Heavy Duty Air Conditioning and Heating

Service Training Manual

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Red Dot Corporation

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Second Edition

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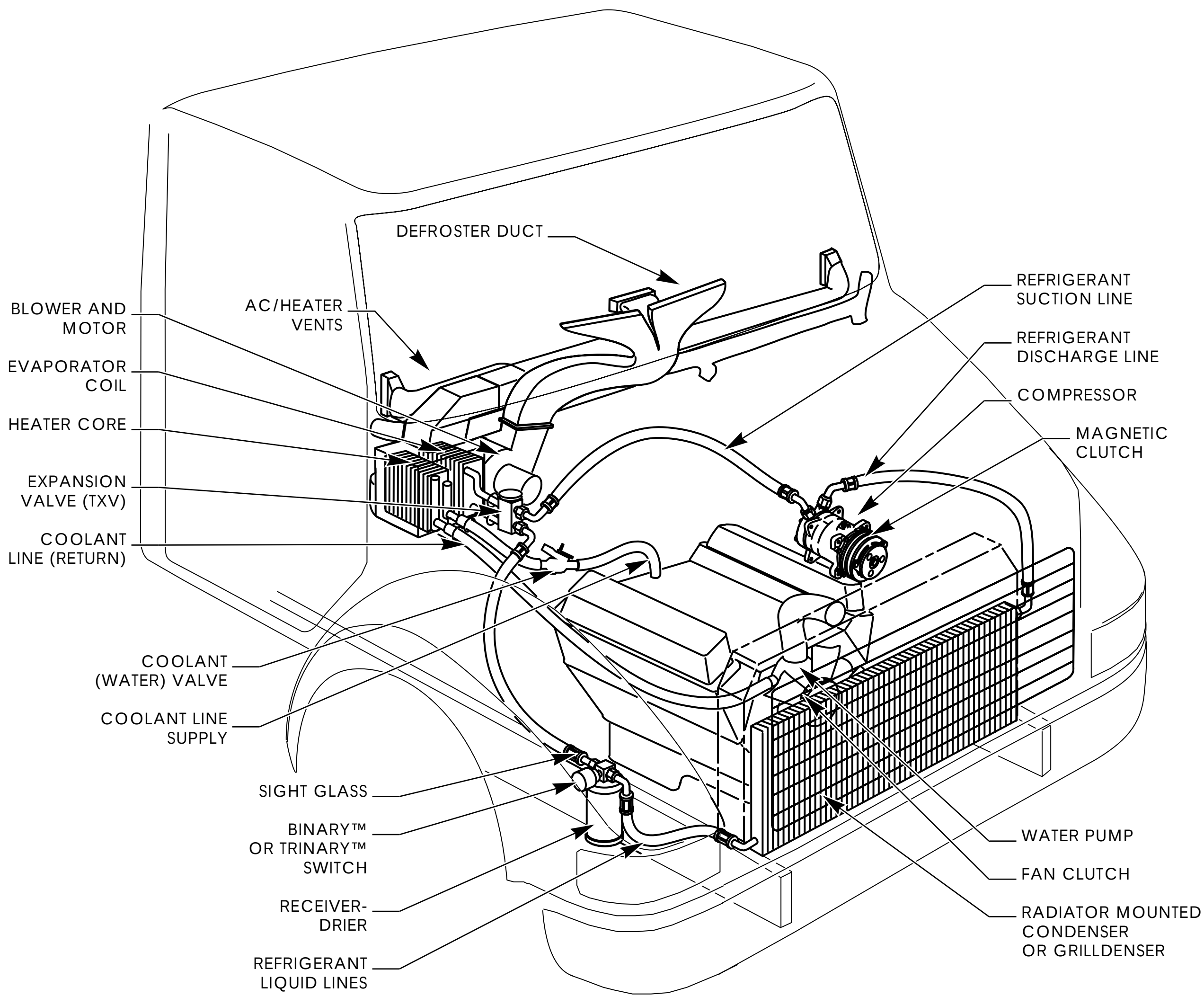
Introduction

This manual has been designed and written for your use. Take your time reading it. Study the illustrations, charts and photos. Figure 1 shows a typical HVAC system (heating, ventilating, air conditioning) installed.

The illustration is cut away so you can see component locations. All of the main components are labeled, connected together and positioned approximately as they appear in the vehicle. These components may differ from one cab to another. There could be other system devices for safety or perhaps sleeper cab comfort.

Figure 1

The illustration shows a typical HVAC system with in-cab components mounted on the fire wall. The main system components are noted in this illustration.



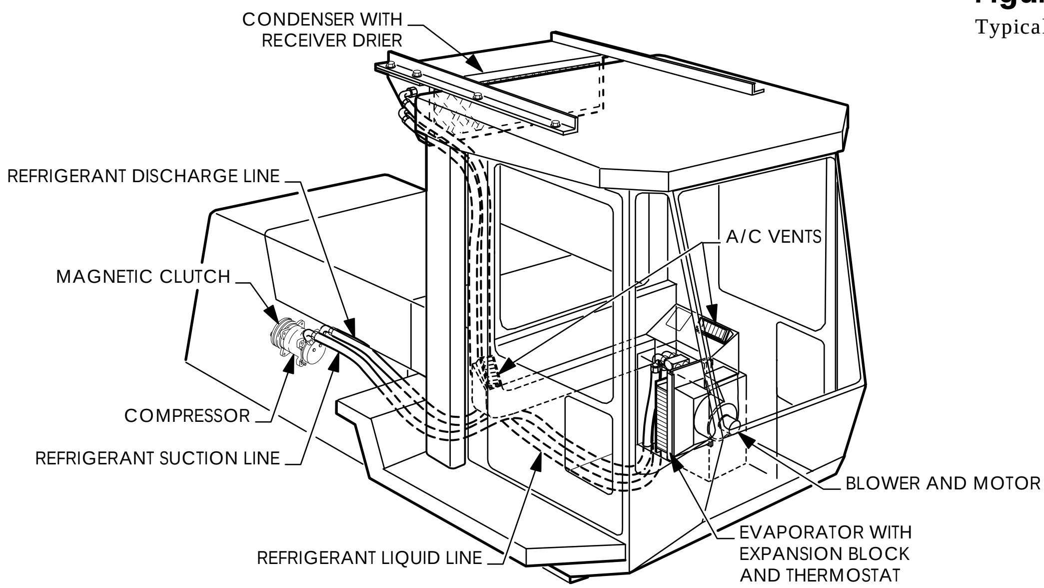


Figure 2

Typical off-road installation.

The Table of Contents lists the chapters and gives you their page locations. There are two separate indexes at the back of the manual. The Figure Index describes each figure with its number and page location. The Subject Index will help you locate each subject covered in the manual.

Each chapter begins by listing the main topics you will want to learn and remember. Key points are repeated for your review at the close of most chapters. The illustrations are explained and parts are labeled where necessary for easy identification. You should feel free to make notes in this manual and underline or circle anything that is important to you.

Our purpose is to give you knowledge, and confidence in your ability to work on heavy duty air conditioning and heating systems. Your working speed and trouble shooting skills will improve with experience.

The systems we cover here for heavy duty heating and air conditioning are easy to understand. They are a little different from most other mechanical systems, because they are closed (sealed) systems and have to function under pressure to work properly. You will become familiar with a few of nature's laws that most of us take for granted. These concern how heat really works and the effects of pressure under different conditions. There is a *Glossary of Terms* at the back of this manual. The *Glossary* explains words that may be new or not clear to you.

Safety is very important to all of us. *Chapter 6*, page 6-10, reviews safety procedures in detail. We also use "NOTES," "CAUTIONS," and "WARNINGS" in this manual. Any time you see a CAUTION, we are talking about a situation that could lead to equipment damage or failure. A "WARNING" specifically warns you about the potential danger to humans (the operator, the serviceperson) when equipment use or instructions are not properly followed. You will be handling engine coolant and air conditioner refrigerant in your work. Both are chemicals and can be unsafe to work with when used incorrectly.

The Clean Air Act, passed in 1992, specifies that anyone who works on vehicle air conditioning systems must be certified as proof of their training. Organizations such as the Mobile Air Conditioning Society (MACS) and the National Institute for Automotive Service Excellence (ASE) are approved by the Environmental Protection Agency (EPA) as organizations having approved independent testing and certification programs. At the time of this writing, others are being considered. For more information, please contact your regional EPA office.

Now it is time for the details, the things that make these systems work. Take a few moments now to study Figure 1. Familiarize yourself with the component names and then move on to the chapters that follow. All the details are covered there.

Chapter 1 Air Conditioning / Heating Function

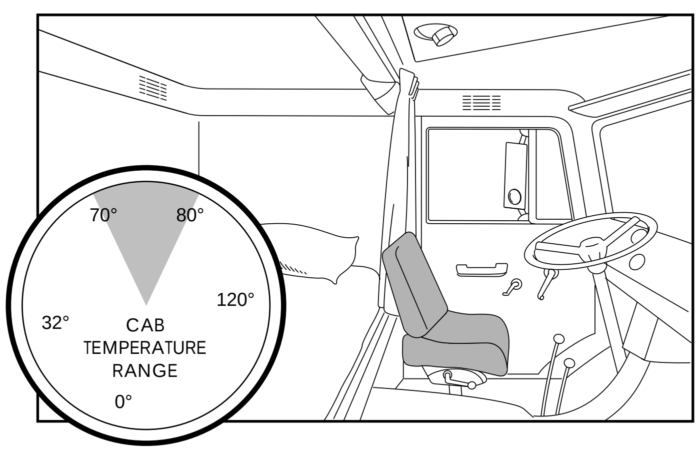
Click on any of these subject headings to go directly to the page

Cab Environment

The purpose of a heater/air conditioner system is to keep the driver comfortable. You are already familiar with your car system—if you are cold, you turn on the heater. On a warm summer day, you either turn on the air conditioning system or open the windows. Most people feel comfortable when they are surrounded by air that is 70 to 80 degrees. Because truck drivers and heavy-duty vehicle operators are usually in their cabs for long periods of time, the cab temperature is very important to their comfort.

Truck and off-road cabs are hard to heat and cool. They have a large glass area and are not always well insulated. Hot and cold weather directly affect the temperature inside the cab. This means that any air conditioner/heater system must have the capacity to do a lot of cooling or heating. Figure 1-1 shows the temperature range inside a cab.

Figure 1-1
Inside cab environment
A 70 to 80 degree temperature range and modest humidity level is best for most people. The heater/AC system should reach and remain within this temperature range after a few minutes of operation.



The ideal cab environment has a modest humidity level. The temperature should reach and then remain in the ideal range, 70 to 80 degrees. The cab should reach this temperature range after a few minutes of system operation with the windows closed. Air within the cab should be exchanged every few minutes to remove smoke, products of respiration and other odors.

Most air conditioner systems cycle on and off by the action of thermostatic and/or pressure sensitive devices. It is this on-off, open- closed action that maintains a comfortable temperature range for the driver and any passengers.

Heat Sources

Heat is a form of energy. The control of heat energy is what air conditioning and heating is all about. In summer a vehicle cab absorbs heat from various sources such as the sun, the road surface, engine, transmission, hot outside air, and even the people in the cab. In winter the cab looses heat to the cold outside air.

Figure 1-2 illustrates a truck cab in two situations—operating in summer and winter.

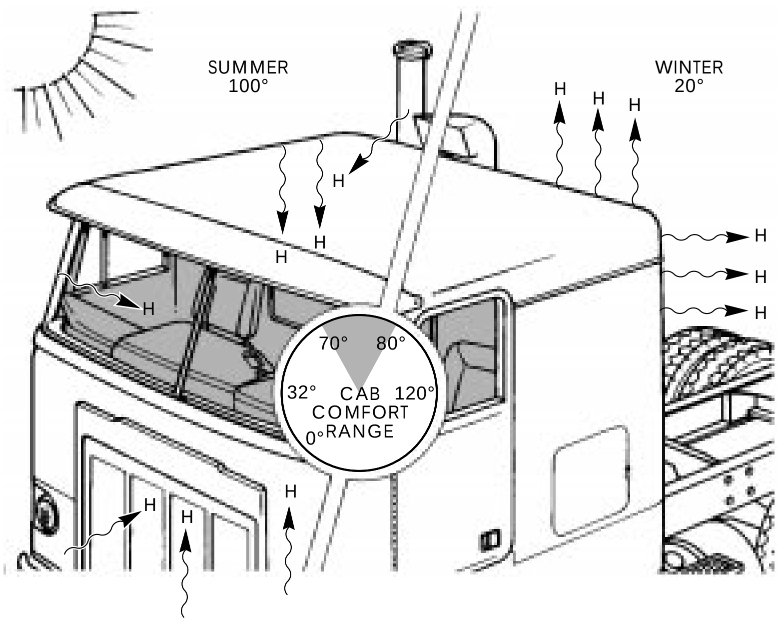


Figure 1-2
This drawing shows how heat moves; one of nature's laws. Heat always moves from a warm to a cool area—heat flows into the cab in hot weather and flows out in cold weather.

Heat Movement

Heat always moves from a warm area to a cooler one until both areas are at the same temperature. You know from experience that on a cold day, when you drive somewhere with the heater on, your vehicle is comfortable. But if you park it for awhile with the engine off, the cab and the engine will both eventually reach the same temperature as the outside air. Figure 1-3 illustrates this in a parked vehicle.

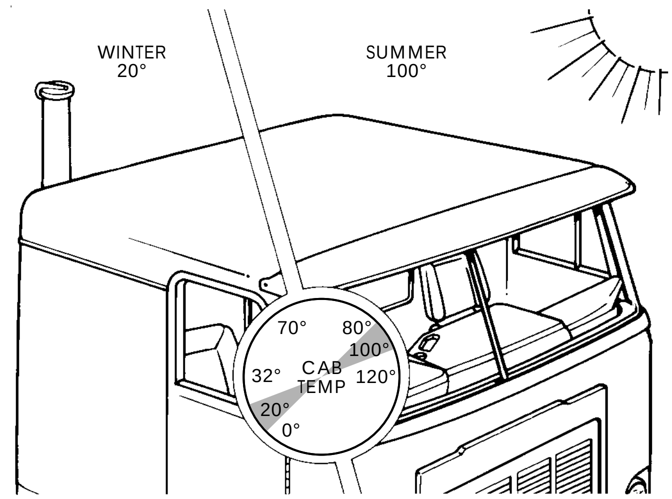


Figure 1-3

The inside cab temperature will be the same or higher than the outside temperature when parked for awhile with all systems turned off.

Figure 1-4 displays the key components in the HVAC system. The arrows show the direction of refrigerant flow in the system.

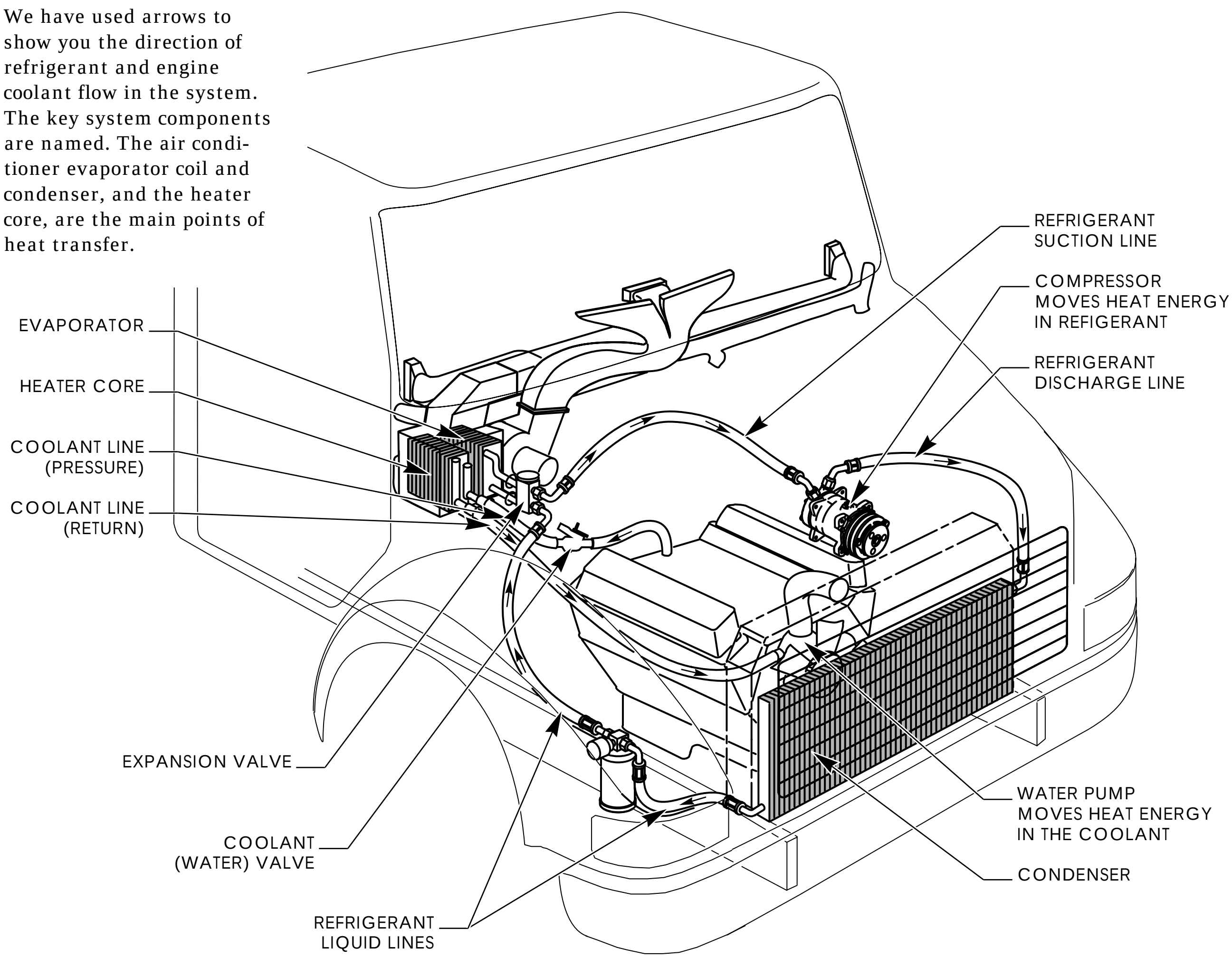


Figure 1-4

We have used arrows to show you the direction of refrigerant and engine coolant flow in the system. The key system components are named. The air conditioner evaporator coil and condenser, and the heater core, are the main points of heat transfer.

