point of water also increases with the rises in atmospheric pressure.

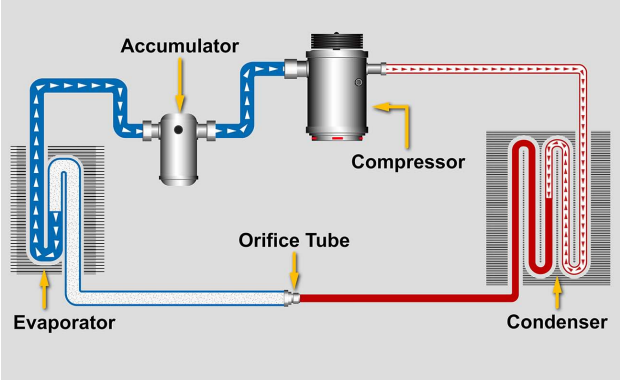
Denver, Colorado is located 1 mile above sea level. At this altitude water boils at 201°F. Water at sea level is at a higher pressure than water in Denver causing the boiling point to be higher at sea level than in Denver.



Temperature and pressure are used to control the state of the refrigerant in an air conditioning system.

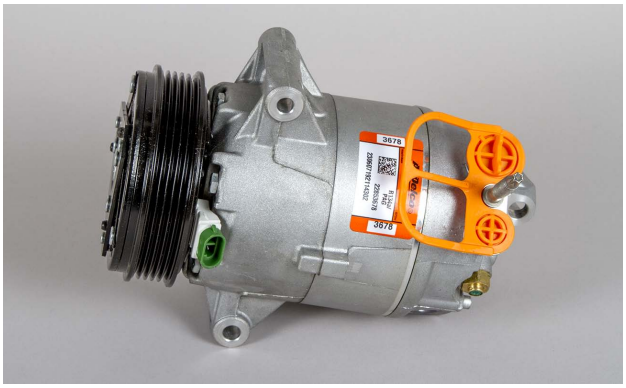
Temperature and pressure affect the state of a material. An A/C system regulates pressures to control the temperature and state of the refrigerant. Pressure, temperature, and state are used to diagnose system problems.

A/C System Parts - Accumulator



This is an accumulator-based A/C system.

There are five main parts of an accumulator-based A/C system, including the compressor, condenser, orifice tube, evaporator, and accumulator.



The compressor is used to change the pressure in an A/C system.

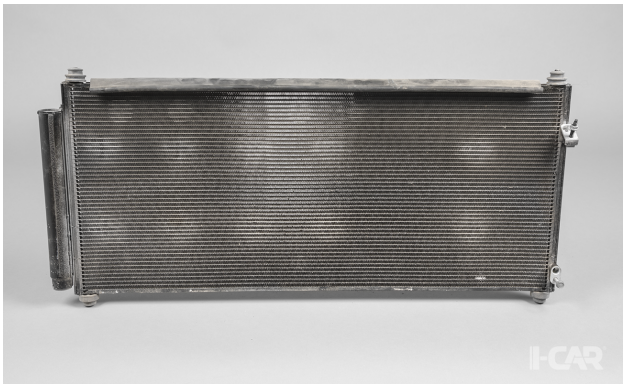
The compressor pushes the refrigerant through the A/C system.

The compressor is used to change the pressure of the refrigerant and create a flow in the system. The refrigerant enters the compressor as a low-pressure gas and exits as a high-pressure gas. On most vehicles, the compressor uses a:

- belt and pulley to externally drive the compressor. This allows visual verification of operation.
- mechanical pump that requires oil lubrication. The oil travels through the A/C system with the refrigerant.

Electric vehicles and some hybrid-electric vehicles use an electrically driven compressor. More information on electrically driven compressors will be covered later in the course.

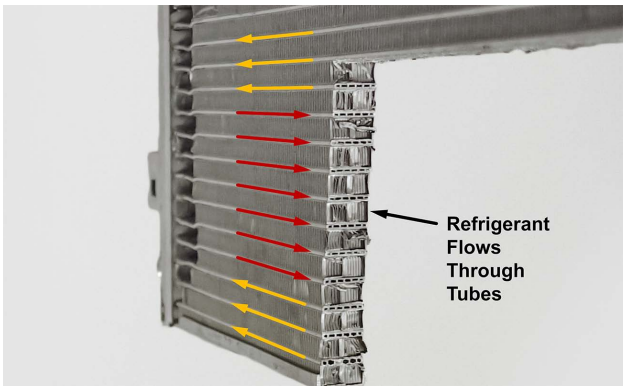
Refer to Video: Compressor Cutaway, for a video showing the wobble plate and one of the three dual-action pistons on a compressor cutaway.



The condenser is positioned in the front of the vehicle.

A condenser changes the state of the refrigerant. The refrigerant enters the condenser as a high-pressure gas and exits as a high-pressure liquid. The condenser:

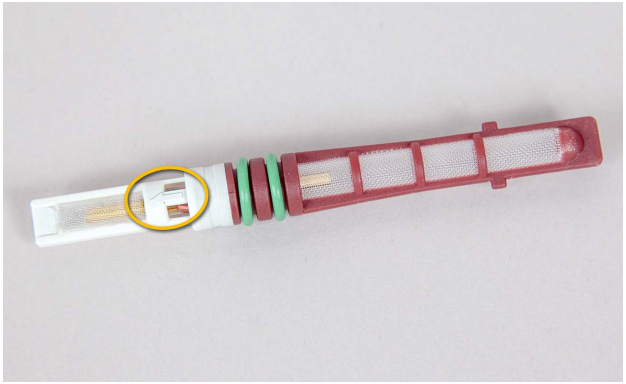
- changes the state of the refrigerant through condensation and heat exchange.
- releases the heat that was taken from the passenger compartment into the atmosphere.



This cutaway shows one example of the flow pattern of a condenser.

Some A/C systems may have a secondary condenser, or sub-condenser to provide additional heat transfer.

Many R-134a systems use a parallel flow condenser as shown in the cutaway.



Orifice tubes are installed with the arrow on the part pointing in the direction of the refrigerant flow.

A special tool is required to remove and install an orifice tube.