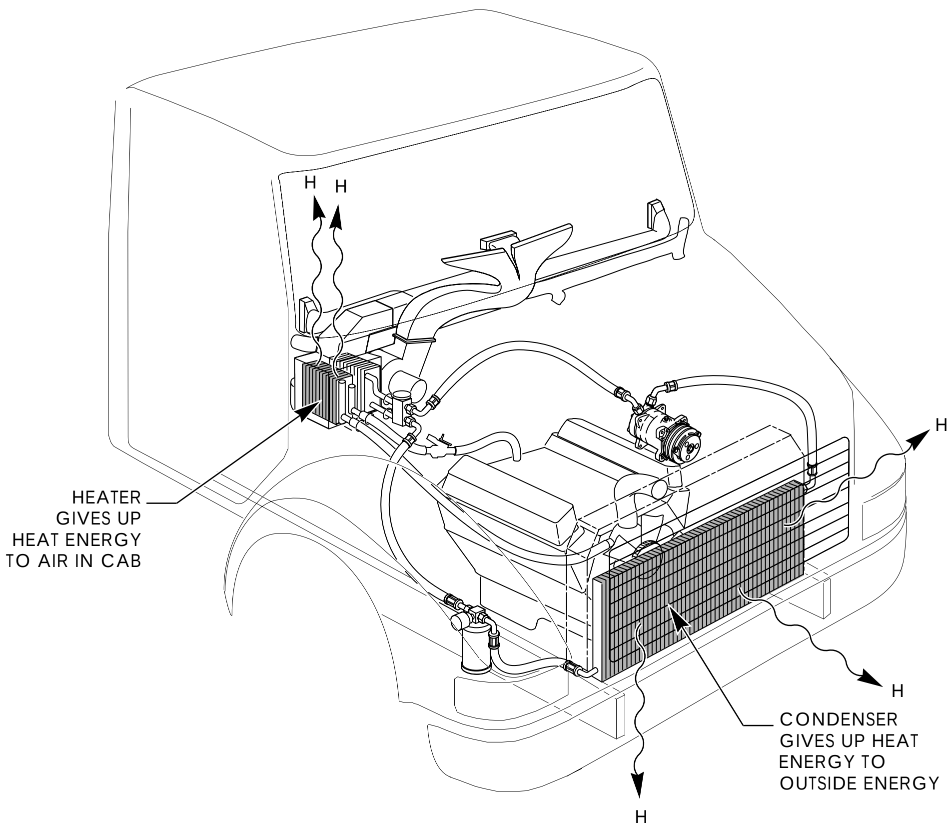


Figure 1-5

Note the heater core and air conditioner condenser in this illustration. Both serve these systems as the main point of heat energy radiation. The heater radiates heat to warm the vehicle occupants. The condenser radiates heat from the refrigerant to the air outside the cab.

Heat Measurement

There are two ways to measure heat—heat intensity in degrees Fahrenheit, or degrees Celsius, and heat quantity in British thermal units (BTU's).

Heat Intensity

We measure heat intensity (how hot something is) as temperature in degrees Fahrenheit (or in the metric form, degrees Celsius). In your service work on HVAC systems, you may use a dial type thermometer to measure heat intensity. Figure 1-6 illustrates a typical dial type thermometer. It's an ideal tool for measuring heat intensity as you work to check out or troubleshoot these HVAC systems. The chart in Figure 1-7 converts degrees Fahrenheit to degrees Celsius.

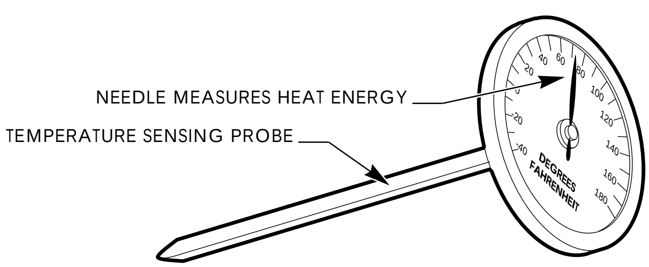


Figure 1-6

A typical dial type thermometer has a probe on it that extends about six inches. The probe senses and indicates the temperature in hard to reach places—such as in air distribution ducts.

Figure 1-7

Fahrenheit/Celsius Conversion																	
F°	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
C°	-1	4	10	16	21	27	32	38	43	49	54	60	66	71	77	82	88
F°	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	
C°	93	99	104	110	116	121	127	132	138	143	149	154	160	166	171	177	

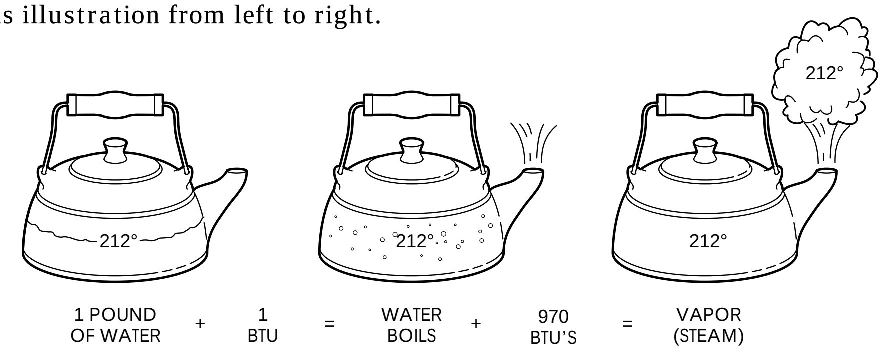
Heat Quantity

Another measurement is heat quantity, or how much heat there is. British thermal units or BTU's are the accepted unit for measuring heat quantity. For example, at sea level one BTU of heat energy raises the temperature of one pound of water one degree Fahrenheit. If we keep adding BTU's to that pound of water, we will get to the boiling point of 212 degrees. At that point the temperature will normally stop going up even if we continue to add heat (BTU's).

If you want the pound of water to change to steam (from a liquid to a vapor), you have to add a lot of BTU's. In fact you would add 970 BTU's of heat energy before the entire pound of water would change to steam. You would only add 180 BTU's to take that pound of water from 32 degrees to the boiling point of 212**.** Look at the three kettle drawings in Figure 1-8 for a moment. They show what happens to water when heat quantity is added. Review the drawings in this illustration from left to right.

Figure 1-8

In this illustration a pound of water changes to vapor when 970 BTU's of heat energy are added to it. This change in water is called a "**change of state**". Note that the temperature in the middle picture and the one on the right remains the same, 212 degrees.



Here is the interesting part. When you add 970 BTU's to change the water to steam, the temperature stays at 212 degrees. All the BTU's of heat energy went into the steam. It took 970 BTU's of energy to cause the water to change. If you were to cool the steam back to water again, the 970 BTU's of heat energy would be given up to the air. The important thing about the example and illustrations in Figure 1-8, is the large amount of heat it takes to change a substance like water from one state to another. In fact, this is one of the reasons HVAC systems are able to handle heat effectively. To put it another way, when you can control a "**change of state**" you can move a lot of heat.

The heavy duty HVAC systems you will be working on are designed to move heat energy quickly. Engine coolant and refrigerant are used to carry heat energy into or out of the cab. Both of these liquids are good at absorbing and giving off BTU's of heat in the vehicle cab to make us comfortable.

Heat Relationships

Relative humidity plays an important part in our comfort. So does air movement. The relative humidity is a measure of the moisture in the air. Air movement is a measure of the speed or velocity of air as it moves. We use CFM's or Cubic Feet per Minute as a measure of air movement. As they operate, truck HVAC systems remove humidity or moisture and circulate the air around us to keep the cab occupants comfortable.

Changes of State

We talked about "change of state" when we mentioned earlier that 970 BTU's of heat energy were needed to change a pound of water into vapor. We use water in our example because it is familiar to all of us. In AC systems the refrigerant is used instead of water. It evaporates and condenses (changes state) in the system almost continuously. It is this action that makes an air conditioner cool the cab and its occupants. A "change of state" works for us by moving large amounts of heat energy fast, under the right conditions.

Heat Movement During Changes of State

Evaporation and condensation both take place inside the air conditioning system. When either of these conditions occur, a lot of heat moves. We use refrigerant because its temperatures of vaporization and condensation are nearly optimum for this application. Using the familiar 20 pound refrigerant cans, Figure 1-9 shows the effect of a "change of state" on R-12. You can see how fast a change in pressure in the can changes the temperature of the refrigerant.

WARNING Refrigerant can be dangerous if released as shown below. These drawings are for illustration purposes only—to show "change of state".

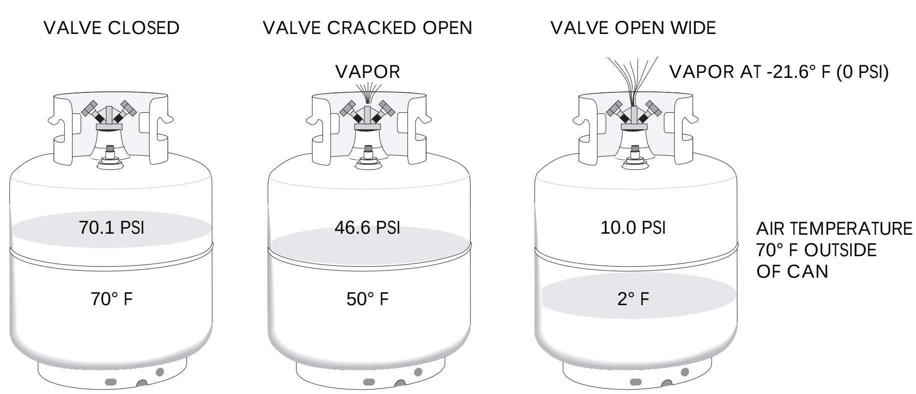


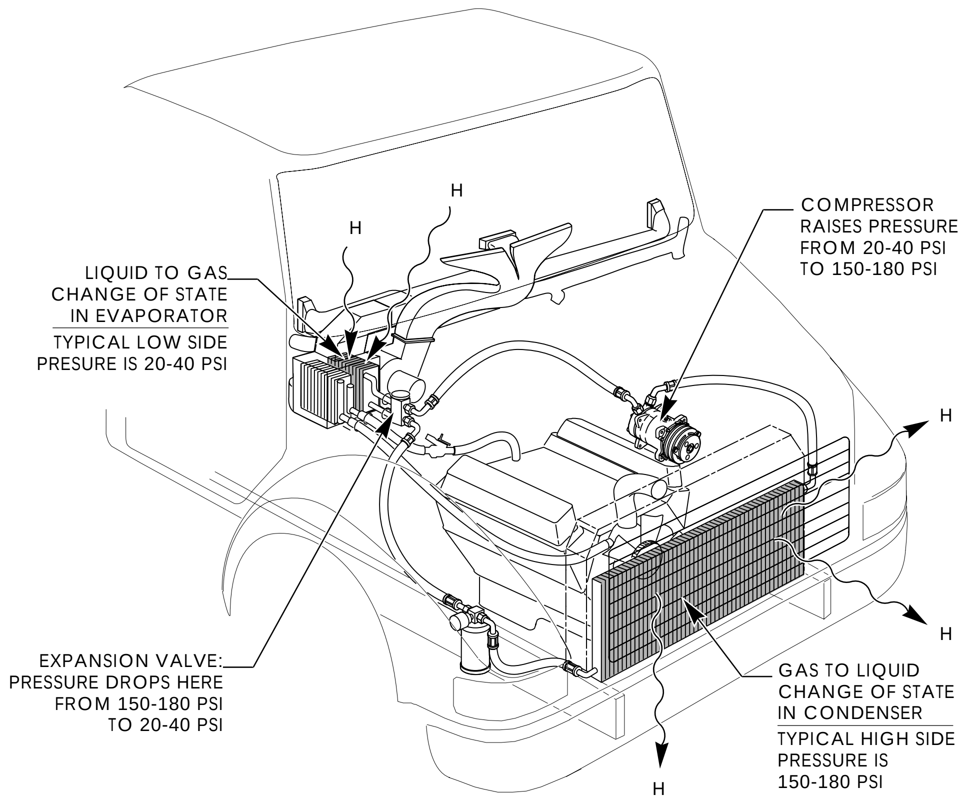
Figure 1-9
In these drawings the dispensing valve is used to release pressure inside the cans. Note that R-12 boils at a temperature of -21.6 degrees Fahrenheit, compared to water at 212 degrees Fahrenheit.

In an air conditioner, the refrigerant is trapped inside a closed system and circulates under pressure. When we put any substance under pressure, the pressure changes the way it acts. We can control the amount of pressure at different locations within an air conditioner in order to change the temperature level wherever a “change of state” occurs. Thus we use “change of state”, one of nature’s laws, to add or subtract heat in large quantities from a substance—fast! Figure 1-10 shows the points where “changes of state” occur in the truck AC system. Refrigerant, in this case R-12, evaporates inside the evaporator coil and condenses inside the condenser.

Under normal operating conditions there is no change of state within the heater system.

Figure 1-10

This illustration highlights the evaporator and condenser in a cutaway view of the typical HVAC system. The R-12 changes from liquid to vapor or gas at the evaporator, and back to a liquid again at the condenser.



Air Conditioner/Heater Functions — What They Do

These systems are designed to provide comfort to the cab occupants as quickly as possible. The systems change the cab temperature and maintain it. They use refrigerant and engine coolant (anti-freeze) to move heat energy. The refrigerant in air conditioning systems removes heat from the cab. The engine coolant takes heat from the engine and transfers some of it to the cab through the heater core.

HVAC systems also control humidity or moisture as the air in the cab is circulated. The system components may act together or independently, switching on or off to meet present control requirements. The driver or passengers can change system control settings to meet their own personal comfort needs. The controls can affect temperature and humidity levels, air direction and speed (CFM). System controls are described in *Chapters 3* (heater) and *4* (air conditioner) of this manual, and explained in more detail in *Chapter 5*.

It is important to remember that all systems are designed to maintain a temperature range. This range takes care of variations in outside temperature which cause heat gain when it is hot, or heat loss when it is cold.

Chapter Review

The following topics were discussed in this chapter:

- The ideal in cab environment for most people is 70 to 80 degrees Fahrenheit, with a modest humidity level and adequate air circulation.
- Heavy vehicle cabs are hard to cool or to heat because of the weather, minimal insulation, and the large glass area of the cab. In summer the cab picks up heat from the sun, road, engine, transmission, and body heat from the occupants. An operator who spends long periods in the cab can be more critical of the cab environment.
- We measure heat (energy) two ways—in degrees Fahrenheit or Celsius, and BTU's. Degrees measure heat intensity. BTU's measure heat quantity.
- One of nature's laws is that heat (BTU's) always moves from a hot area to a cooler area until both are at the same temperature (intensity) in degrees Fahrenheit.
- Another of nature's laws is that a "change of state" accounts for the movement of a lot of heat. If the change of state happens fast, the heat moves fast. When refrigerant changes state, it can give off or absorb large quantities of heat (BTU's).

Chapter 2

Overview of System Operation

Click on any of these subject headings to go directly to the page

Truck and Heavy Equipment Systems

A variety of HVAC systems are in use today, some old and some new. There are:

- Vehicle manufacturer installed systems
- Owner specified systems
- Add-on systems
- Retrofit systems

The system components come in different colors, shapes, and sizes. They may be mounted in or on the cab in varied locations. Owners or fleet maintenance people can modify systems by adding controls, auxiliary units or ducts. Major components are sometimes replaced due to damage or failure. All systems were, at least originally, designed and installed to meet the needs of an operator. Figure 2-1 includes illustrations of various AC and Heater systems. They illustrate system advantages and disadvantages explained in the paragraphs that follow.

The HVAC system includes both heater and air conditioner components, usually a common control, and air ducts. The system cools the cab by removing heat energy. It removes moisture from damp air in the cab and adds fresh outside air to the cab. In this way, the operator can work comfortably in all kinds of weather.

A sleeper unit, built in or added on, increases the air volumes in the cab. The air conditioner or heater must circulate and cool or heat a larger amount of air. This is accomplished by routing ducts and controls to the sleeper compartment as part of system design. Components may be increased in size to handle the larger cab air volume. A bigger heater core, air conditioning evaporator coil, condenser, blower or fan may be included. Often, on long haul trucks, auxiliary air conditioning and heater components and controls are added. The objective remains the same, to move heat energy and maintain occupant comfort.

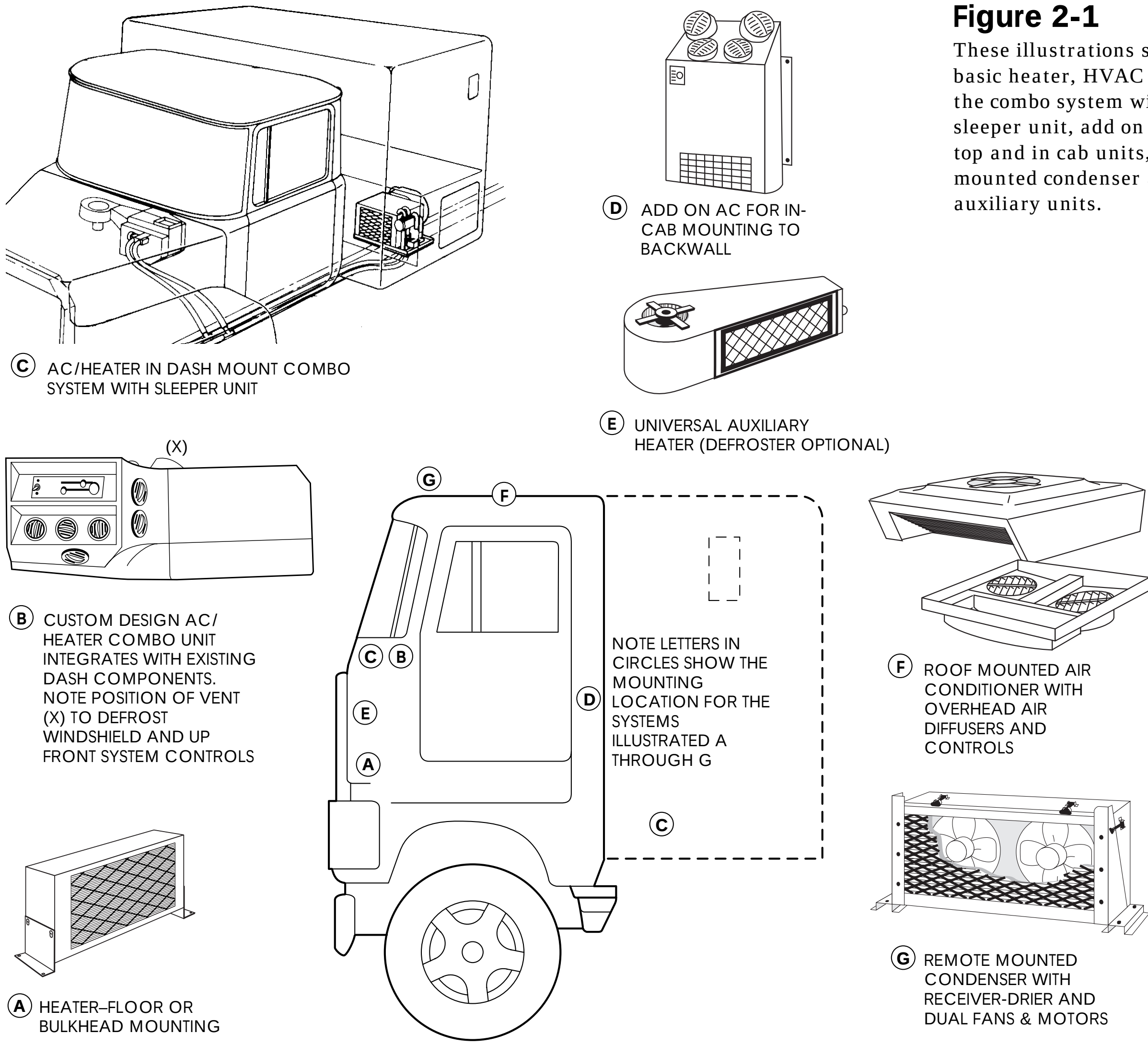


Figure 2-1

These illustrations show a basic heater, HVAC system, the combo system with sleeper unit, add on AC roof top and in cab units, roof mounted condenser and auxiliary units.

By law, all trucks have a heater/defroster as part of the standard equipment. When there is a reason to add air conditioning, there are options to meet different needs. The available space in the cab, operating environment, and owner preference can all play a part in the type of AC unit selected. You will probably encounter roof-mounted and in-cab add on systems, and even systems where the condenser is mounted on the roof and the evaporator is attached to the back panel or mounted under the dash. In cooler climates you may come across a cab with two heaters, the original and an auxiliary unit.

Air Conditioner—System Operation

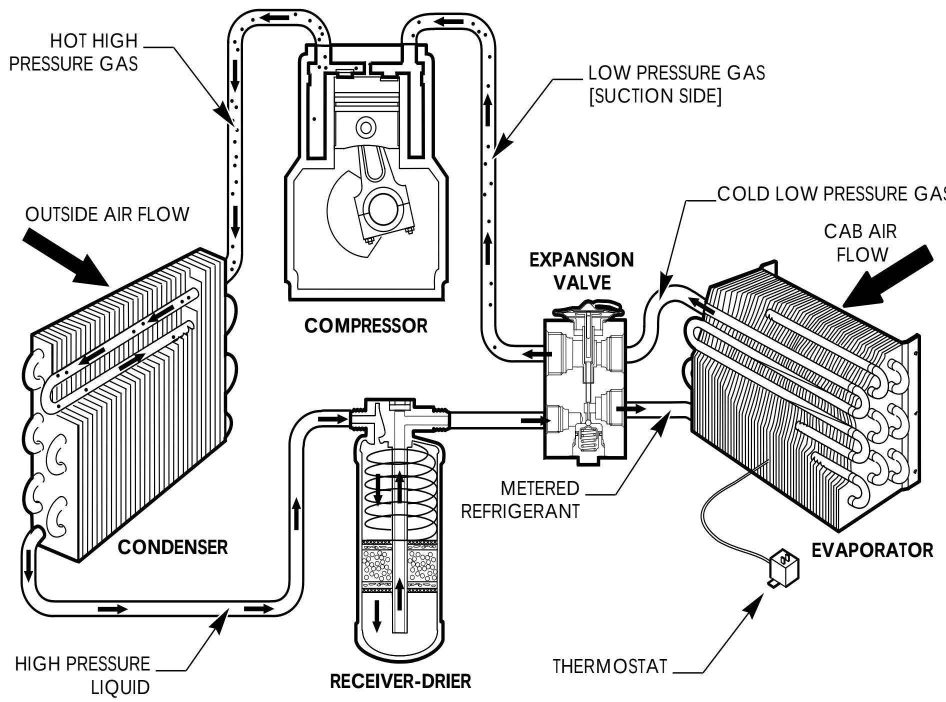
We have described the movement of heat energy and basic HVAC system function in Chapter 1. Now we will go into some detail on how an air conditioner operates. The system is sealed to keep out air and moisture. To operate properly, the inside of the system contains a measured amount of refrigerant and special refrigerant oil that keeps the system lubricated. Figure 2-2 is an illustration of system components without the cab outline, in-cab controls, component housing, and air ducts or vents. Please study it for a moment. Note the information printed next to each component. Remember that the components may be positioned and attached to the truck in various locations.

The following AC components are discussed in detail in this section:

1. Compressor/Clutch Assembly
2. Condenser
3. Receiver-Drier
4. Expansion Valve
5. Evaporator Coil

Figure 2-2

Air Conditioner components are connected together to illustrate system operation. The components shown are not to scale. The refrigerant and refrigerant oil are clear in color and not visible in this drawing. The small arrows inside the components and connecting hoses show the direction of refrigerant flow (refrigerant circuit).



1. Compressor/Clutch Assembly

The compressor/clutch assembly is the heart of the system. When the clutch is engaged, the compressor pumps refrigerant and oil around the system. It raises the temperature and pressure of the refrigerant gas, and forces it to the condenser where it changes state and becomes a liquid. The compressor also sucks the vaporized refrigerant out of the evaporator and back inside itself in the form of gas. One way valves inside the compressor separate the compressed gas (high pressure) side of the system from the suction (low pressure) side. Figure 2-3 shows a cutaway view of a compressor with the high and low pressure sides noted.

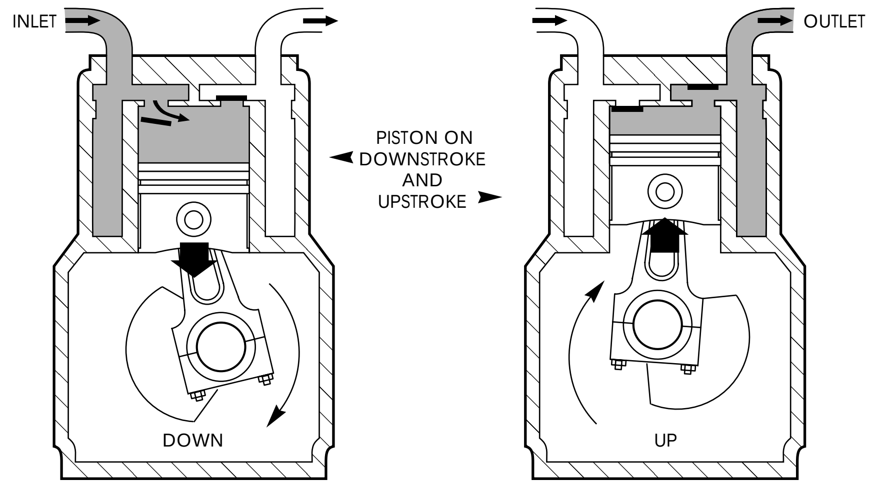


Figure 2-3

The compressor inlet is low pressure and the outlet is high pressure. The reed valves are one way. They open to allow refrigerant gas to enter the compressor on the down stroke and exit on the upstroke. Note the open valves in the illustrations.

The clutch is mounted on the shaft of the compressor and is engaged by electromagnetic action. Part of the clutch assembly is an electromagnetic wire coil. The coil is energized through a thermostat that senses the temperature in the evaporator coil. If the evaporator is too warm the electrical contacts close and allows power to flow to the clutch. The compressor shaft is engaged and moves the refrigerant around inside the system. Figure 2-4 is a cutaway view of the clutch mounted on the compressor.

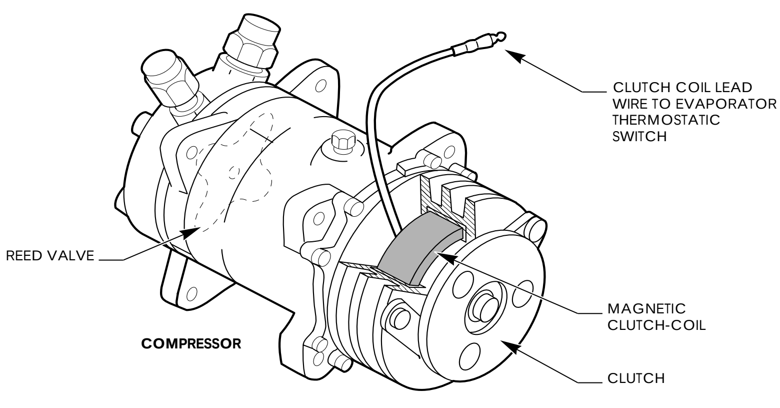


Figure 2-4

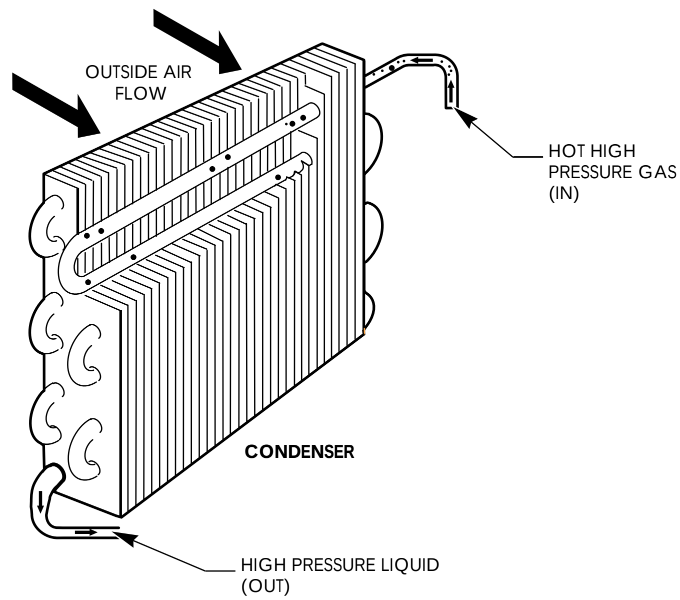
The clutch shown here has its electromagnetic coil mounted on the compressor body. When the coil is energized, magnetic force pulls the clutch drive plate into the pulley. This action locks the pulley to the compressor drive shaft and drives the compressor.

2. Condenser

The refrigerant gas leaves the compressor and moves through a high pressure hose to the condenser. Inside the condenser the gas “changes state” and becomes a liquid. It is still hot and under pressure. Remember in Chapter 1 when we talked about water at 212 degrees Fahrenheit? Heat energy was involved in the “change of state,” but the temperature did not change. The same kind of action happens inside the AC system. The refrigerant gas gives up a lot of heat energy to the outside air as it “changes state” in the condenser. Figure 2-5 illustrates a condenser. Air moving through the condenser absorbs heat from the refrigerant. The amount of air flow through the condenser is the major factor in how well the condenser functions.

Figure 2-5

As the refrigerant gas moves through the tubing coil from top to bottom, it condenses (changes state) into a liquid. For ease of installation, condenser fittings are often routed close together.

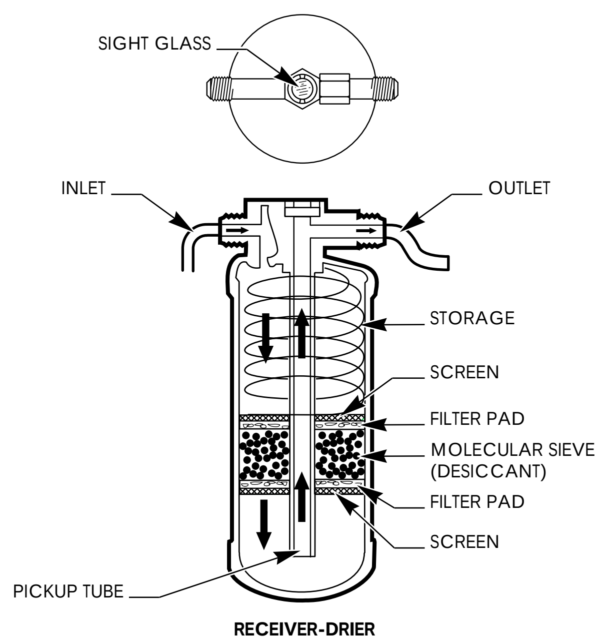


3. Receiver-Drier

The liquid refrigerant continues to move inside the system, out of the condenser through a tube or hose to the receiver-drier. The receiver-drier serves as a small storage tank and filter for the refrigerant. It is also a good location to mount pressure switches and often contains a sight glass (small window) used to view activity inside the system. The receiver-drier, Figure 2-6, also separates gas (bubbles) from the liquid with a pick-up tube as shown in this illustration. Some receiver-driers have a spring to preload the desiccant pack.

Figure 2-6

This cutaway view of a receiver-drier shows the filter elements, inlet, outlet and refrigerant path. The sight glass is a small window into the system used in diagnosis and when adding refrigerant (charging the system).



4. Expansion Valve (Refrigerant Metering Device)

When refrigerant moves from the receiver-drier, it travels through another high pressure hose to a metering device at the inlet of the evaporator coil. The metering device can be an expansion valve, an expansion tube or a combination (multiple function) valve. Between the compressor and this point inside the system, the pressure is high and can range from 150 to 250 pounds per square inch. The expansion valve (TXV) is closely connected to the evaporator. A diaphragm opens the valve by exerting pressure on the spring. Pressure comes from gas inside the diaphragm housing on top of the valve and in the sealed sensing bulb. The sensing tube is located in the outlet of the evaporator and picks up heat from warm refrigerant leaving the evaporator. The gas in the valve diaphragm housing and sensing tube expands when it gets warmer and forces the expansion valve open at the metering orifice.

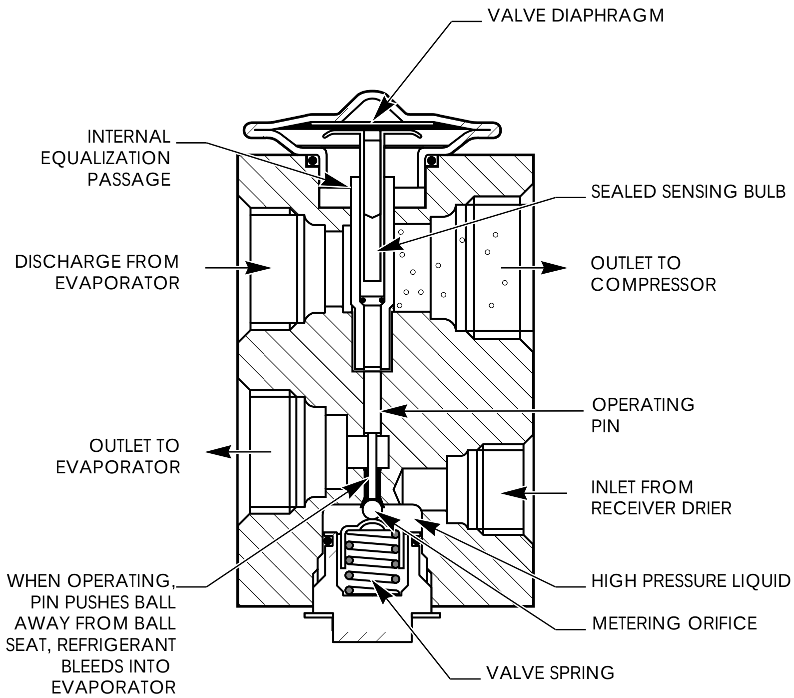


Figure 2-7

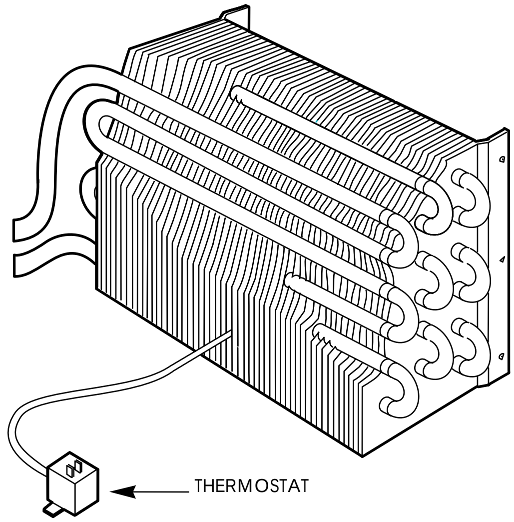
This block type expansion valve cutaway view will give you a better idea how these valves work. Spring pressure holds the valve closed.

5. Evaporator Coil

The expansion valve or other type of metering device bleeds high pressure refrigerant into the evaporator coil, where the pressure is low. The refrigerant expands rapidly in this low pressure environment. When it expands it “changes state”. The sudden drop in pressure brings the refrigerant temperature down quickly inside the evaporator coil. Figure 2-8 shows an evaporator coil and thermostat. Refrigerant is sprayed into the evaporator by the high side pressure when the expansion valve opens. The refrigerant absorbs heat from the air when the blower forces the air through the fins. When the thermostat probe senses the upper limit of the thermostat heat setting, a circuit closes. The compressor clutch engages and the compressor operates and moves more refrigerant to the high side of the system.