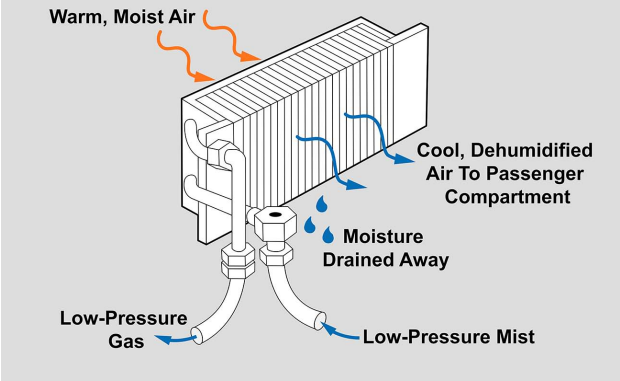
Orifice tubes are found on A/C systems with accumulators. A change in refrigerant pressure and temperature occurs as the refrigerant passes through the orifice tube. The refrigerant enters the orifice tube as a high-pressure liquid, passes through the orifice tube, and exits as a low-pressure mist. Orifice tubes:

- have arrows showing the direction of refrigerant flow. Replace orifice tubes with the arrow pointing in the direction of refrigerant flow.
- are an in-line part with a fixed diameter tube to allow one specific flow.
- are color coded to identify the orifice size.
- also have a variety of inlet end designs that may require specialized removal tools or a tool attachment. Specific attachments or separate tools may be needed for different makes and models. The orifice tube is twisted out and removed without tearing. Needle-nose pliers should not be used to remove orifice tubes.
- use the compressor cycling to control system pressure. This is done through a cycling switch or variable displacement compressor, not through the orifice tube.

One troubleshooting method is a visual examination of system parts, such as with this orifice tube.

Common system conditions can be identified by a visual inspection of the inlet filter screen of an orifice tube. The appearance of:

- a brown or gray powdery material may indicate an accumulator failure. This buildup on the orifice tube inlet filter may be caused by moisture traveling through the system. Accumulator replacement may be required along with any other in-line filters.
- shiny metal chips on the inlet filter, and possibly on the outlet, may indicate a damaged or worn compressor. Compressor replacement may be required along with any other system parts that may have been contaminated or restricted.



The moisture that accumulates on the evaporator is drained away and leaves a puddle of water under a parked vehicle.

An evaporator absorbs the passenger compartment heat and leaves behind cool, dehumidified air to be circulated in the passenger compartment. The refrigerant enters the evaporator as a low-pressure mist and exits as a low-pressure gas. The evaporator:

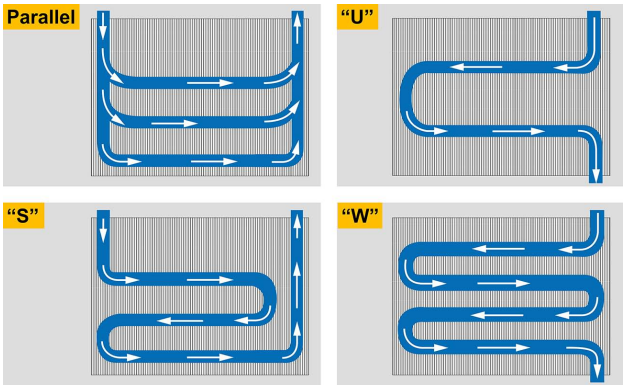
- uses the evaporation process to absorb heat from the passenger compartment.
- removes humidity as the warm passenger compartment air contacts the cooler evaporator.
- feels cold to the touch while the heat exchange is taking place.

Refrigerant flow through evaporators may be followed by looking at how the tubing is routed. A tube-and-fin type is shown on the left, and a serpentine type is shown on the right.

The main designs of evaporators include:

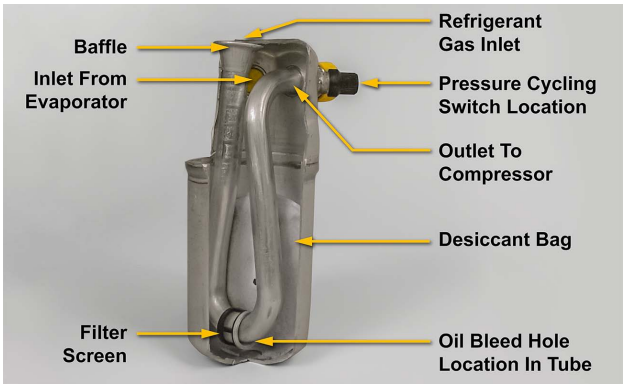
- tube-and-fin: single, round tubes zig-zagging back and forth through a pattern of fins.
- serpentine: flat tubes with fins winding between them.
- plate-and-fin: series of plates with various paths.

Refrigerant flow through tube-and-fin and serpentine evaporators can be seen by looking at how the tubing is routed. There is typically only one path for the refrigerant to flow, unlike the plate-and-fin design which has multiple paths.



The flow patterns for plate-and-fin type evaporators are parallel, U, S, and W.

Plate-and-fin evaporators are most common in late model vehicles. The flow patterns for plate-and-fin type evaporators may vary. The flow of refrigerant through a plate-and-fin evaporator cannot be identified visually.

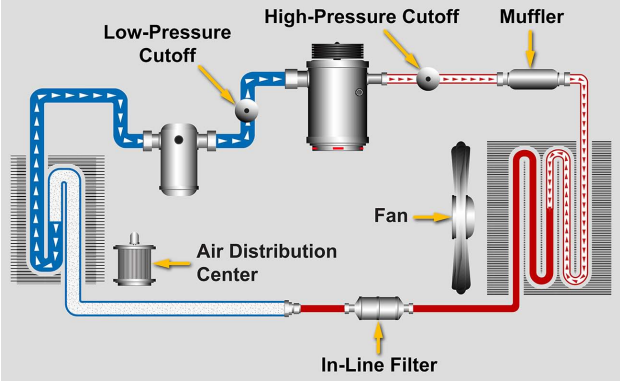


This cutaway shows the parts of an accumulator.

The accumulator is not used to change state or pressure in an A/C system. A system with an accumulator will have a fixed orifice tube. The refrigerant enters and exits the accumulator as a low-pressure gas. The accumulator:

- is located on the low side of the air conditioning system before the refrigerant returns to the compressor.
- is found on systems with fixed metering such as an orifice tube. Since orifice tubes are an in-line part, an accumulator may act as an indication that an orifice tube location should be identified during problem solving.
- uses an internal desiccant material to remove moisture from the refrigerant as it passes through.
- acts as a storage area for excess liquid refrigerant.
- prevents liquid from entering the compressor and damaging it. Liquid cannot be compressed.
- may contain an external pressure cycling switch. This switch monitors pressures and cycles the compressor on and off as necessary.