Figure 2-8

The evaporator coil as shown is of fin and tube construction. The thermostat probe is positioned in between the evaporator fins and senses the temperature.



Note: Moisture in the air (humidity) condenses on the fins of the evaporator as water droplets which drain out of the evaporator through a drain hose. This action dehumidifies the air in the cab as part of system operation, and contributes to operator comfort.

Cab air forced across the evaporator coil gives up heat energy to the cold refrigerant inside the coil. The cooled air circulates in the cab for occupant comfort. Refrigerant continues to expand and absorb heat energy in the evaporator coil. Refrigerant changes from liquid to gas before it leaves the evaporator on the way back to the compressor. The refrigerant gas moves to the compressor through a low pressure (suction) hose. When the compressor is operating, it sucks the refrigerant gas back inside, compressing and raising its temperature and pressure.

Some of AC system operation is controlled by the operator, and some is automatic. The operator can turn the system on and off, regulate the air velocity with the blower control, and in some designs adjust the thermostat control. The system and component operating range settings automatically cycle the clutch on and off. The operation of the expansion valve or other refrigerant metering device at the inlet to the evaporator is automatic.

Individual system features may differ, but the basic system function remains the same. Variations in components and controls are described in Chapters 4 and 5. The engine provides the power for both air conditioner and heater operation. It drives the AC compressor and the cooling system water pump. Engine RPM affects the efficiency of both the heater and air conditioner. The slower the engine RPM, the less capacity a heater or AC system will have.

WARNING

When an AC system is operating, the high pressure side components, fittings and high pressure lines or hoses can be hot enough to burn your skin if you touch them. This includes the compressor, clutch, hoses, condenser, receiver-drier, and any control devices or metal tubing. The low pressure side will be cool to the touch. In operation the AC system is under load and high side pressures normally range between 150 and 250 pounds per square inch for R-12 and higher for some other refrigerants.

Heater System Operation

Heater and air conditioner systems both have the same basic function of moving heat. They take advantage of nature's laws where heat energy always moves from a warmer to a cooler area. In a heater system there is no "change of state" involved in system operation. The system is sealed and operates under pressure, but the pressure is low when compared to an air conditioner.

A heater system uses the engine coolant to carry excess heat energy to the cab air. The heart of the system is the water pump. The water pump forces hot coolant through a hose from the engine block and through the heater core. The coolant is returned to the engine cooling system either at the suction side of the water pump or to the radiator.

A control cable, attached to a water valve between the water pump and the heater inlet, is used to control the flow of coolant to the heater. The heater fan or blower forces cab air through the heater core where heat energy moves from the engine coolant to the air in the cab. Figure 2-9 illustrates the main heater system components. In-cab controls, component housing and air vents are not shown.

The following heater components are discussed in detail in this section:

1. Heater Core
2. Water Valves
3. Defrosters and Ducts
4. Blowers and Fans

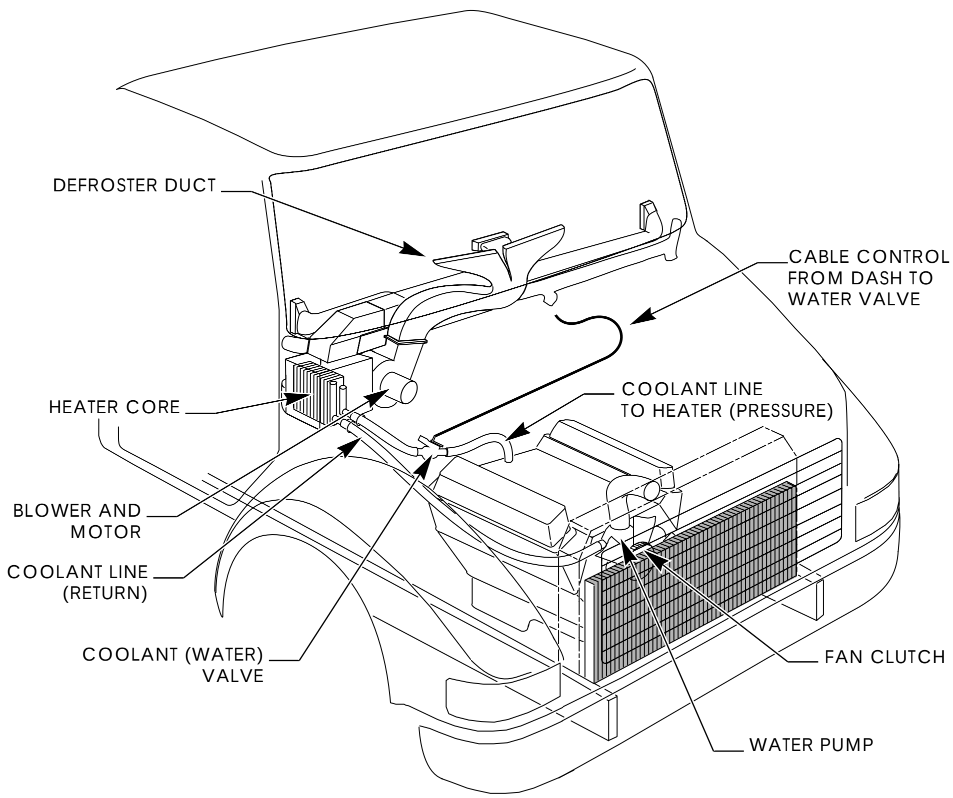


Figure 2-9
This view of a heater system shows the main components and how they are connected.

Additional heater controls, ducts, air vents, blend-air doors, temperature regulating devices and auxiliary heaters may be installed as part of a heater system. These may be air, vacuum, electrical or mechanically operated.

1. Heater Core

Heater cores are like small radiators. The fin and tube construction is designed to route coolant flow for the best possible heat energy transfer from coolant to cab air. Hoses from and to the engine are connected to the core with clamps. The core outlet may be larger or the same size as the inlet.

2. Water Valves

Water valves may be cable, vacuum or air controlled. The valve can be either open, closed or set part way open. Some valves have a bypass design to return coolant to the engine. Most are manually controlled although electronic systems are now being installed.

3. Defrosters and Ducts

Defrosting is accomplished by directing heated dry air through ducts to the windshield. The heater system serves the dual purpose of defrosting and heating. Controls are used to route the air flow to the windshield and occupant areas by opening and closing duct doors. Controls may be manual, air or vacuum.

Many vehicles use a “defrost interlock” system which utilizes the air conditioner to dry the defrost air and clear the cab windows more quickly.

4. Blowers and Fans

Blowers or fans are used in the system to move cab air through the heater core and evaporator. Air can be pushed or pulled through the core depending on system design. Blower or fan speed is usually selected by the operator.

Environmental Effects on System Operation

The environment outside the cab involves more than the weather. It may be hot and humid or cold and dry. That is only part of the condition the HVAC system must handle to maintain an ideal comfort range. A truck can be at idle, in traffic or moving along for hours on the Interstate at 65 M.P.H. The load condition on a trip can include going out full, coming home empty, or driving across the Rockies or Kansas plains during the day or night. The truck color and shape, the windows and angle of the sun are all variables that can increase or decrease the “load” on the system. The following are a few examples of environmental effect:

- A black cab-over (COE) with a dark color interior will be more difficult to cool than the same vehicle with white paint and a light colored interior. The black cab picks up and holds the radiant heat from the sun more easily than the white one.
- In Florida or Houston the humidity in mid summer can be very high with the temperature in the high 90’s or low 100’s. The AC unit must remove a lot of moisture from the air in the cab as the air moves through the evaporator fins. The more moisture on the fins, the less effective the transfer of heat is to the refrigerant inside the evaporator coil.

- On a cold day the temperature can drop below zero. The engine may run cooler so the engine coolant is cooler when it circulates through the heater. The heat in the cab moves out of the cab faster (remember heat always moves to a cooler area until both are the same temperature—nature's law). To maintain cab comfort you have to increase the flow of coolant through the heater, increase coolant temperature, and/or move more air through the heater core.
- On a hot day, an off-road vehicle experiences cooling at a slower rate than an on-road vehicle. This is a result of high sun-load, large window area and often less insulation.

It is important for you to keep environmental effects in mind when you are servicing or diagnosing heater or air conditioner systems. If you work in Denver the altitude will affect system function and pressure. In Houston the heat and humidity may lower heat transfer to the air at the condenser and increase system operating pressures.

Chapter Review

- HVAC systems range from simple cab heaters to multi-function combination systems. The multi-function system can heat and cool the cab and sleeper unit, and have separate auxiliary components and controls for driver and passenger comfort.
- Both heater (engine) coolant and air conditioner refrigerant circulate inside sealed, pressurized systems. The normal air conditioner operating pressure ranges from 150 to 250 pounds per square inch, sometimes higher with a different refrigerant.
- Air conditioners have a high and a low pressure side within the system. The compressor is the starting point of the high side. Pressure drops at the expansion valve opening to the evaporator.
- The basic components of an AC system are the compressor-clutch assembly, high pressure lines, condenser, receiver-drier, expansion valve, evaporator, thermostat, blower assembly, and suction lines. There may be other controls installed for more complex systems.
- The basic components of a heater system are the inlet and outlet hoses, a water valve and valve control, heater core and fan or blower assembly. There may be other controls for more complex systems.
- An air conditioner system uses the "change of state" of refrigerant inside the system to move heat from the cab air to the outside air. Refrigerant changes from a gas to a liquid in the condenser, and back to a gas in the evaporator.
- A heater system uses the heat from the engine, carried to the heater core by the action of the water pump, to warm the air in the cab. There is no change of state within the heater system.
- Environmental conditions affect how both heaters and air conditioners work. Weather, driving conditions, color of the vehicle are factors. All contribute to heat gain or loss inside a cab and how much heat energy must be moved to maintain occupant comfort.

Chapter 3 Heater Components and Controls

Click on any of these subject headings to go directly to the page

Engine Coolant or Anti-freeze

Ethylene glycol-type coolant (anti-freeze) is mixed with water and used in most vehicle cooling systems today. Additives in the coolant formula lubricate the water pump, reduce the chance of rust or corrosion, and prevent foaming. Although it is often called permanent anti-freeze, the additives break down in time and loose their protective qualities. For this reason coolant should be changed at regular intervals. Five main reasons to use coolant in the engine are:

1. It has a much lower freezing point than water.
2. It has a higher boiling point than water.
3. It is inexpensive.
4. It prevents corrosion for a reasonable period of time.
5. It absorbs and gives off heat energy effectively under a great range of operating conditions.

Mixing 60% ethylene glycol with 40% water protects the cooling system from freezing to -65 degrees Fahrenheit. Adding more anti-freeze does not prevent freeze up at lower temperatures, but it does raise the boiling point of the solution.

WARNING Use care in handling anti-freeze. It is a petroleum based liquid that can irritate the skin and eyes. The sweet taste is appealing to animals and can be deadly if consumed. Check for local regulations on disposal and recycling.

Cooling System Thermostat and Radiator Pressure Cap

These two cooling system control devices affect heater system operation, including coolant temperature, circulation, boiling point, and coolant overflow and recovery system. Figures 3-1 and 3-2 illustrate the function of the thermostat and radiator pressure cap respectively. Descriptions of how the thermostat and radiator cap work follow the figures.

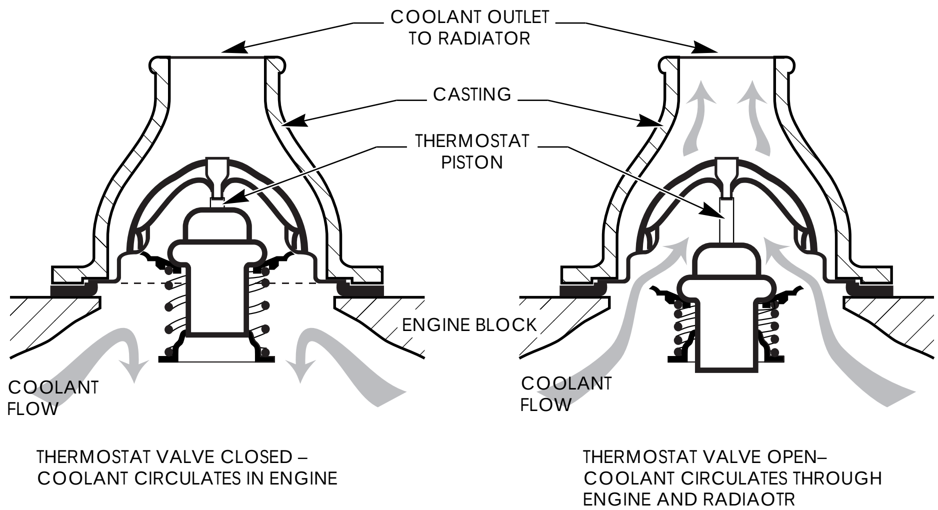


Figure 3-1

The thermostat is shown in both closed and open positions. When closed coolant does not circulate through the radiator.

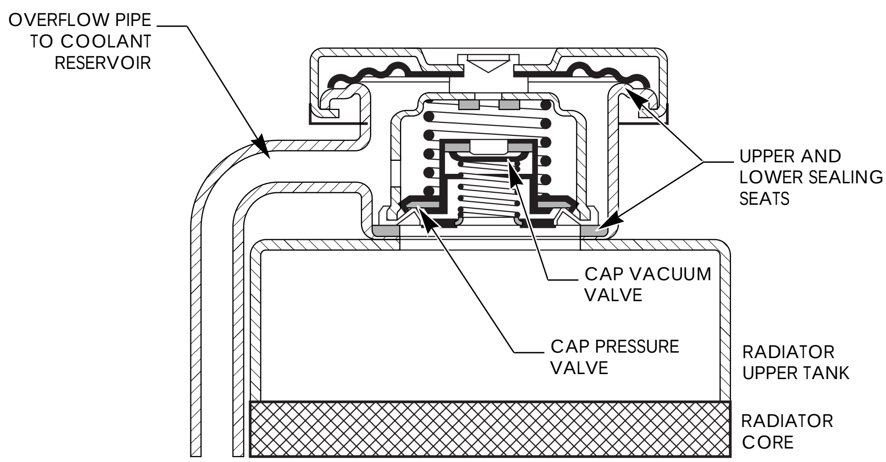


Figure 3-2

The pressure radiator cap seals the cooling system. The cap pressure valve opens when operating pressures are high.

1. **Thermostat -** controls the direction of flow of the coolant from the water pump, through the engine and radiator. As the engine warms up the thermostat opens, allowing the coolant to flow to the radiator. The coolant gives up excess engine heat to the outside air as it moves through the radiator. If the engine is cold, the thermostat stays shut and the coolant by-passes the radiator and circulates in the engine, as well as the heater core.

2. **Radiator** – radiator cap seals the cooling system at the inlet on top of the radiator. Caps are pressure rated to match cooling system design. Each pound of pressure on the cooling system raises the boiling point of coolant three degrees Fahrenheit, so the pressure cap extends the cooling system operating range above the normal boiling point. Coolant can flow through the heater core regardless of thermostat position.

Altitude lowers the boiling point of coolant by two degrees Fahrenheit for every 1000 foot increase of elevation above sea level. As you can see, the pressure cap tends to compensate for a lower boiling point at higher altitude. When high system pressure forces the radiator cap to open, coolant escapes to the coolant reservoir. A low pressure or slight vacuum inside the system sucks coolant back to the radiator from the reservoir.

Water Pump

Modern water pumps have a centrifugal design. Vanes or impellers in the pump circulate the coolant. Figure 3-3 shows a cutaway view of a water pump assembly.

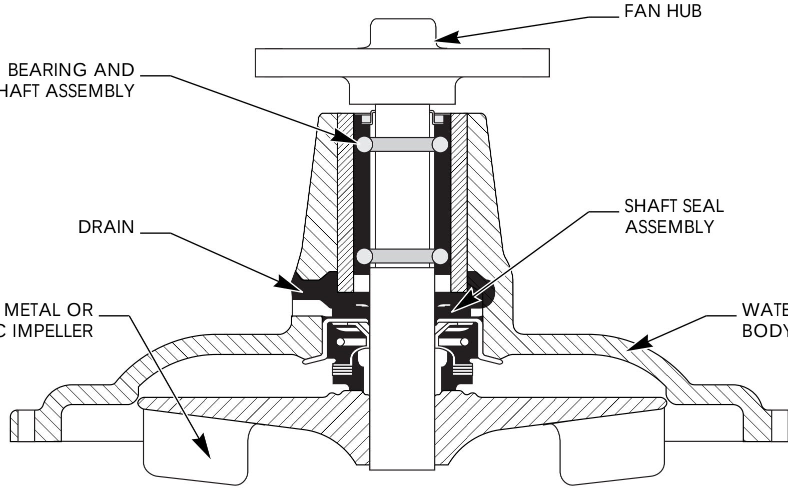


Figure 3-3

This cutaway drawing shows the main components of a water pump. Vane or impeller type pumps work best at high speed. Keep in mind that the speed of the pump is in proportion to engine RPM.

Heater Components and Controls

The basic heater system components discussed in this section are:

1. Heater Core
2. Heater System Ducts
3. Blower or Fan and Motor Assembly
4. Hoses and Fittings
5. Controls

1. Heater Core

Most heater cores are of tube and fin construction, with the inlet and outlet on one end of the core. Hoses connect the core to the engine and are held securely by hose clamps. Figure 3-4 illustrates a heater core. They come in many sizes and shapes to meet cab space and heat energy transfer requirements.

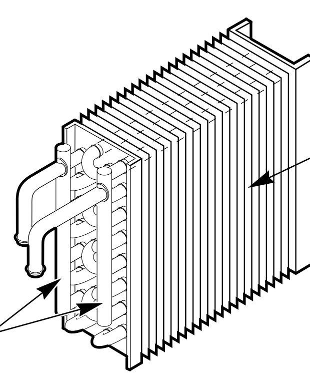


Figure 3-4

In the heater core heat energy moves from the hot engine coolant to the air in the truck cab. Cores come in all sizes and shapes to meet heat transfer needs.