Accumulator or receiver / drier replacement recommendations vary. Typically following collision repairs, accumulators and receiver / driers require replacement when the system has been open for an extended period of time. Additional evacuation time may be needed for R-134a systems. Moisture is a contaminant and can cause corrosion and insufficient cooling problems. The refrigerant oil in R-134a systems absorbs moisture. Extra evacuation time will help remove the moisture.



This illustration shows some additional parts found on an accumulator-based A/C system.

There are additional parts that may be located on an accumulator-based or a receiver / drier-based A/C system. They include a high-pressure cutoff switch, fan, in-line filter, air distribution center, and low-pressure cutoff switch.

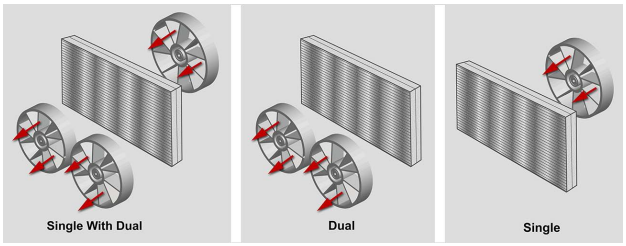
This is a high-pressure cutoff switch.

This switch is an environmentally safe way of controlling excessively high system pressures.

High-pressure cutoff switches can be located throughout the system. The most common locations are on the:

- high-side line.
- compressor discharge muffler.
- back of the compressor.

High-pressure cutoff switches disengage the compressor clutch when excessively high pressures are sensed.



Fans either push or pull air through the condenser. Fan configuration may vary, depending on vehicle make and model.

Fans:

- can be mechanical or electric.
- are used to direct airflow through the condenser. This assists the heat transfer in the condenser.
- provide airflow. Airflow is needed for the condenser to remove the heat absorbed from the passenger compartment from the refrigerant and release it into the atmosphere.
- may be single or dual.
- function differently depending how they are positioned around the condenser. When fans are positioned in front of the condenser, the fans push air through the condenser. Pushing

fans may be used when sufficient airflow cannot be obtained with air deflectors or airflow through the grille. When fans are positioned in back of the condenser, the fans pull the air.

This is one example of fans found in a vehicle. These airflow parts are placed in accordance with vehicle style and engine compartment configuration.

Aerodynamic vehicle designs have increased the need for sufficient airflow through the condenser. Sufficient airflow is needed for the condenser to release the heat removed from the passenger compartment. It is important to repair and / or replace these parts if they are damaged or removed. A reduction in grille size has increased the need for assisting the fan with:

- foam seals.
- air dams.
- shrouds.

During diagnostic procedures, it is important to place a fan in front of the vehicle to increase the airflow past the condenser and simulate a vehicle in motion.

The direction of refrigerant flow through an in-line filter is determined by the direction of the arrow.

In-line filters are located:

- in the high-side (liquid) line. The refrigerant is filtered through and contaminants are trapped. These filters may be installed after a part failure (such as a compressor) to trap any contaminants that may be remaining in the system.
- before the orifice tube. When the orifice tube is located immediately after the condenser, in-line filters may contain a replacement orifice tube and the original would be removed and discarded. If the in-line filter is placed after the orifice tube, the orifice tube filter screen will clog instead of the in-line filter trapping the particles first.

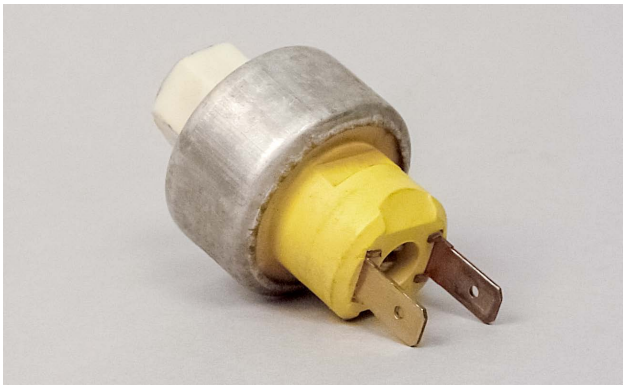
In-line filters may be factory installed or aftermarket. In-line filters are used in addition to receiver / driers or accumulators and the orifice tube filter. In-line filters:

- trap small particles that may be flowing through the system.
- prevent particle buildup in the orifice tube and other parts.

The air distribution center is located in the engine compartment and under the instrument panel.

The parts of an air distribution center include the:

- defrost outlet.
- evaporator.
- heater core case.
- fresh air intake.
- recirculation door motor.
- blower motor.



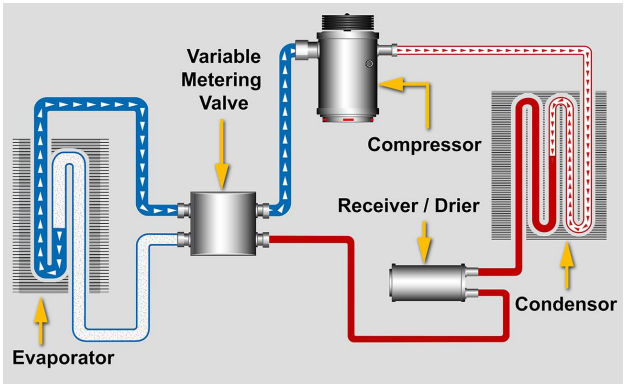
This switch is used to prevent compressor failure due to insufficient lubrication.

Low-pressure cutoff switches can be located throughout the system. The most common locations are on the:

- low-side line.
- accumulator.
- H-valve.
- back of the compressor.

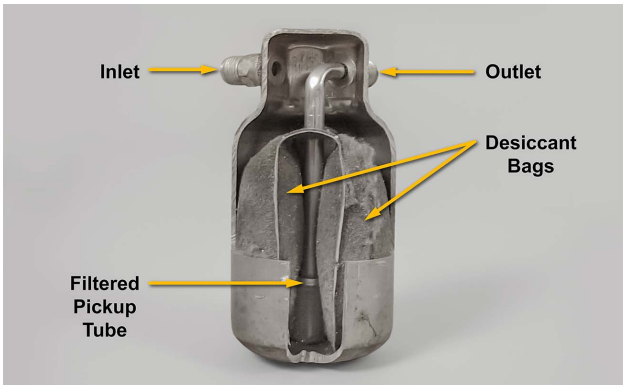
Low-pressure cutoff switches cycle the compressor clutch when low pressures are sensed or will not allow the compressor clutch to engage to prevent damage to the A/C system.