A large capacity heater core has more tubes and more fin area so that more coolant can circulate through the tubes and more air moves through the fins. The result is more heat energy transfer to the air in the cab.

2. Heater System Ducts

Ducts direct and control air as it circulates through the heating system. The heater core housing is usually part of the duct system as is the blower or fan assembly. Air outlet duct openings are usually located close to the floor. The outlets are positioned to direct warm air to the feet and body of the occupants.

All heater/defroster systems pick up some outside air and mix it with cab air. They often have doors inside the duct system to regulate, mix or restrict air flow as part of the heater control system. Many heater systems use 100% outside air. Only auxiliary heaters use 100% cab air. Figure 3-5 illustrates typical heater system ducts with heater components. The arrows indicate the air flow pattern through the duct system. This view of a typical heater system does not include heater hoses, clamps, a water valve or controls.

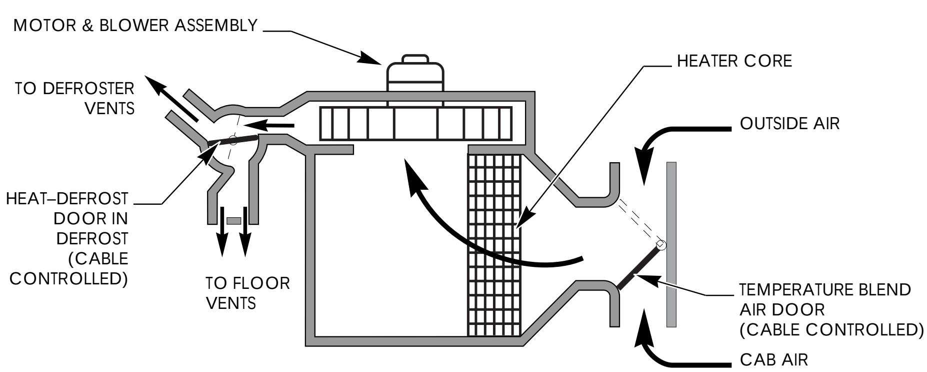


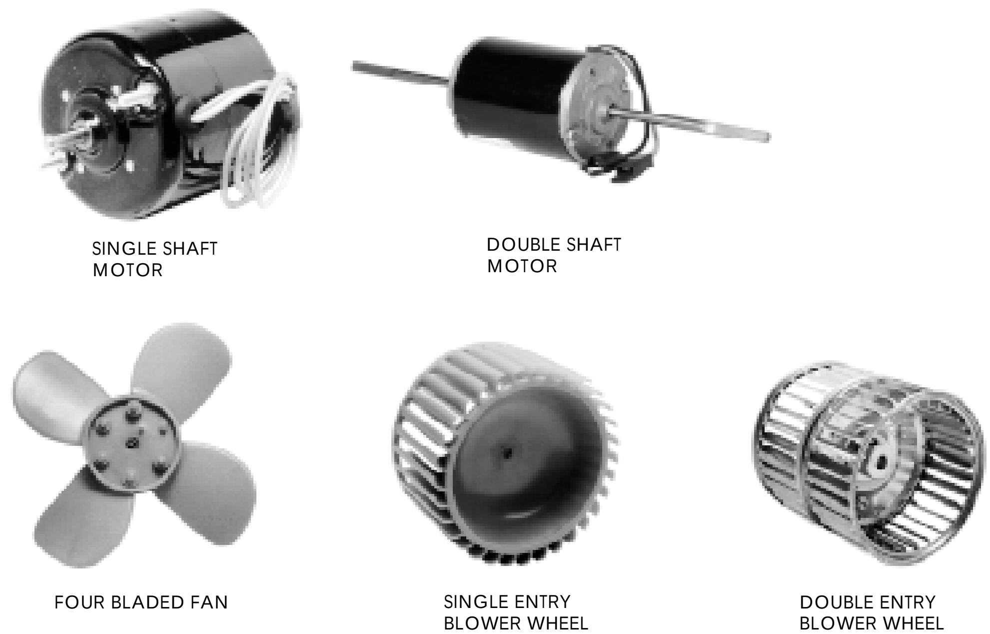
Figure 3-5

The drawing illustrates the relative position of the heater core, a (pull through) motor and blower assembly, and two doors inside the duct system. These doors control air mixing at the inlet side of the system and direct the air to the cab and defroster vents.

3. Blower or Fan and Motor Assembly

Air movement in a heater system depends on the blower or fan. The operator selects the motor speed to control the amount of air circulated through the system. Motors have one to four speeds, depending on heater design. Both single and double entry blower wheels are used. Figure 3-6 shows and describes typical motors, blower wheels, and a fan.

Figure 3-6
These illustrations show a single shaft motor, double shaft motor, double and single entry blower wheels and a four-bladed fan.



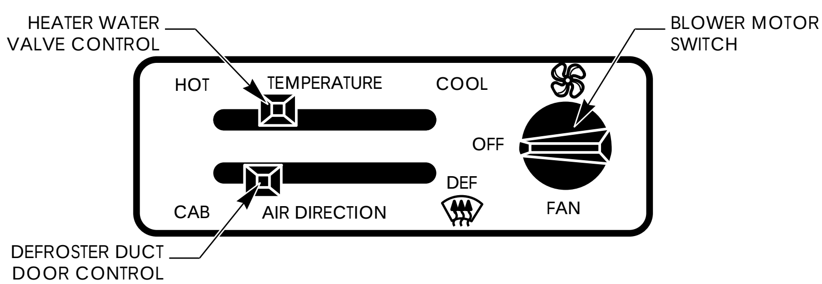
4. Hoses and Fittings

Heater hoses are usually 5/8", but may be 3/4" or 1" sizes. The heater inlet hose may be smaller or the same size as the heater outlet hose. Hoses are usually held in place by clamps. Some water valves shunt excess flow or pressure back to the coolant return hose, assuring full flow of coolant and relieving pressure on the valve.

5. Controls

The controls allow the operator to turn the heater on and off and regulate the direction and quantity of warm air flow. Figure 3-7 shows a typical heater control panel.

Figure 3-7
This heater control panel includes water valve, defroster duct, and blower motor controls.



When you turn the system on, the water valve opens to allow hot engine coolant to flow through the heater core. The blower motor circulates cab air through the heater core to warm the air. Water valves may be cable or air operated. Figure 3-8 illustrates both types.

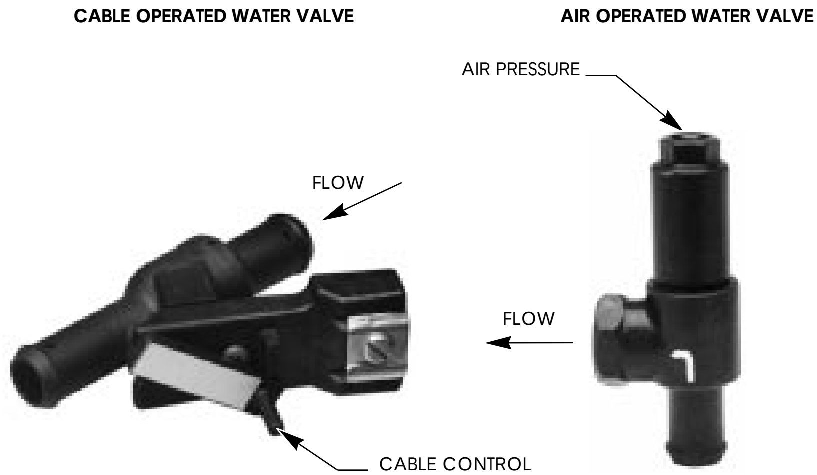


Figure 3-8

This illustration shows air and cable controlled water valves.

When a separate control panel is installed in the bunk area of a cab, there may be one type of control for the cab and another type for the sleeper. The bunk control is often a thermostat, cycling the fan on and off to maintain a constant temperature. Motor switches usually have one to three speed positions plus off.

In a typical heater system, other controls you may encounter position the doors inside the ducts to direct air flow. The defroster control is the main one you will find in basic heater systems. This is usually a cable controlled door that diverts warm air to the windshield or floor.

In HVAC systems the number of doors in the system and their function will vary depending on system design. Doors operate electrically, manually, or automatically, by cable, vacuum, compressed air or by some combination of these controls. In certain HVAC systems, the defrost mode activates the air conditioning system. The air conditioner will dry the heated air flowing to clear the windshield. This is commonly referred to as a “defrost interlock.”

Chapter Review

- In review, the heat energy for heating cab air comes from the hot engine coolant. The coolant is a combination of water and anti-freeze (ethylene glycol). The engine water pump circulates coolant. The thermostat directs the flow of coolant in the engine and to the radiator. The radiator pressure cap allows the cooling system to operate under a preset amount of pressure. Each pound of pressure increases the boiling point of the coolant by three degrees Fahrenheit. The boiling point drops by two degrees Fahrenheit for every 1000 feet of truck operating elevation.
- Heater systems are designed to transfer heat energy from the engine coolant to the air in the cab. A water valve controls coolant flow to the heater core. A fan or blower forces cab air through the fins of the heater core and heat from the coolant is transferred to the air. The heater duct system and air vents direct air movement in the cab.

- There are various methods for controlling air temperature and movement in a heater or HVAC system. In a simple system there is usually an on-off switch for the fan or blower motor. Most have three speeds plus “off.” The water valve may be cable controlled, as is the defroster door. More complex systems may have air pressure switches and air controls, vacuum controls, electronic controls, and various doors to control air flow direction.
- In heater systems air outlet temperature is controlled by one of three methods:

  1. The water valve which varies the amount of coolant passing through the heater core.

  2. A blend air door where cool air is mixed with heated air to obtain the desired temperature.

  3. Electronic controls, which we will cover in Chapter 5 of this manual.
- Full fresh air system designs use 100% fresh air in all but “off” and “maximum” air conditioning control settings. These systems offer advantages you should be aware of. Fresh air increases air pressure in the cab, thus any openings leak outward. This eliminates cold spots and provides a more uniform cab temperature. Air moving out of the cab openings tends to act as a sound barrier and reduce cab noise levels. The fresh air leaking out of the cab also provides a continuous change in the cab air and purges smoke, other air contaminants and any excess moisture.
- Some systems activate the air conditioner in the defrost mode to remove moisture from the heated air. This ensures quick defogging of the windows.

Chapter 4

Air Conditioner Components

Click on any of these subject headings to go directly to the page

Refrigerant

The refrigerants we use in AC systems are commonly referred to as R-12 (Freon 12) or R-134a (HFC-134a). They have no color and only a slight odor. They are non-toxic, non-corrosive and non-flammable chemicals in the form of liquefied gas. Because the boiling point of a refrigerant is far below 0 degrees Fahrenheit, it is sold in sealed metal containers so it won't evaporate.

WARNING Although refrigerants are safe to use, they can be dangerous to you and others if you do not use common sense when you work with them. AC systems operate under pressures much greater than the truck engine cooling system. The containers refrigerants are sold in are also under pressure. At 77 degrees Fahrenheit outside temperature, the pressure inside the refrigerant container is 80 PSI. When released into the air, a refrigerant boils away and becomes a gas. It's temperature drops ***INSTANTLY***. Please be sure to read about safety and safe handling of refrigerants in *Chapter 6*. Improper use can cause frostbite and eye damage. Breathing refrigerant gas can result in respiratory problems, especially for people with cardiovascular disease.

R-134a (HFC-134a) is gaining favor as the “environmentally friendly” substitute for R-12 in mobile HVAC systems. Properly designed R-134a systems will equal or surpass the performance of R-12 systems, without danger to the earth’s ozone layer. As the production of R-12 and other CFC chemicals ceases during the mid-1990’s, more emphasis will be placed on the development of R-134a systems and the recovery and recycling of R-12 in existing equipment.

Refrigerants have the ability to absorb and move a lot of heat energy from inside a truck cab to the outside. This is because the refrigerant in the system is controlled to change state at just the right temperature and pressure. Note in Figure 4-1 that a refrigerant changes state in the condenser and the evaporator.

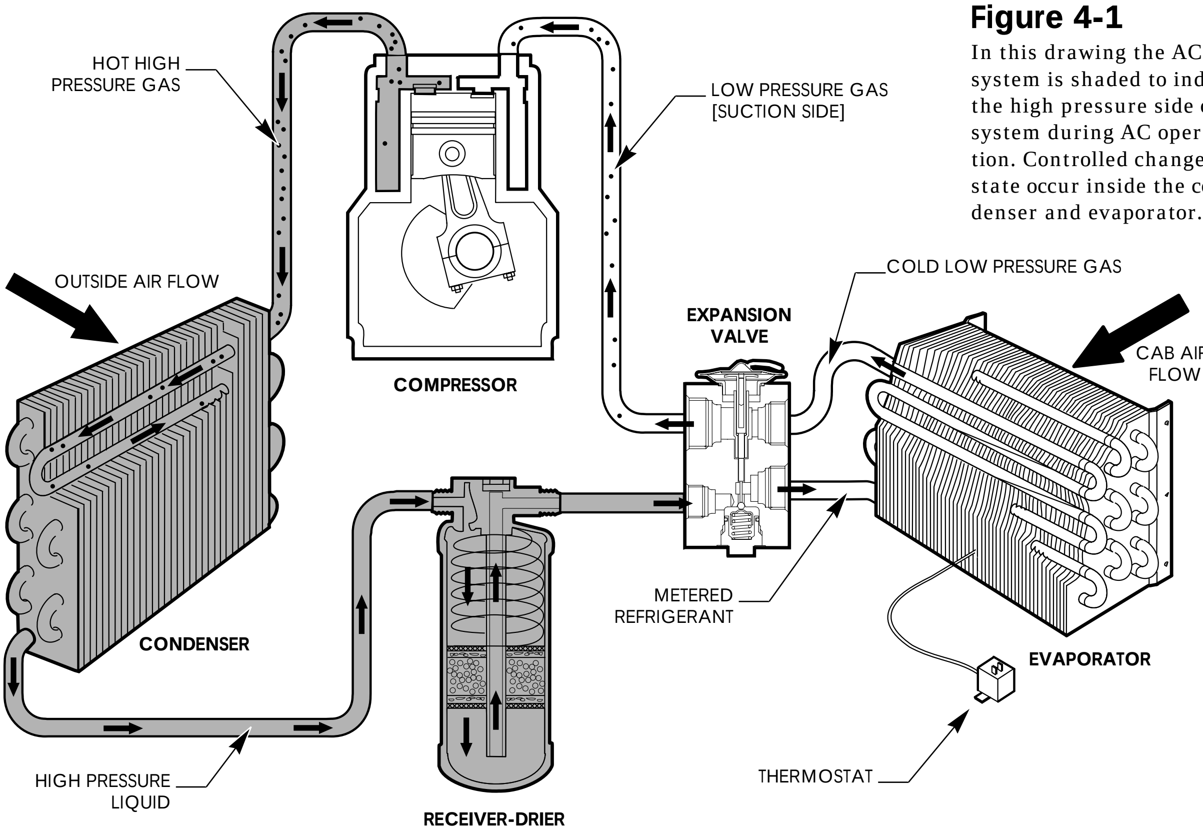


Figure 4-1

In this drawing the AC system is shaded to indicate the high pressure side of the system during AC operation. Controlled changes of state occur inside the condenser and evaporator.

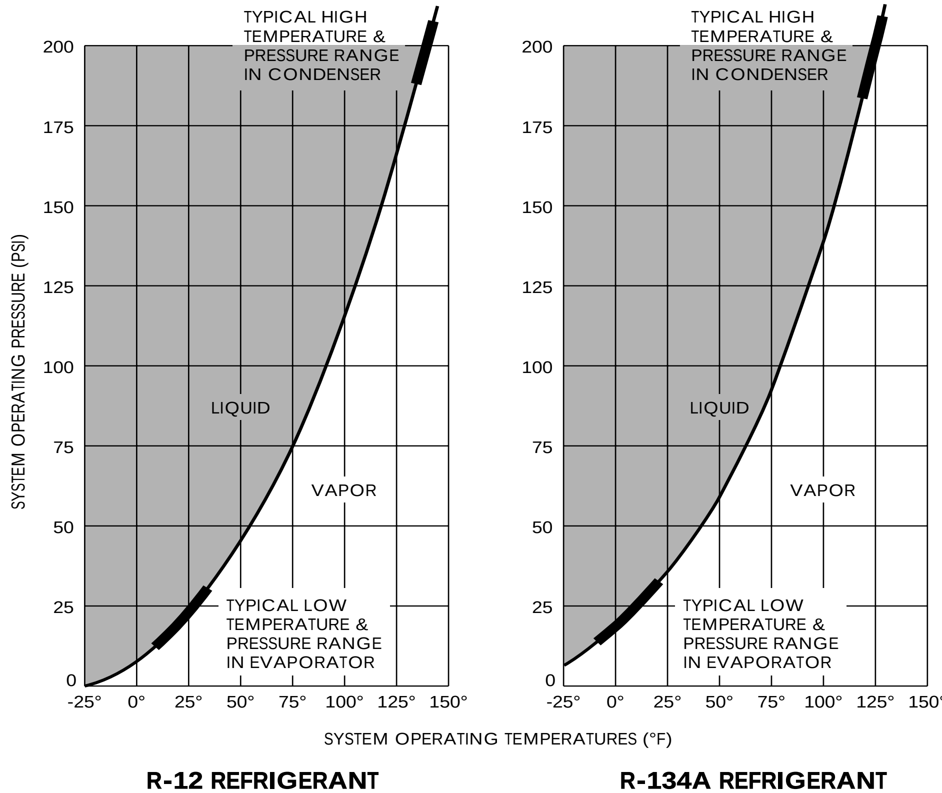
Vehicle operating conditions such as engine RPM and air temperature influence actual AC system operating temperature and pressure. These factors, along with the relative humidity, influence operator comfort (how efficiently the system moves heat energy from the cab to outside air).