A/C System Parts - Receiver / Drier



This is a receiver / drier-based A/C system.

Parts found on a receiver / drier-based system include the receiver / drier and metering valve. Additional parts include the compressor, evaporator, and condenser.



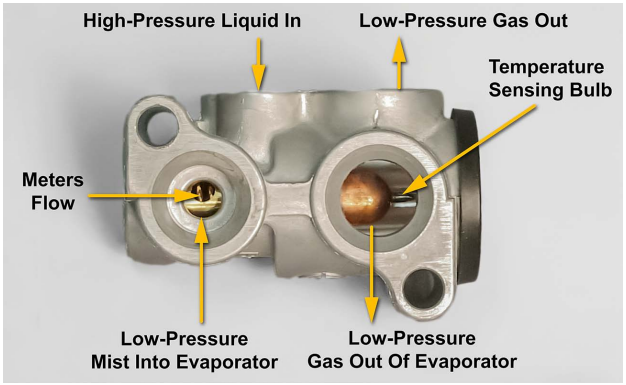
This cutaway shows the parts of a receiver / drier. Receiver / driers may also contain refrigerant flow arrows that must be followed when attaching refrigerant lines.

A receiver / drier works the same way as an accumulator. The difference is its location. Refrigerant enters and exits as a high-pressure liquid. Receiver / driers:

- are located on the high-side (liquid) line after the condenser.
- are found on systems with variable metering. Variable metering includes expansion valves and H-valve systems.
- use desiccant material to remove moisture from the system. Moisture can damage the system and cause insufficient cooling.
- like accumulators, store extra refrigerant.
- may have a sight glass located on top.

Two types of metering valves include expansion valves (left) and H-valves (right).

A metering valve changes the high-pressure liquid into low-pressure mist. Two different types of metering valves include expansion valves and H-valves. The two types are used on different systems but serve the same purpose.

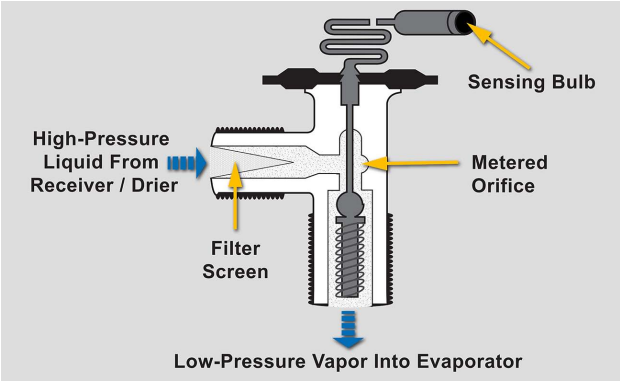


This shows the parts and operation of an H-valve.

With an H-valve, high-pressure liquid refrigerant flows from the receiver / drier and enters through the inlet of the H-valve. The information is collected and pressure is changed as the refrigerant flows past the temperature sensing bulb. The refrigerant exits the H-valve and enters the evaporator as a low-pressure mist. The refrigerant re-enters the H-valve from the evaporator as a low-pressure gas. The gas is metered, according to information collected by the sensing bulb,

and exits the H-valve as a low-pressure gas.

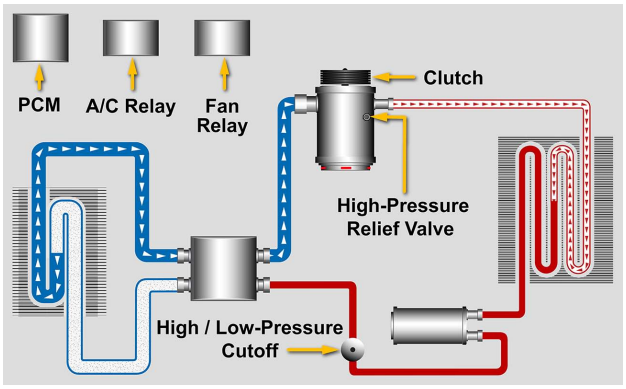
The term H-valve is not an acronym. It is a description of how the part typically looks.



This shows the parts and operation of an expansion valve.

The expansion valve changes the pressure in an A/C system. The expansion valve is located in the same position as the orifice tube in an accumulator-based A/C system.

With an expansion valve, high-pressure liquid refrigerant flows from the receiver / drier and enters through the inlet of the expansion valve. The refrigerant changes from a high-pressure liquid to a low-pressure mist as it is filtered through the expansion valve. A sensing bulb is attached to the low-side line on the output of the evaporator and before the compressor. The refrigerant flowing through the expansion valve is metered by information collected by the sensing bulb.



This shows additional parts of a receiver / drier-based A/C system.

Additional parts that may be found on an accumulator-based or a receiver / drier-based A/C system include the clutch, high-pressure relief valve, high / low-pressure cutoff, powertrain control module (PCM), A/C relay, and fan relay.

This variable displacement compressor continuously cycles the clutch and regulates pressure internally.

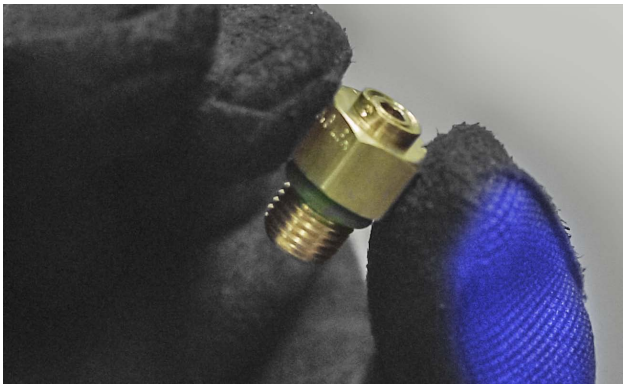
The clutch is located on the front of the A/C compressor. It is used to engage the compressor when the A/C is turned on. The clutch, along with other electrical switches, is also used to provide cycling, engaging and disengaging, to regulate system pressures. The clutch:

- uses current to engage the electromagnet.

- must have clean and dry friction surfaces.
- must be oil-free. Oil can cause slipping and damage to the clutch.
- may require replacement because of a noisy bearing.

Typically, a cycling clutch regulates system pressures.

Variable displacement compressors do not use a cycling clutch. Pressures are regulated internally. Variable displacement compressors use a variable angle wobble plate. The crankcase-suction pressure controls the wobble plate angle and piston displacement. As the angle decreases the displacement decreases. As the angle increases the displacement increases. Suction pressure decreases when the heat load at the evaporator decreases or when compressor RPM increases. Suction pressure increases when the heat load at the evaporator increases or when compressor RPM decreases.

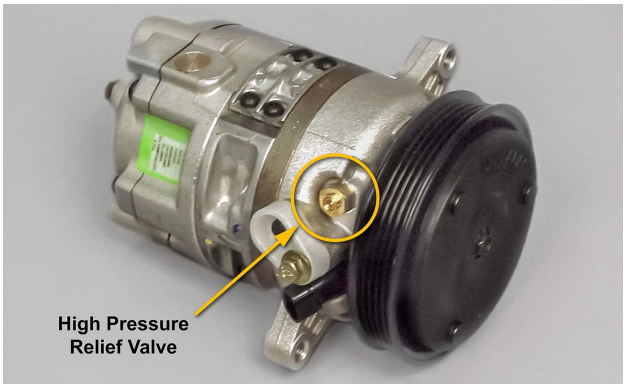


This is a high-pressure relief valve that prevents compressor failure caused by excessively high pressures.

High-pressure relief valves can be located in many areas on the high side. Common locations are on the:

- high-side line.
- receiver / drier.
- back of the compressor.

High-pressure relief valves vent refrigerant if excessively high pressures are sensed to prevent compressor damage.



This relief valve prevents compressor failure caused by excessively high pressures.

When a high-pressure relief valve has released pressure from the system, there is normally a visual indicator such as a piece of tape being blown off the valve indicating that high pressures were reached at some time. Some systems may contain an electrical control that prevents the high-pressure relief valve from venting refrigerant into the atmosphere. These systems may use a:

- single contact switch that disengages the clutch and shuts down the compressor.
- dual contact switch that turns the cooling fan to HIGH in attempts

to increase the airflow and heat transfer at the condenser.
- compressor shutdown switch that disengages the clutch and prevents internal damage to the compressor.

This high / low-pressure cutoff switch protects the compressor from excessive high and low pressures.

A high / low-pressure cutoff switch is a combination of a high-pressure and a low-pressure cutoff switch. The dual function switch prevents compressor operation at both high and low pressures. It may also control fan operation on some systems. The high / low-pressure cutoff switch:

- is commonly located on the high-side or low-side line.
- controls the compressor operation to prevent compressor and system damage from excessively high or low pressures.
- disengages the clutch at specific minimum and maximum pressures that are set from the factory for that system. Check vehicle maker specifications for exact measurements.

Powertrain control modules may look similar to other types of control modules including ABS and traction control.

The powertrain control module (PCM) is commonly located:

- under the hood. Locations may include the fender, core support, and areas that allow large amounts of airflow for cooling the PCM.
- below the instrument panel.
- behind the glove compartment.
- under the seat.

The PCM is a computer that controls many functions including transmission operation, cooling functions, and A/C functions. Internal measurements are typically not taken. Output measurements that are monitored include voltage signals and ground connections to operate relays. Other functions and operation of the PCM include:

- monitoring high and / or low-pressure cut-out switches. When excessive pressures are sensed, the switches will disengage

the compressor clutch when commanded by the PCM.
- operating the A/C and fan relays for excessive temperatures and activation.
- receiving the A/C request from the HVAC control head to activate the A/C system.
- checking outside air temperature. This is used on some vehicles for climate control or digital climate displays of outside temperature.

Late model vehicles may require the PCM to be programmed with the vehicle identification number (VIN).

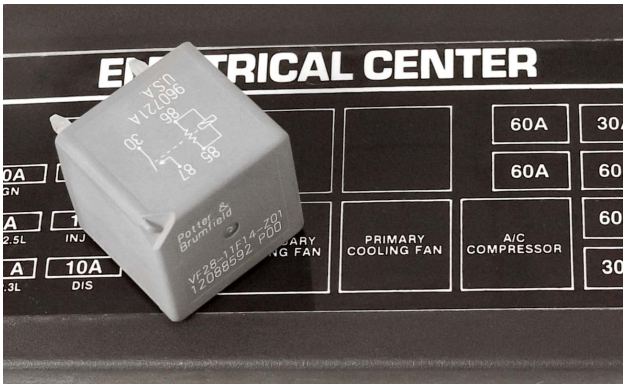
The compressor clutch uses a large amount of current and requires a relay to operate.

The A/C compressor clutch relay is commonly located:

- under the hood in the fuse box.
- under the instrument panel.
- in the instrument panel.
- anywhere in the wiring harness.

The A/C compressor clutch relay uses a smaller current to operate a larger current. Some relays are normally open while others are normally closed. They are typically shown in a de-energized position on a wiring diagram. The A/C compressor clutch relay:

- controls the compressor clutch.
- is operated by the PCM.
- is grounded through the PCM.



One fan relay may control the primary fan while another fan relay controls the secondary fan.

The fan relay is commonly located:

- under the hood in the fuse box.
- under the instrument panel.
- in the instrument panel.
- anywhere in the wiring harness.

The fan relay also uses a smaller current to operate a larger current. Some relays are normally open while others are normally closed. They are typically shown in a de-energized position in a wiring diagram. The fan relay:

- is operated by the PCM.
- is provided a ground by the PCM.

- is energized when the air conditioning is engaged.
- may also be energized by excessively high engine temperatures. Fans may be engaged to return the system to normal operating temperatures.

Module Wrap Up

The topics discussed in this module included:

- A/C system design identification.
- A/C system operation.
- A/C system parts terminology, function, and location.

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Module 2 - Refrigerant And Oils

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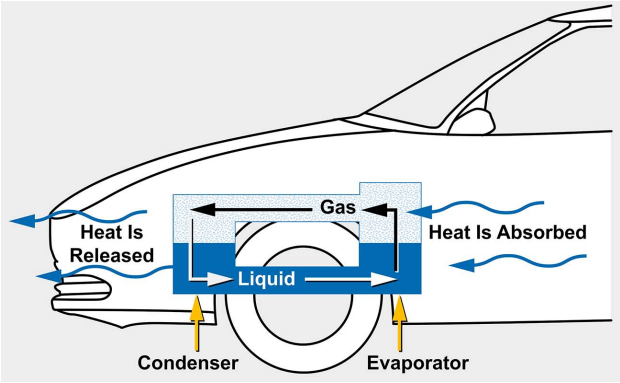
R-134a Identification And Oil

The learning objectives for this module include:

- identifying R-134a refrigerant.
- identifying R-134a oil.
- identifying R-1234yf refrigerant.
- explaining electric A/C systems and refrigerant oil requirements.