When a refrigerant changes from a high pressure liquid to a low pressure gas in the evaporator, the refrigerant is much cooler than the air in the truck cab. Nature's law takes effect, (remember how heat energy always moves from a warm to a cooler environment) and the heat energy in the cab air moves into the refrigerant in the evaporator coil. The refrigerant gets warmer and the cab air colder. Figure 4-2 shows the refrigerant “change of state” in graphic form as that change is related to pressure and temperature. The curved line indicates a typical pressure/temperature range inside the evaporator and condenser.

When refrigerant enters the condenser (from the compressor) as a high temperature high pressure gas, it is much hotter than the outside air. Again, natures law takes effect and heat energy in the refrigerant moves into the air as the air passes through the condenser fins.

Figure 4-2

This graph shows the pressure/temperature relationship of R-12 and R-134a inside the AC system. Refrigerant is a liquid on the left (shaded) side of the curved line. On the right side it is a vapor or gas.



WARNING	
	As controlled by federal law and in agreement with other countries, the production of R-12 is being phased out. Air conditioner systems with R-134a are appearing in many vehicles. These two refrigerants must not be mixed. This means that different equipment must be used in the handling of each refrigerant. The Society of Automotive Engineers (SAE) has created certain Standards or Recommended Practices for handling refrigerants. For example, different service fittings are specified for R-12 and R-134a. Combining R-12 and R-134a can result in poor cooling performance, higher operating pressures and inadequate lubricant circulation.

Lubricants

Lubricants, like other system components, are developed for use with specific refrigerants. Mineral oil works very well with R-12 but becomes chemically unstable with R-134a.

Polyalkylene glycols, called PAGs, are being considered by many for use with R-134a. In addition, a family of ester based lubricants are being given serious consideration.

The lubricant is in the system to protect the compressor from wear and failure. With R-134a the compressor manufacturer specifies the lubricant best suited to its product. On new R-134a systems labeling should identify the type and amount of lubricant.

All PAG-based lubricants are not necessarily the same. Different compressor manufacturers use different additives. Unlike the mineral oil lubricant for R-12, you may need to keep several different lubricants on hand for use with R-134a.

In retrofit systems use that lubricant recommended by the compressor manufacturer.

Lubricants that come out of an air conditioning system should never be reused. Contaminants and moisture are probably contained in such material.

Compressors

When a compressor is engaged and driven by the engine through the clutch pulley, the compressor functions as a pump to move refrigerant and refrigeration oil around the AC system. The compressor pistons move back and forth within their cylinders as the compressor shaft revolves. A special lubricating oil is used for each AC compressor. This oil, called refrigeration oil, is formulated to be moisture free and compatible with the refrigerant used. It circulates throughout the AC system. The lubricant used with R-12 is not compatible with R-134a.

We generally refer to an AC system as having a suction or low (pressure) side and a discharge or high (pressure) side. The two sides of the system are divided at the compressor, and at the expansion valve (refrigerant metering device) located at the inlet to the evaporator.

The compressor pulls refrigerant gas from the evaporator, through the low pressure suction hose, the inlet service valve and one way reed valves, and into the compressor. During compression strokes, refrigerant gas is forced out of the compressor through more one way reed valves, an outlet service valve and a high pressure discharge hose to the condenser. The pressure from compressor action moves the refrigerant through the condenser, receiver-drier and connecting hoses to the expansion valve. Figure 4-3 shows typical compressor function in the AC system. Note the parts of the system under high and low pressure.

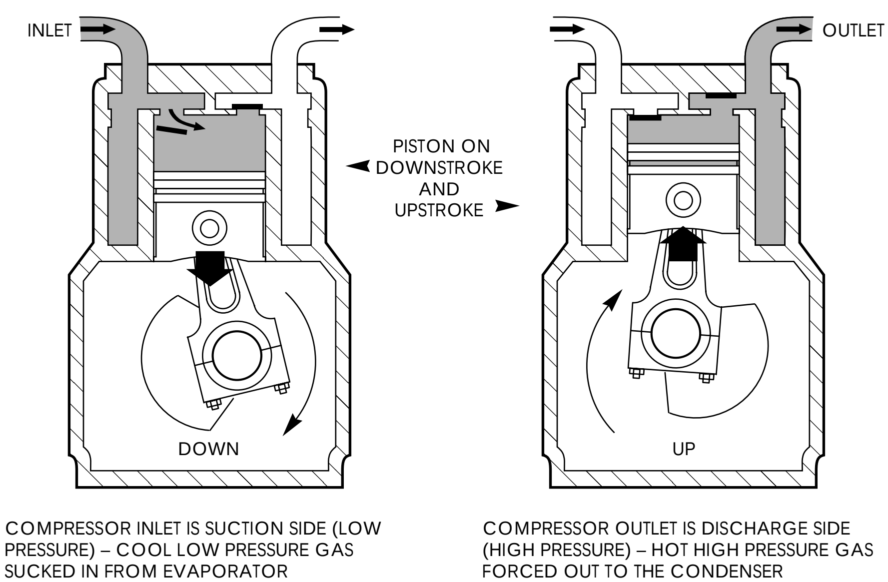


Figure 4-3

In these drawings of a two-cylinder compressor the suction or low pressure side and discharge or high pressure side are noted in a cutaway view.

We deliver power to the compressor through the clutch pulley. The pulley is driven by a V-belt connected to another pulley powered by the truck engine. The location of the compressor relates to the truck design and options, available space under the hood, and the AC system components selected.

CAUTION Heavy duty vehicles are subject to severe extended use and much more vibration and road shock than passenger cars. For this reason secure compressor mounting, accurate pulley alignment and proper belt tension are very important. The compressor mounting bracket is adjustable to allow for proper belt tension.

Pulley alignment and belt tension are critical for efficient compressor operation and good belt life. To tension the V-belt properly, the compressor or it's mounting bracket must be adjustable and securely bolted in position when attached to the engine.

The proper type and amount of lubrication is critical to achieving good compressor life.

The five types of compressors you are likely to encounter in your work are:

1. Two-Cylinder Compressor
2. Four-Cylinder Compressor
3. Five-Cylinder Compressor
4. Six-Cylinder Compressor
5. Wankel Compressor

Each is identified in the photos in Figure 4-4. They are different in design and construction, but all do the same job.

Figure 4-4
The compressor designs shown here all function to move refrigerant and refrigeration oil around inside an AC system. The two, four, five, several six cylinder, and the Wankel compressors are illustrated.

1. Two-Cylinder Compressor

Many two-cylinder compressors are in use today. The Tecumseh has a cast iron body and the York or CCI (Climate Control Inc.) is made of cast aluminum. Both use reed valves mounted in a valve plate between the top of the cylinders and the cylinder head. These in-line compressors may be mounted horizontally, vertically or any angle in between. A pressure differential of low pressure at the intake and high crankcase pressure—along with centrifugal force from the rotating crankshaft—create lubrication pressure for oil circulation. The service fittings for charging or evacuating the AC system are attached to the cylinder head of these compressors.

2. Four-Cylinder Compressor

Four-cylinder radial compressors are produced by Tecumseh and Harrison (GM). The cylinders are arranged inside a round housing in such a way that they radiate from the center like the spokes of a wheel. The pistons are moved in and out within the cylinders by a scotch yoke. A scotch yoke is like a figure eight-shaped cam. The yoke pushes two opposite pistons out to the top of their stroke and pulls the other two in to the bottom of theirs. Each of the cylinders has it's own reed valve plate. The movement of the pistons circulates the refrigerant oil.

3. Five-Cylinder Compressor

The five-cylinder axial compressors made by Sanden and Zexel have five cylinder bores, each fitted with a piston. The pistons are moved back and forth by a rod that is attached to a rotating cam rotor by a ball and socket joint. A reed valve plate mounts between the top of the cylinders and the cylinder head. An inlet and a discharge port are mounted on the cylinder head. The pressure differential between the inlet pressure and the pressure inside the crankcase forces lubricating oil to all of the moving parts in the system.

Note: Seven cylinder compressors will be found on many R-134a applications.

4. Six-Cylinder Compressor

Six-cylinder axial compressors are made and marketed by Zexel, GM (Harrison Division), Ford, Chrysler and Nippondenso. All have three cylinder bores, each fitted with double-acting pistons. The pistons have a head on both ends. As they move back and forth inside the cylinder bores, they cause each bore to act as two separate cylinders. The pistons are moved by a swash plate that is mounted on the compressor shaft. These compressors have two reed valve plates, one at the front and one at the rear. Internal passages join the six cylinders so that refrigerant can flow into and out of all cylinders through the one high and one low side service fitting mounted on the rear of the compressor.

The Zexel compressor has design improvements for easy seal replacement. The General Motors (Harrison) DA-6 is a downsized, lightweight version of earlier GM A-6 six cylinder axial compressors. The DA-6 is easy to service or repair, and has all metric dimensions. It looks different than the old A-6 but works the same way internally. Components have smaller dimensions so parts are not interchangeable with the A-6.

5. Wankel Compressor

The Wankel Rotary compressor, has a figure eight-shaped cavity in the compressor center housing. A triangular rotor is driven by gears from the compressor drive shaft. As the rotor turns, a low pressure (suction) is formed at the suction ports and a high pressure is built up at the discharge ports. The suction and discharge ports are located on the compressor end plate, along with the two service ports. There is no suction valve, only a discharge valve.

Compressor Output (Efficiency)

Engine speed has an effect on the output of all compressors. The two charts in Figure 4-5 show typical compressor output variations. The column of numbers on the left of each chart represent BTU's per hour (x1000) based on the compressor speeds (RPM) shown across the bottom. As you can see, the faster the engine turns the compressor shaft, the greater the output. Note how rapidly output is increased by operating speed of the compressor, and the effect suction pressure (operating conditions) can have on compressor output. Actual operating conditions will affect these performance curves.

Note: Larger capacity compressors like the Climate Control Inc. 210 and Sanden model 510, are frequently specified for heavy duty vehicle applications. Larger capacity compressors are very important when a separate bunk AC unit is part of the system.

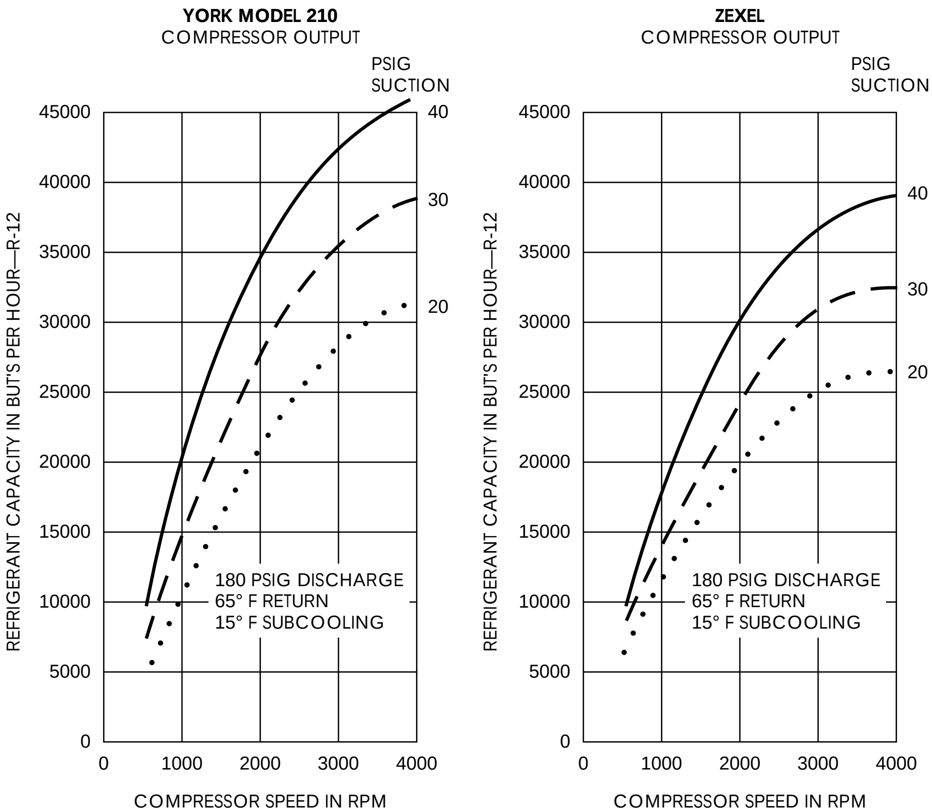


Figure 4-5

Each chart plots compressor output curves at three suction pressures or PSIG (pounds per square inch gauge). The three pressures represent variations in operating conditions for these two compressors.

Clutch

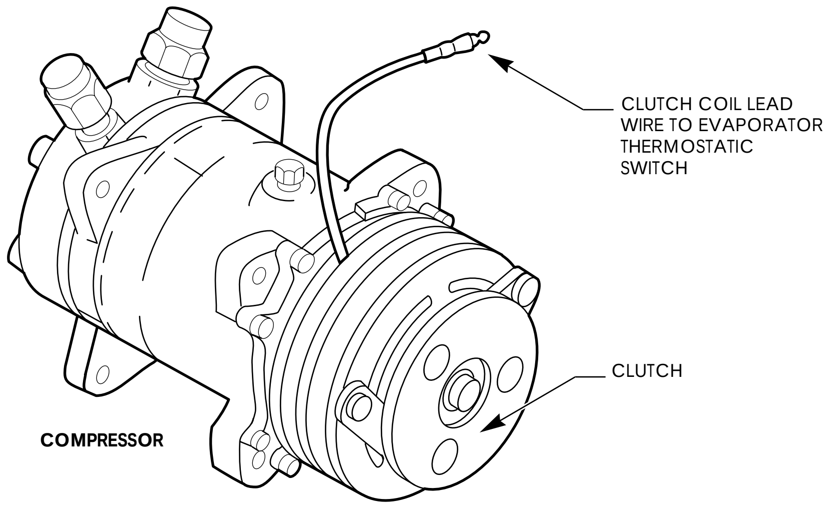
The clutch is driven by the truck engine through a V-belt running in a grooved clutch pulley. The clutch pulley rides on ball bearings and can turn without driving the compressor shaft. Heavy duty clutches have double row ball bearings. An electromagnetic coil is mounted inside the pulley housing and bolted to the compressor body. The clutch drive plate is bolted to the compressor shaft. There is a small amount of clearance between the plate, pulley and coil.

When the AC system thermostat control in the evaporator calls for cooling, current flows through the coil inside the pulley. This sets up a magnetic field between the drive plate and the pulley. The magnetic field locks the pulley to the drive plate, causing the pulley to turn the compressor shaft. When the clutch is not engaged the pulley spins free without turning the compressor.

Electrical connection to the clutch coil is made through lead and ground wires. Figure 4-6 illustrates the clutch mounted on a compressor.

Figure 4-6

A clutch is shown in this illustration. Typically, a thermostat in the evaporator acts as a switch and directs electrical current to the clutch coil. When the coil is energized the drive pulley turns the compressor shaft.



Note: In some systems (primarily GM systems) the clutch remains engaged to drive the compressor continuously during normal operation of the air conditioner. System pressure and refrigerant flow are controlled using suction throttling or POA valves at the outlet of the evaporator.

Condensers

Condensers transfer heat energy to the outside air. Condensers may be mounted on the roof, or behind the grill on the front of the radiator, or may replace the grill. There are many shapes and sizes to accommodate AC system design requirements. They include:

1. Radiator Mounted
   a. Serpentine
   b. Parallel Flow
   c. Tube & Fin
2. Remote Mounted

Radiator-mounted condenser construction, currently in use, is as follows:

a. Tube and fin construction is characterized by the use of round tubes inserted through fin material and then expanded. Hairpin tubes are used to complete the circuit. This is the strongest type of construction.

b. Serpentine construction uses single, flat tubing containing multiple passages that snake from the top to the bottom of the core. Fins are either the Skyve-type or brazed-ribbon. Serpentine condensers are 3/4 to 2 inches thick and exhibit high heat rejection in a compact size. The pressure drop through the core is most often greater when compared to tube and fin construction.

c. Parallel-flow condensers are highly efficient, using brazed-ribbon fins. This is the most efficient type of construction, but is not as strong as either tube and fin or serpentine. There is also a greater pressure drop through the core than the tube and fin style.

Refrigerant flows through the condenser tubing from top to bottom. The fittings are located for convenience of assembly. As hot refrigerant gas from the compressor moves through the condenser tubing, it gives up heat energy to the outside air stream. The refrigerant gas becomes cooler and at the right temperature and pressure will “change state” in the condenser and become a liquid. This change usually takes place in the bottom third of the condenser.

Condenser function requires the movement of a large amount of air between the condenser fins. The air passing through the fins absorbs BTU’s of heat energy from the hot, high pressure refrigerant gas inside the condenser. Engine radiator or auxiliary fans must work properly and the condenser fins must be kept clear of debris or obstructions for efficient condenser function. Figure 4-7 shows several types of condensers.

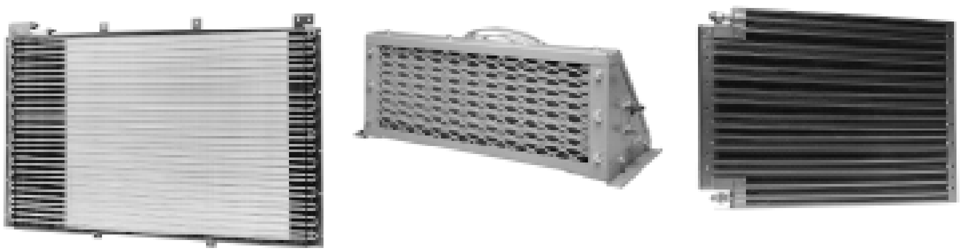


Figure 4-7

These condenser types are explained in the illustrations. The typical behind the grill condenser, a remote mounted unit and a Grilldenser.

Note: When refrigerant gas gives up heat to the outside air and becomes a liquid inside the condenser—**it is still hot**. Review the graph (Figure 4-2) for a moment and note how hot the condenser temperature can be when the refrigerant gas changes to a liquid inside the condenser.