The evaporator and condenser are used to absorb and release the heat and control the state of the refrigerant in an air conditioning system.

A refrigerant needs qualities that allow it to be used effectively in an A/C system. A refrigerant must be non-destructive, and must not harm system lines and parts or absorb contaminants.

A refrigerant must absorb and release large amounts of heat easily. Heat transfer is a major consideration in an efficiently operating A/C system.

A refrigerant must have a state that is easily controlled by pressure. A good temperature and pressure relationship is used in an A/C system for evaporation and condensation.

An R-134a system label lists the type of oil used and the amount of system charge.

Refrigerant 134a (R-134a) is the refrigerant that has been used in automotive A/C systems since the mid-1990s. Properties of R-134a include:

- it is a hydrofluorocarbon (HFC). R-134a affects global warming and must be recovered and recycled.
- it is colorless. A leak cannot be detected through visual observation of a color change.
- it is odorless. A leak cannot be detected through an odor expelled from the system.
- its state is easily controlled by pressure.

The type of refrigerant will clearly be labeled under the hood of the vehicle. Labels may be found on A/C system parts or on painted surfaces under the hood.

This is a container of GM A/C system oil.

PAG 46 is a thin viscosity oil. Refrigerant oil is available in thin, medium, or thick viscosities. Always use the recommended oil.

R-134a refrigerant oil is:

- polyalkylene glycol or PAG oil. PAG oil is used on R-134a systems that do not have an electric compressor.
- a compressor lubricant. The oil and refrigerant travel through the system together and return to the compressor to lubricate it and prevent excessive friction and compressor failure.
- mixed with the refrigerant and is removed with the refrigerant during recovery procedures.

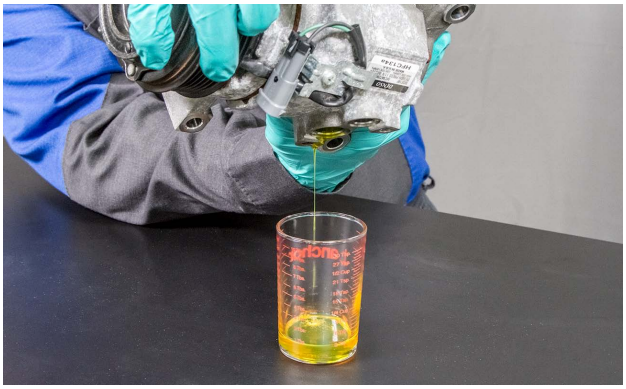
PAG oil absorbs moisture. This makes it important to prevent moisture from entering the system to prevent corrosion and additional system problems.

System capacities are important for proper system operation. Correct amounts of oil are valuable to the operation of the compressor and the system. Too little could result in compressor seize and too much could result in insufficient cooling.

Environmental Protection
Used refrigerant oil is considered a hazardous waste. Adding refrigerant oil to engine waste oil can be easily detected and could result in fines.

Vehicle Protection
Use caution when handling R-134a lubricant. Lubricants can damage vehicle finishes, plastic parts, engine drive belts, and coolant hoses. If a spill occurs, flush the area with water.

Use a clean container to collect and measure the amount of oil in a compressor.



Oil can be drained from a line port on the compressor.

Because refrigerant oil levels affect the efficiency of an A/C system, service information should be referenced for oil level capacities and the amount of oil that should be added when replacing parts. Part replacement oil information is vehicle specific and may not be included in all service information. Checking refrigerant oil levels includes:

- removing the compressor.
- draining out the old oil.
- measuring how much oil was removed. After measurements have been taken, new refrigerant oil may be added to the compressor.

Environmental Protection
When handling refrigerant:

- technicians must be certified.
- keep all fittings, hoses, and connections clean.
- only use Department of Transportation (DOT) approved containers for recycling.
- always evacuate disposable containers. Disposable containers are a common type of container for new refrigerant. After transferring the refrigerant to the service equipment, the disposable container must be evacuated and discarded.
- never use disposable containers for storage or recycling of used refrigerants.

Observe the following refrigerant storage considerations:

- Evacuate containers to at least 27" mercury (Hg) before filling.
- Store at room temperature only.
- Do not store in direct sunlight. Excess temperature may create dangerous pressures.

Personal Safety
Observe the following safety cautions while handling refrigerants:

- Keep containers away from heat above 125°F.
- Do not allow skin contact with refrigerant. Even slight contact can cause frostbite on skin.
- Contact with eye tissue can cause damage and blindness due to extreme cold. Flush immediately with cool water and seek medical help.

Other safety items to observe when working with refrigerants include:

- wearing safety glasses.
- wearing the appropriate gloves.
- keeping hands, fittings, and equipment clean.
- keeping the area well ventilated.

R-1234yf Identification And Oil

An A/C label will specify if the vehicle uses R-1234yf refrigerant.

Vehicle makers are now using R-1234yf refrigerant to replace R-134a in some models. The development and use of R-1234yf refrigerant became necessary to comply with environmental impact standards. R-1234yf:

- is used in A/C systems similar in design to those using R-134a.
- should not be used in R-134a systems. These refrigerants are not compatible.
- requires specifically designed service equipment.
- systems cannot be retrofitted from R-134a. The system must be installed by the vehicle maker when the vehicle is built.

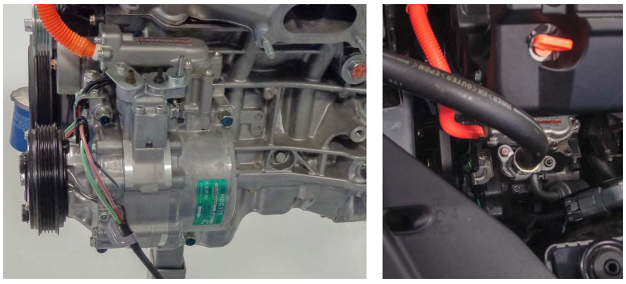
Some examples of vehicles equipped with R-1234yf systems include the 2014 Cadillac ATS, CTS, and XTS, Chrysler 300, Dodge Charger, Challenger, and Dart, Jeep Cherokee, and Ram 1500.

The A/C label may identify the recommended refrigerant oil for the system.

The refrigerant oil and refrigerant travel through the system together and return to the compressor to lubricate it and prevent excessive friction and compressor failure. R-1234yf:

- systems use the same PAG oil as R-134a systems. PAG oil absorbs moisture. This makes it important to prevent moisture from entering the system to prevent corrosion and additional system problems.
- system refrigerant oil capacities are important for proper system operation.

Electric A/C Systems



The orange cables on the compressor are for high voltage.

Electric vehicles and some hybrid-electric vehicles are equipped with electric A/C compressors driven only by the high voltage battery. Electric compressors:

- use the rated voltage of the high voltage battery.
- have a bright orange covered high voltage cable connected to the high voltage system.

Personal Safety

Follow all appropriate safety precautions during repairs for personal protection from electric shock.

Electric A/C compressors have specific refrigerant oil requirements.

A/C systems that use a high voltage electric A/C compressor require polyolester (POE) refrigerant oil. The compressor oil for these systems:

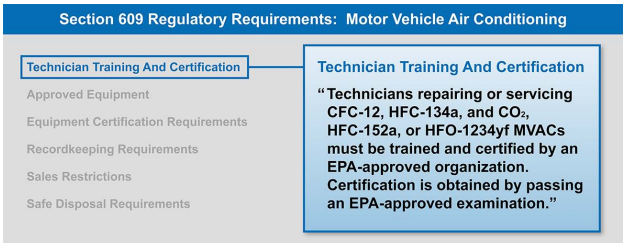
- absorbs less moisture than other types of compressor oil. Moisture conducts electricity.
- functions as an electric insulator, preventing the compressor case from conducting high voltage.

If the incorrect A/C oil is used, it may set a diagnostic trouble code (DTC) and disable the system. According to some vehicle makers, if the wrong oil is added to a part, that part may require replacement. Additionally, if the A/C system is charged or operated with the wrong compressor oil, the entire A/C system, including the lines, may require replacement.

Compressor oil requirements are typically found on the A/C label. The A/C label is typically located in the engine compartment on the underside of the hood or on the radiator core support.

Some vehicle maker service information states that once a container of POE compressor oil has been opened for use, it cannot be stored for later use. This is because it absorbs moisture.

A/C Service And Repair Regulations



Proof of certification is required to meet regulations.

The U.S. Environmental Protection Agency (EPA) ozone layer protection program has specific requirements for motor vehicle service and repair. These are found in Section 609 Regulatory Requirements and include:

- technician training and certification. All persons repairing or servicing motor vehicle A/C systems must be trained and certified by an EPA-approved organization. A list of approved organizations can be found at EPA.gov.
- approved equipment.
- equipment certification requirements.
- recordkeeping requirements.
- sales restrictions.
- safe disposal requirements.

Module Wrap Up

The topics discussed in this module included:

- R-134a refrigerant and R-134a oil.
- R-1234yf refrigerant and R-1234yf oil.
- electric A/C systems and refrigerant oil requirements.

Module 3 - Air Conditioning Tools And Equipment

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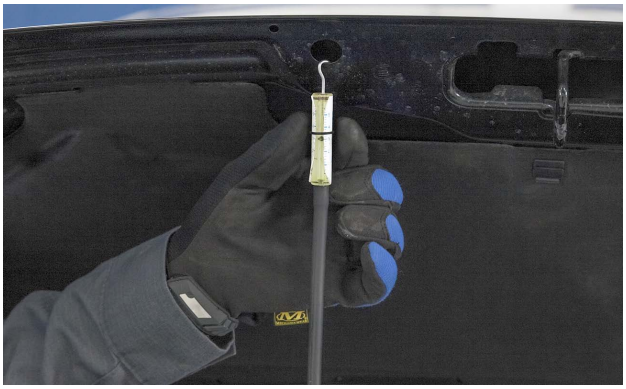
Air Conditioning Tools

The learning objectives for this module include:

- identifying service ports and connecting service equipment.
- identifying the purpose of refrigerant identification equipment.
- identifying the purpose of leak test equipment.
- identifying different types of recovery / recycle / recharge equipment.
- maintaining refrigerant recovery and recycling equipment.

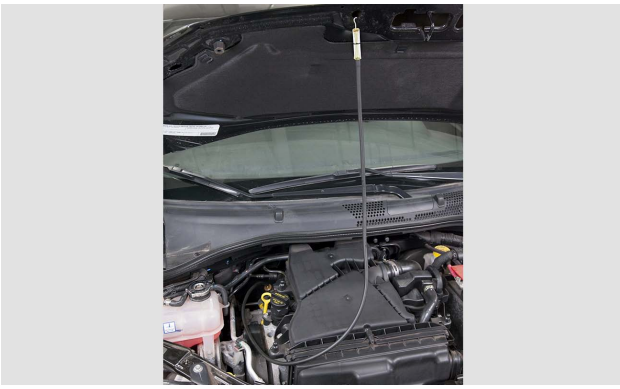
This is one type of refrigerant identifier. Refrigerant identifiers should be used before attaching refrigerant recovery / recycle / recharge equipment.

Use a sealant detector to verify there is no sealant in the A/C system. Sealant can damage recovery equipment.



This sealant detector is designed to simulate an A/C leak.

The sealant detector is connected to the high side A/C system service port.



The flow meter is monitored for the amount of refrigerant flow.

The flow meter will indicate little or no refrigerant flow if sealant is present in the system.

Refrigerant identification is the first step in A/C repair. Refrigerant identifiers:

- sample refrigerant vapor from a service port on the vehicle.
- are used to prevent cross contamination of R-134a and any other refrigerant that may have been used. Contaminated refrigerants should be disposed according to local regulations. Proper identification should be made before attaching any recovery equipment to the vehicle.

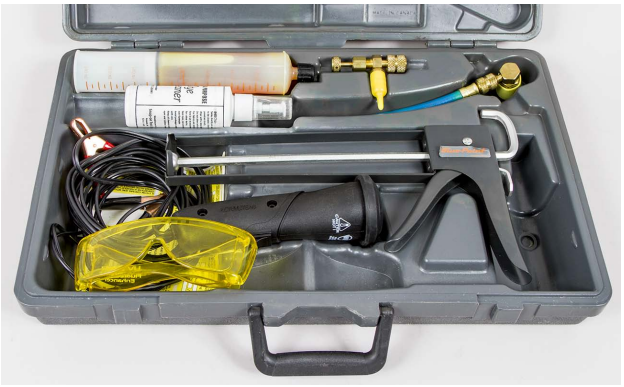
The diagnosis of the refrigerant may be displayed in different ways such as:

- a pass or fail display. If hydrocarbons are detected the refrigerant will fail.
- the percentage of pass / fail.
- the type of refrigerant found in the system.