Most condensers are mounted in front of the radiator and attached to radiator supports or the hood assembly. This location is the least costly for several reasons: the engine cooling fan eliminates the need for a separate condenser motor/fan assembly; the refrigerant hose to and from the condenser can be shorter; and the condenser is better protected from the weather.

A Grilldenser is a condenser design that takes the place of a decorative non-functional grill in front of the radiator.

Remote mounted condensers (such as roof mounts) are normally used when there is no room for front mounting. Other reasons for remote mounted condensers are:

- A lack of room between the radiator and grill
- Critical engine cooling requirements
- Use of a radiator mounted air-to-air intercooler
- Insufficient airflow on off-highway equipment, pick-up or delivery vehicles

Note: Intercoolers, are also called aftercoolers or chassis-mounted charge-air coolers. These devices may be installed on the engine or in front of the radiator on some heavy duty vehicles. They are designed to achieve improved fuel economy and performance, and lower emissions by reducing air temperature at the intake manifold. The cooler, denser air boosts horsepower, efficiency and engine durability. For these reasons, intercooler installation is on the increase on heavy duty trucks.

In some intercooler applications, the condenser used for AC may be mounted in front of the radiator and below the intercooler. Figure 11-9 in *Chapter 11* shows this condenser location.

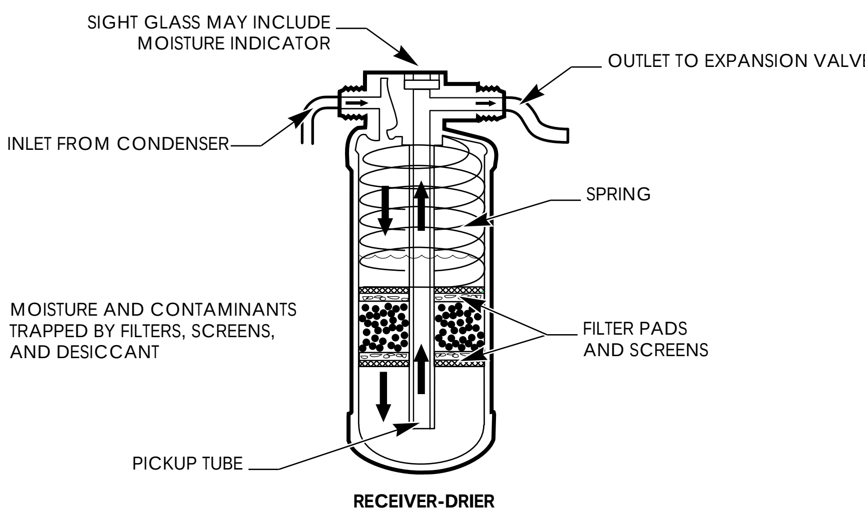
Receiver–Drier

The receiver-drier functions as a drier, refrigerant filter and temporary storage tank for refrigerant moving through the AC system. When refrigerant leaves the condenser as a liquid, it flows to the receiver-drier. Figure 4-8 shows a cutaway view of a receiver-drier. Refrigerant enters at the top and flows through a desiccant material and filter before it moves on through a pickup tube near the tank bottom. The most common desiccant is a molecular sieve. This is a porous material, usually in the form of 1/8 inch balls, that attract and hold moisture.

The desiccant commonly used with R-12 is identified as XH-5. It is not compatible with R-134a. Many driers in both new and replacement systems are now using an XH-9 desiccant which is compatible with both R-12 and R-134a. Driers that do not carry a special labeling are probably only good for R-12 usage.

Figure 4-8

This illustration shows the inside of a typical receiver-drier. Note the path of the arrows which indicate the movement of refrigerant. The desiccant, filter(s), and screens trap any water or particles that might accidentally be inside the system.



Note: Moisture (water) or particles can cause system malfunctions and corrosion. They can block the natural flow of refrigerant at the expansion valve. Moisture can change state there and form ice. It may also mix with the other elements inside the system (refrigerant and the oil) to form acid.

Sometimes refrigerant that leaves the condenser is part liquid and part vapor. When this happens the receiver-drier acts as a separator. The liquid refrigerant settles to the bottom of the tank where the pickup tube inlet is located. Receiver-driers vary in size and shape and many have a sight glass to aid in system diagnosis and charging. A sight glass may include a moisture indicator to let you know if the system is contaminated with moisture. There are high capacity units, variations in mounting location, fitting types, and the number and position of filter elements for receiver-driers.

The preferred receiver-drier design for heavy duty vehicle applications is shown in Figure 4-8. Sandwiched between the two metal baffles are a screen, two fiberglass filter pads, and at least ten cubic inches of desiccant. In this design the desiccant is squeezed between the two filter pads. This helps prevent movement of the molecular sieve material as the refrigerant flows through. As a result, there is less chance of desiccant breakdown and loose material reaching and blocking the expansion valve.

AC system design may include single or multi function pressure switches, a pressure relief valve or fuse plug. These are usually mounted on or connected to the receiver-drier.

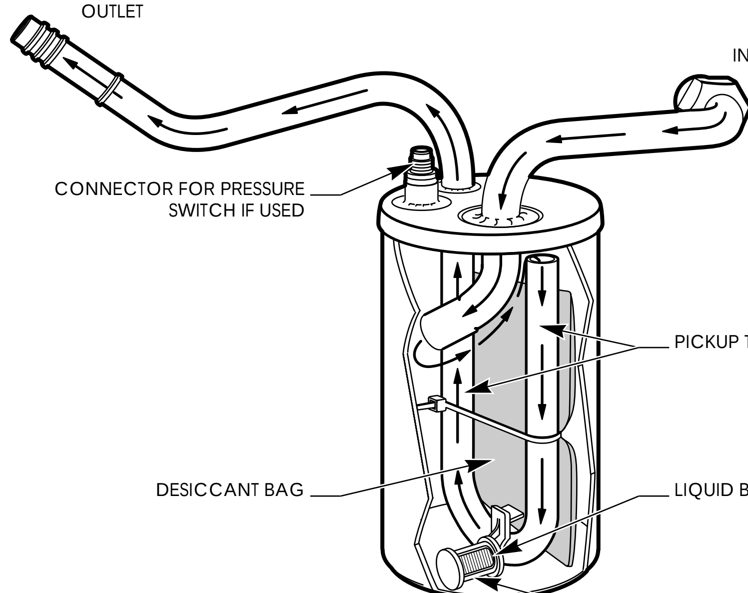
Accumulator

Some AC systems use an accumulator for temporary refrigerant storage instead of the usual receiver-drier. An accumulator is located close to the evaporator outlet and stores excess refrigerant before it moves on to the compressor. When an accumulator is used instead of a receiver-drier, the typical expansion valve is replaced with an expansion tube (also called a fixed orifice tube).

An expansion tube allows refrigerant to flow continuously through the evaporator. At times the refrigerant does not all change to gas and may enter the accumulator as a liquid. The accumulator prevents liquid refrigerant from going to the compressor. The pickup tube opening inside an accumulator is at the top as shown in Figure 4-9.

CAUTION	Serious damage results when liquid is sucked into the compressor.

Figure 4-9
The accumulator has filtering elements like a receiver-drier. Parts are named in this drawing and arrows show the path refrigerant follows as it moves through the accumulator.



Most AC systems with an accumulator have a thermostat to control the clutch. The thermostat is usually positioned to sense refrigerant temperature between the evaporator outlet and the accumulator. Some AC systems with an accumulator have a pressure switch mounted on the accumulator to control the compressor clutch.

Expansion Valves & Other Metering Devices

Various types and designs of refrigerant metering or control valves are used in AC systems. The valves are actuated by temperature and/or pressure. All are designed to control the flow of refrigerant into and/or out of the evaporator or compressor.

In addition to the block type expansion valve shown and described in *Chapter 2*, Figure 2-7, there are other valve designs. The types of expansion valves discussed in this section are:

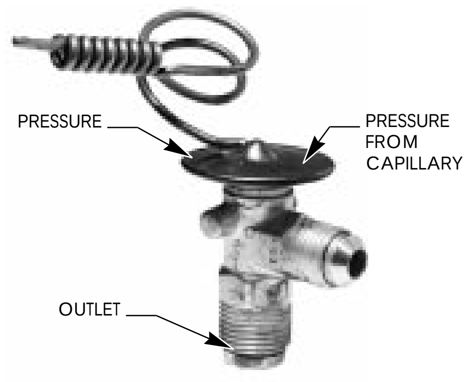
1. Thermostatic Expansion Valves
2. Expansion Tubes

1. Thermostatic Expansion Valves

The traditional internally and externally equalized expansion valves each work the same way. Valve function is controlled by temperature and pressure of the refrigerant gas as it leaves the evaporator on it’s way back to the compressor. A small diameter hollow tube (capillary tube) is attached to the top of the valve diaphragm housing.

The capillary tube contains a small amount of gas or liquid such as refrigerant. The coil or bulb at the end of the tube is clamped to the outlet manifold from the evaporator. The gas in the capillary tube expands and contracts from heat in the outlet tube. It pushes to open the valve orifice.

The valve opens and closes depending on system need for refrigerant at the inlet to the evaporator. Figure 4-10 shows an internally equalized valve.



INTERNALLY EQUALIZED VALVE

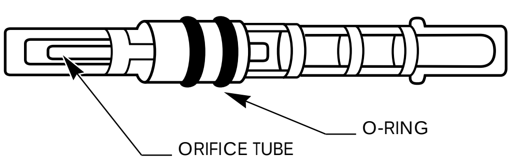
Figure 4-10
The internally equalized TXV is shown. This valve is designed with either temperature sensing coils or bulbs at the end of its capillary tubes.

Note: Insulating material is wrapped around the expansion valve, and coil or bulb where it attaches to the evaporator outlet. This is done to improve heat energy conduction and prevent condensation forming on the valve.

2. Expansion Tubes

Expansion tubes are also called fixed orifice tubes. They are used in some systems, always in combination with an accumulator instead of a receiver-drier. The tubes have no moving parts and are not adjustable. When used, an expansion tube is located inside the inlet tube of the evaporator. It restricts but allows a continuous flow of refrigerant to the evaporator coil.

An expansion tube is shown in Figure 4-11. When an expansion tube is used in place of a valve, liquid refrigerant may pass through the evaporator before it can change to a gas. The accumulator prevents liquid refrigerant from reaching the compressor. When an expansion tube is defective it must be replaced using a special tool.



EXPANSION TUBES FIT INSIDE THE EVAPORATOR INLET FITTING

Figure 4-11
The expansion (fixed orifice) tube is used in place of an expansion valve. There are no moving parts.

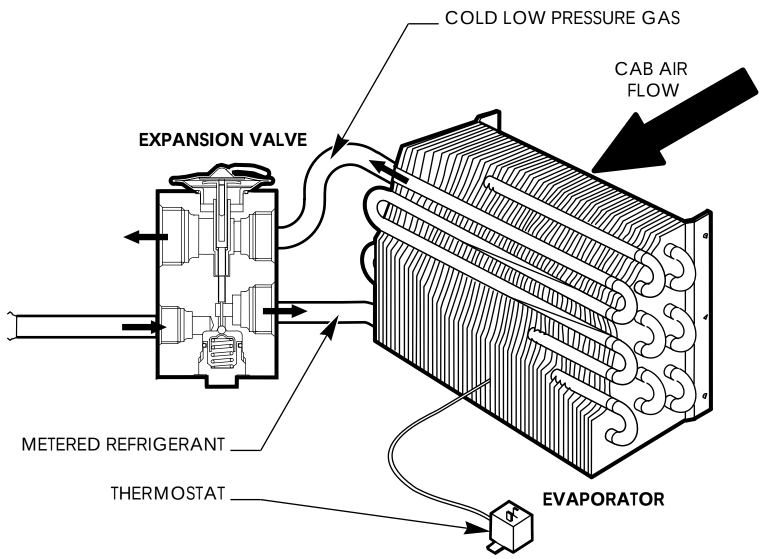
Evaporator Coil

Evaporator coils come in various shapes and sizes. Most are of fin and tube construction. The fins and tubing are designed to transfer heat from the cab air to the cool refrigerant vapor as it moves through the evaporator tubing. The fins are colder than the cab air, so moisture in the air blown across the coil condenses on the fins. The moisture forms into droplets and drains to the bottom of the evaporator housing and out of the cab through a drain tube. Dust or other airborne particles may also be trapped in the condensed moisture droplets. In this way the AC system dehumidifies, filters and cools the air in the cab.

Refrigerant enters the evaporator coil, expands rapidly and changes state (drops in temperature and pressure). The refrigerant absorbs heat energy from the air in the cab and moves through the tubing to exit the evaporator coil. A variety of expansion valve or other refrigerant flow regulating devices (described earlier) are used in an AC system design, at the inlet to and/or the outlet from the evaporator coil. Each is designed to control the flow of refrigerant to provide maximum heat transfer in the evaporator. The drawing, Figure 4-12, is a cutaway view of a typical evaporator coil.

Figure 4-12

The evaporator coil illustrated is mounted inside an enclosure (not shown) designed for efficient air flow between the fins of the evaporator.



Air Conditioner Blower/Fan and Motor Assembly

In HVAC system designs, a blower assembly is positioned to move air through the evaporator coil and heater core. For efficient air movement, the air must be confined within a housing. The blower assembly used in a system may be located for functional or space considerations. Some pull air and others push air through evaporator and/or heater fins.

Fans are used to move air through the fins of the condenser. In underhood applications the engine cooling fan is used. Roof or remote mounted condensers have separate fan/motor assemblies.

Figure 4-13 shows both evaporator blower and condenser fan assemblies in a roof mounted air conditioner. An outer cover directs the flow of outside air through the condenser. The fan blows the air out through an opening in the top of the cover. The blower assembly pulls air from the cab, through the evaporator coil and back into the cab. An inner cover encloses the evaporator and blower assembly to control cab air flow.

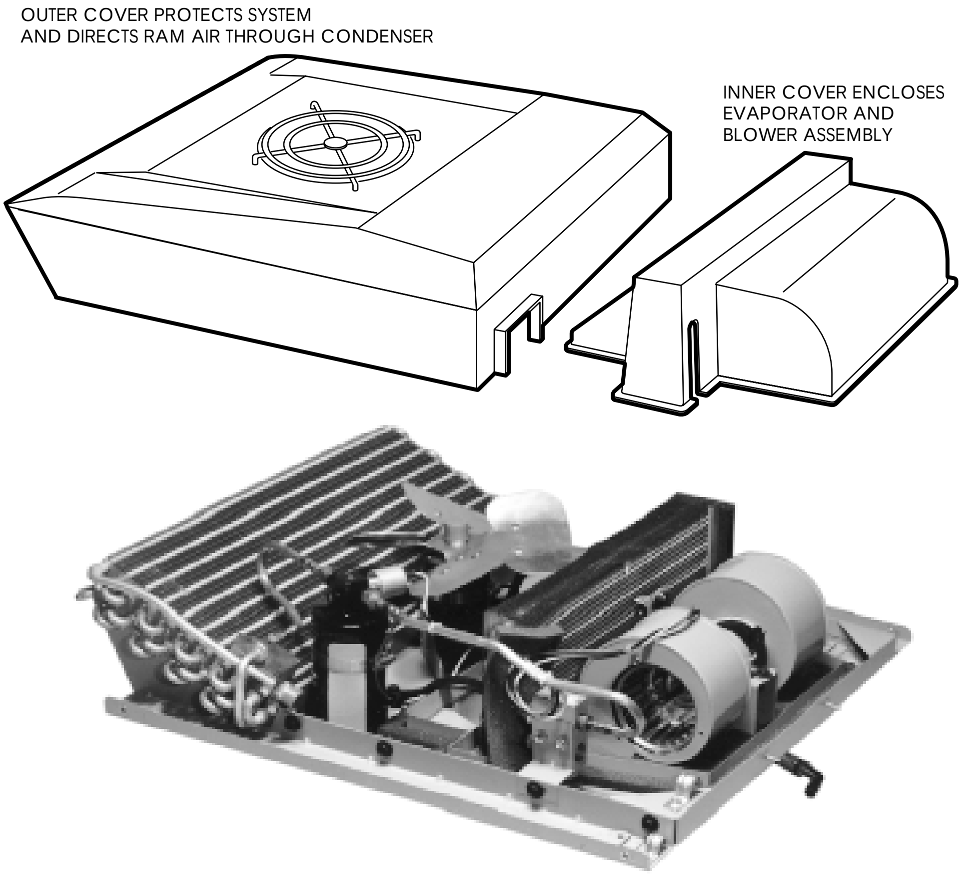


Figure 4-13

In this roof top air conditioning system the fan and blower assemblies pull air through the condenser and evaporator.

Air Conditioner System Ducts

In Figure 4-13 above, outer and inner component covers are shown. When fastened in position, they control air flow direction. AC system ducts come in different shapes and sizes to fit space requirements. The positions of doors and louvers control air movement and flow in the cab. Figure 4-14 shows a combination HVAC blend air duct system. The doors in a duct system could be controlled by cable, vacuum, compressed air, electric, or by a combination of these controls. Some function automatically, while others are controlled by the operator.

Figure 4-14
This HVAC system cutaway drawing shows the various duct doors and the air flow pattern. Most heavy duty HVAC systems have a stacked core arrangement where air passes through both coils.