Some identifiers:

- calculate percentage of air in the refrigerant. Air is a contaminant to the A/C system because it may contain moisture. Air can also put additional stress on the system.
- have purging capabilities. Purging is done to remove air from the A/C system.

Leak detectors can be electronic.



Leak detectors may use UV die and a black light.

A/C leak detectors can be electronic or use ultraviolet (UV) dye and a black light. Leak detectors are used:

- before repairs to identify leaks in an A/C system.
- after repairs to verify a quality repair that is free of leaks.

Topping off a leaky system is allowed in the United States, except when prohibited by state and local jurisdictions. Be sure to check local regulations before adding refrigerant to a system that has a low charge of refrigerant due to a leak

Manifold gauges read system pressures in pounds per square inch (psi) and / or kilopascals (kPa).

The blue hose is for the low side. The red hose is for the high side.

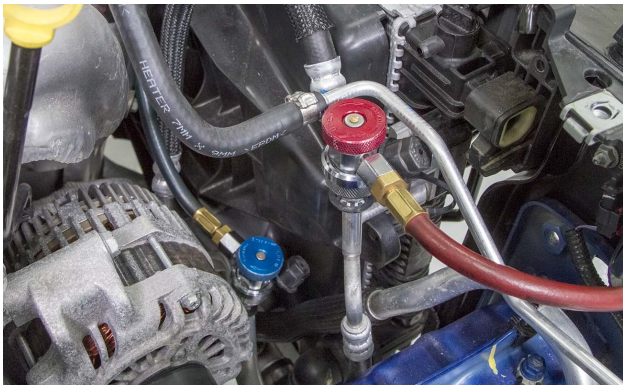
Manifold gauges:

- are specific to the type of refrigerant.
- monitor the system pressures through designated areas on the low and high side.
- have a red high side hose. This hose is used with a pressure gauge to monitor the high side system pressure.
- have a blue low side hose. This hose is used with a pressure gauge to monitor the low side system pressure.
- have a yellow center hose. This hose is used to supply vacuum during recovery and evacuation, and allow for recharging through the gauge set.

Service hoses may be connected to a gauge set or directly to the recovery / recycle / recharge equipment.

Service hoses are connected to the gauge set and allow the gauges to monitor system pressures and vacuum. Service hoses:

- are refrigerant specific and cannot be used for both types. Service hoses for specific refrigerants will be color coded and labeled.
- must have shut-off valves. Shut-off valves are required to be located within 12" of the service connection.
- for R-134a are red with a black stripe (high side), blue with a black stripe (low side), and yellow with a black stripe (utility). They are labeled "SAE J2196/R-134a."



Service ports are a specific area on the high-side and the low-side of the air conditioning system that allow system pressures to be measured.

A/C service ports allow the manifold gauge hose to be attached to the system. Look for A/C service ports on the:

- high side line.
- low side line.
- compressor.
- accumulator.

R-134a service ports use quick connect couplers.

Personal Safety

Observe the following safety cautions when making connections:

- Protect hands and eyes from any possible contact with refrigerant.
- Use caution when opening any valves.
- Use caution when disconnecting or connecting hoses.
- Wrap a clean cloth, cap or airtight seal (water balloon) around fittings when disconnecting or connecting hoses.

- Properly tighten hose fittings, too loose may leak, and too tight may distort fittings.
- Minimize any pressure release when connecting or disconnecting.
- Never apply heat to service connections.

Observe the following safety cautions while servicing A/C systems:

- System pressures can reach over 500 psi.
- Injury can result from a burst line or part.
- Do not weld or steam-clean near A/C parts that may cause excessive pressure in the system.
- Injury can result from automatic cooling fans turning on suddenly with or without the engine running.
- Injury can result from working in the engine compartment with the engine running. Stamped parts can have extremely sharp edges that can easily cut skin.
- Never attach the A/C service lines to the vehicle fuel system.

Refrigerant Recovery / Recycle / Recharge Equipment

R-134a recovery / recycle / recharge equipment must have refrigerant-specific manifold gauge sets.

Recovery / recycle / recharge equipment is used to service A/C systems by removing, recycling, and recharging the system. Basic operations are the same for all machines, but options may differ. This equipment:

- may be specific to the type of refrigerant being recovered.
- cannot be used to recover / recycle blends of refrigerant. A specific machine must be used to recover refrigerant blends.
- has service fittings that are specific to the type of refrigerant that is being recovered, recycled, and recharged.

The Society of Automotive Engineers (SAE) has established standards for refrigerant recovery and recycling equipment and service procedures. All recovery and / or recycling equipment must be Underwriters Laboratories (UL) or ETL tested. SAE standard J1732 states the requirement for R-134a recovery-only equipment.

Service procedures for a vacuum hold test include:

- waiting at least five minutes after turning off the equipment for the vacuum pressure to hold.
- holding a stable vacuum for an additional two minutes.

Do not use extension cords with this equipment. Extension cords are a potential fire hazard and may cause equipment malfunction, including overheating.

Environmental Protection

Certification may be required to comply with federal, state, provincial, or local regulations. This may include:

- compliance with federal laws.
- equipment having to meet SAE performance certifications and SAE purity (or Section 609 of The Clean Air Act) requirements.
- requiring the technician to be certified to work on A/C systems.
- requiring the repair facility be certified to work on A/C systems.
- issuing fines and penalties.

Personal Safety

Never fill a refrigerant container to more than 60% of its gross weight rating. For example, do not exceed:

- 18 lb in a 30 lb container.
- 30 lb in a 50 lb container.

Some refrigerant equipment may have a specific refillable storage tank that must be used. Overfilling may cause a discharge of liquid refrigerant or even a violent explosion of the container. A safety mechanism may have been built-in to prevent tank overfill.

Module Wrap Up

Topics discussed in this module included:

- the identification of service ports and connection of service equipment.
- the purpose of refrigerant identification equipment.
- the purpose of leak test equipment.
- different types of recovery / recycle / recharge equipment.
- the maintenance of refrigerant recovery and recycling equipment.