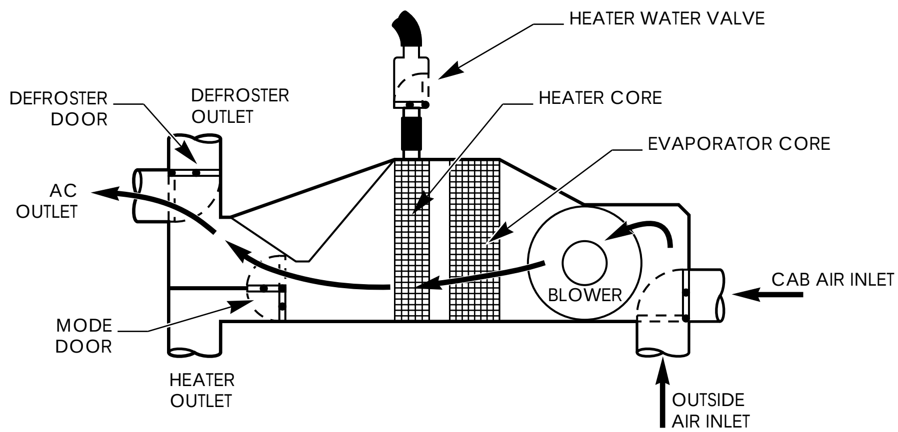
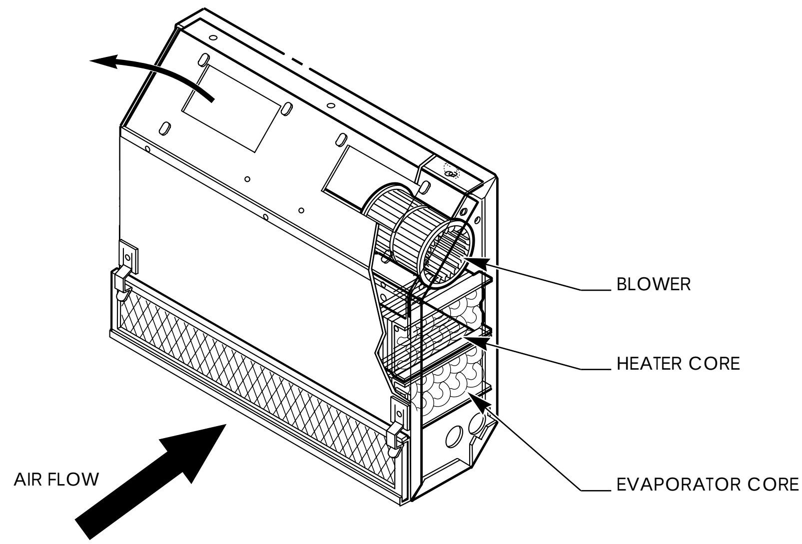


Figure 4-15
This is a cutaway of a standard stacked core arrangement.



Air Conditioner Hoses and Fittings

The refrigerant hoses used in air conditioning systems are much stronger than heater or radiator hoses because of pressure restraints. These are available in single braid, double braid and nylon lined rubber hoses.

Fittings of many types, shapes and sizes may be used depending on the application and location. There are push on, flare, O-ring and quick disconnect fittings. Various adapter, step up, tee block, splicer and special application fittings may be used as connectors during initial installation, service or when a system is modified.

Chapter Review

- The standard refrigerants used in vehicle air conditioning systems are R-12 and R-134a. **Although safe to use, a refrigerant may be dangerous if not handled carefully. At sea level pressure, a refrigerant will boil at a very low temperature.** A refrigerant can be controlled to change it’s state inside the AC system and absorb, move and give up a large amount of heat energy. A refrigerant is cold in the evaporator and hot in the condenser.

- All compressor designs function as pumps to move or circulate refrigerant inside the AC system. Compressors are driven through a clutch pulley and V-belt by the engine. For efficient operation, a compressor must be mounted securely with proper belt tension and alignment. Engine speed and suction pressure have an effect on compressor output. Higher engine RPM means greater output.
- The clutch is used to drive the compressor. In most AC systems a thermostat cycles the clutch on and off, although in some designs the clutch stays on during AC operation.
- Condenser construction allows heat energy transfer to the outside air. Refrigerant changes state in the condenser, from a high pressure and temperature gas to a liquid. It is important to keep the condenser free of dirt and debris for good air flow through the fins and efficient heat transfer. The various condenser designs all function the same way.
- Receiver-driers function as a refrigerant drier, filter and temporary storage tank. The filter and desiccant material trap and hold moisture or other contaminants that may be inside the AC system. The receiver-drier traps any vapor leaving the condenser. Some designs incorporate a sight glass, moisture indicator and/or various other control devices.
- An accumulator may be used in place of the receiver-drier as a temporary storage tank for refrigerant. This device controls the flow of refrigerant to the compressor and also traps contaminants and moisture. Accumulators are used with AC system designs that have an expansion tube. They prevent liquid refrigerant from flowing to the compressor.
- There are a variety of thermostatic expansion valves (TXV's) and other refrigerant flow regulating devices in use today. All control the flow of refrigerant in the AC system to manage the movement of heat energy. There is the block expansion valve, traditional expansion valve, and expansion tube. Some AC system refrigerant flow regulating assemblies combine several components to control refrigerant flow.
- The construction of an evaporator coil is designed to transfer heat energy from the cab air to the refrigerant inside the tube. The evaporator coil also helps to clean and dehumidify the air in the cab. Moisture in the air condenses on the fins of the evaporator coil, then drips off the fins and drains out of the cab. When refrigerant enters the evaporator there is a quick drop in pressure. The refrigerant expands rapidly, changes state and drops in temperature.
- Blower, fan and motor assemblies increase the movement of air for efficient cooling (heat energy transfer). The duct system controls the air flow direction.
- The hoses and fittings used in AC systems connect the various components together. They enclose or contain the refrigerant as it moves around inside the system.

- There is a high and low pressure side in an AC system. The high side begins inside the compressor. High pressure continues through all fittings and hoses that connect the condenser, the receiver-drier, and expansion valve or other refrigerant metering device at the inlet to the evaporator. As refrigerant leaves the expansion valve or other metering device and enters the evaporator tubing, the pressure drops. It remains low in hoses and any components that connect or control the refrigerant as it moves into the suction side of the compressor. AC system components allow refrigerant to change state easily. They control and contain refrigerant as it moves inside the system.

Chapter 5 System Controls

Click on any of these subject headings to go directly to the page

Air Conditioner Controls

The following air conditioner controls are discussed in this section:

1. Active Controls
2. Passive Controls
3. Compressor Clutch Controls
4. Refrigerant Flow Controls
5. Sleeper Unit Controls

System controls accomplish three things. They maintain cab temperature (control the air in the cab, refrigerant and engine coolant), protect system components and related parts from damage or excessive wear, and allow design and operating condition flexibility. This chapter explains control devices in more detail.

Active Controls are used by the driver or a passenger to turn the system on, and adjust air temperature, air flow direction and velocity. The controls are switches, levers, and air louvers or diffusers.

Passive (Automatic) Controls regulate the flow of refrigerant or coolant. These include thermostats and various pressure activated or regulating valves, pressure and temperature switches. Some controls shut down or prevent system operation under certain conditions.

Control Devices are used to open, close, adjust, engage or disengage parts of the system. Examples are air cylinders, air switches, solenoids and other electronic controls. Some system designs take advantage of air pressure and electronics, for more precise control of components and reduced maintenance.

Combination and supplemental control devices can affect system operation. They may prevent, interrupt or support system functions. Examples are ambient temperature switches, Binary™ or Trinary™ (multi-function) switches, radiator fan clutches and radiator shutter systems.

Note: Keep in mind that air conditioning and heater systems are closed (sealed) and function under pressure. Control devices take advantage of system pressure and heat energy. A few control devices are influenced by conditions outside the system.

1. Active Controls

Active control types depend on system design, location and available space. When a heater or AC system has been installed as a separate or supplemental unit (perhaps in the sleeper cab), there is probably more than one control panel location.

The integrated HVAC control panel shown and described as Figure 5-1 is mounted in the dash. With these controls, the AC and heater systems may be turned on, the temperature adjusted, air directed and mixed, and air velocity controlled.

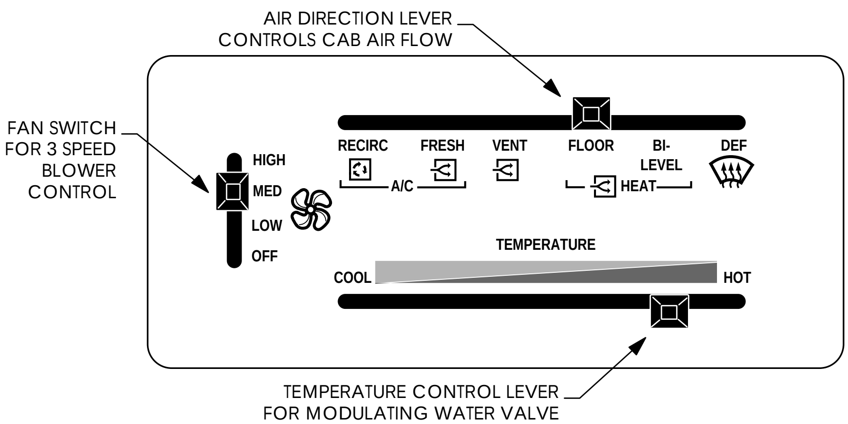


Figure 5-1

HVAC in-cab controls are described in this illustration.

When the air direction lever is in the AC mode, power is directed to the thermostat and from there to the compressor clutch. As the AC unit operates, the thermostat cycles the clutch on and off automatically. Some controls have a separate heat-AC switch for this purpose.

The slide controls could be connected to push-pull cables or an electric or air control module. With air or electric controls and the lever in the RECIRC mode, air within the cab is recirculated through the evaporator. In all other positions, fresh air is brought in from outside the cab. Some control panels have a separate fresh/recirculating air switch or lever.

The fan control knob is connected to a four position switch. There are three “on” positions to control blower speed and regulate air velocity (CFM) in the system.

Note: Blower or fan speed affects air temperature. At lower speeds the cab air moves more slowly through the fins of the evaporator or heater, so more heat energy moves into or out of the cab air than at faster air speeds (CFM). Thus air leaving the vents or louvers will be colder or warmer.

Most air vents or louvers in the cab may be adjusted by hand to moderate and direct air movement. These are in various sizes, shapes and locations in the cab.

The thermostat and expansion valve or refrigerant metering device basic controls because they are necessary in any system. Both function automatically after the system is turned on.

2. Passive Air Conditioner Controls

Most automatic controls function in response to AC system temperature (degrees Fahrenheit) or pressure (PSI) conditions. The thermostat is a good example. It uses temperature to automatically cycle the compressor clutch.

3. Compressor Clutch Control

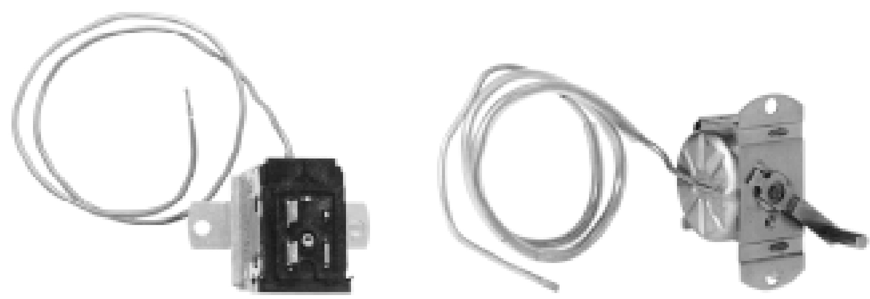
The different types of compressor clutch control are described below.

Thermostatic Control

A thermostat in a basic air conditioning system controls the electrical circuit to the clutch. Most thermostats have a capillary tube that is inserted between the fins of the evaporator coil. The depth of tube insertion and location in the coil are critical to system performance.

Thermostats are either fixed set or adjustable. A fixed set control will operate in the 32 degrees to 38 degrees Fahrenheit range. An adjustable thermostat functions between 32 degrees and 50 degrees Fahrenheit and may be controlled with a knob or push-pull cable. Figure 5-2 shows these types of thermostats.

Figure 5-2
Two thermostats are shown. They are used to cycle the compressor clutch on and off at selected high and low temperatures.



FIXED SETTING THERMOSTAT, PRESET TEMPERATURE

CABLE CONTROLLED THERMOSTAT VARIABLE TEMPERATURE

The thermostats shown have sealed capillary tubes that sense temperature. The capillary tubes contain a small amount of heat sensitive gas or liquid like R-12. System temperature variations raise and lower pressure in the sealed capillary tube. This pressure activates a switch inside the thermostat to open and close the electrical circuit to the clutch. These thermostats may sense temperature in the evaporator coil or at the evaporator outlet.

Another type of user adjustable rotary thermostat has a bimetal heat sensing strip and has been used to control the temperature in sleeper cab AC or HVAC systems. The bimetal strip senses air temperature. When the sleeper box air is too warm (in AC mode), the bimetal thermostat electrical circuit activates a blower motor and opens a solenoid valve. The valve allows refrigerant to flow to a separate evaporator used to cool air circulating in the sleeper compartment. This type of system design is illustrated in *Chapter 11* (Figure 11-7).

Pressure Switch Control

Most of the AC systems that have an expansion tube and accumulator (instead of an expansion valve and receiver-drier) use a thermostat to control clutch operation. However, there are some accumulator systems with a pressure sensing switch instead of a thermostat. The switch opens and closes an electrical circuit to the clutch. Figure 5-3 shows this type of automatic compressor clutch control.

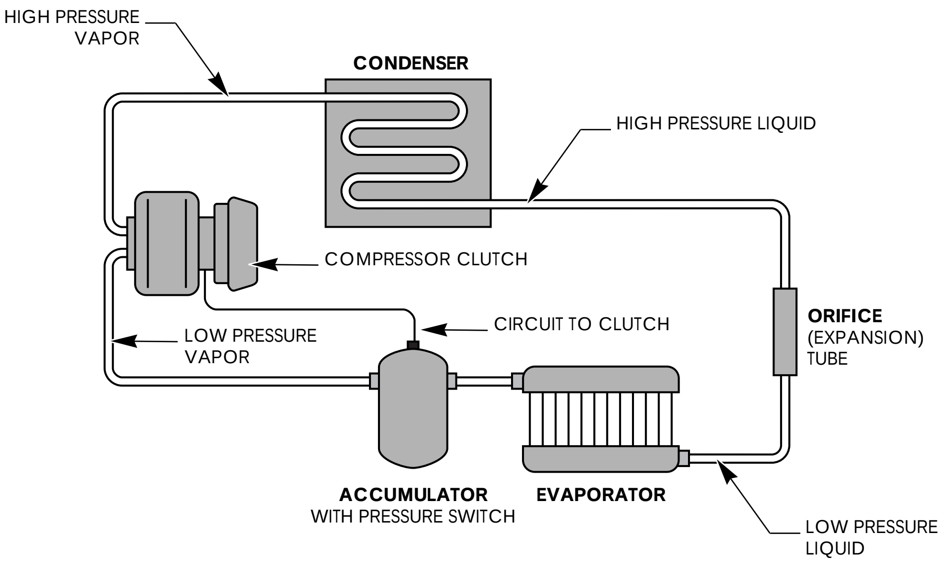


Figure 5-3
The accumulator system schematic uses a pressure sensitive electrical switch to control the compressor clutch. The switch senses refrigerant pressure (PSI) inside the accumulator.

When pressure (PSI) in the accumulator is high, the pressure sensing switch closes an electrical circuit and the clutch is engaged. If the pressure is low, the switch opens the circuit to disengage the clutch.

4. Refrigerant Flow Control

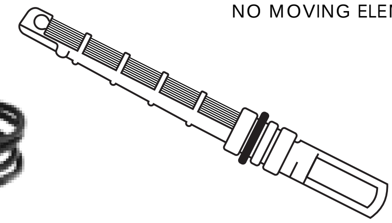
In *Chapter 4* we described devices frequently used to control refrigerant flow into and out of the evaporator. Most are controlled by pressure, temperature or a combination of both inside the system. Some AC systems have two evaporators, one for the cab and the other for the sleeper compartment. A freon solenoid valve may be used to split and direct part of the refrigerant flow to a second evaporator. The solenoid valve is electrically controlled and opens when the sleeper cab AC control is operated. Figure 5-4 illustrates various refrigerant flow control devices and explains what causes them to function.

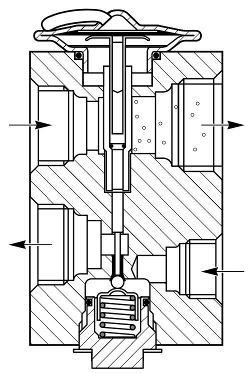
Figure 5-4

This group of illustrations notes how the most frequently used refrigerant metering or flow control devices function.

TYPICAL PRESSURE CONTROLLED TXV (EXTERNALLY EQUALIZED)

EXPANSION TUBE HAS NO MOVING ELEMENT





PRESSURE CONTROLLED BLOCK TYPE TXV

ELECTRICALLY CONTROLLED FREON SOLENOID VALVE

These controls are designed to meter refrigerant flow through the evaporator coil. Thermostat and compressor clutch function are independent of these refrigerant flow control devices.

Note: A thermostat or pressure switch controls the compressor clutch assembly. Automatic refrigerant metering devices sense pressure/temperature in the system and control refrigerant flow through the evaporator. The combination of controls keeps the system balanced so that heat energy can move efficiently by taking advantage of natures laws. When the system is out of balance, refrigerant may move too fast or too slowly. It will not absorb enough heat to cool the cab properly, or may result in too low a temperature in the evaporator. In some cases, the normal condensation collecting on the evaporator fins may freeze instead of draining out of the cab. The frozen condensate will block air flow through the evaporator. No air flow—no cooling.

Many truck and off-road vehicles have control variations, combinations and supplemental controls. We will explain these controls after we describe basic and automatic heater controls.

5. Sleeper Unit Controls

The most familiar type of temperature control is the bi-metallic thermostat. In this type of control, two strips of dissimilar metals are bonded together, such that as the temperature changes, the two metals expand or contract at different rates. These changes cause the strips to bend, making contact and completing or breaking a circuit to control the bunk HVAC unit. The bi-metallic control needs good airflow through the control panel in order to react.

The electronic controls for sleeper units have a sensor (or thermistor) which will detect temperature changes. This sensor is very small and can be unobtrusively mounted on the front of the control panel. This type of control has a far narrower “dead band,” the temperature change needed for the control to react. This allows the sleeper box temperature to be more closely controlled than with a bi-metallic thermostat. The small size of the sensor mounted on the front of the control panel allows the panel to be mounted flush with the walls of the sleeper box.

Heater Controls

The following heater controls are discussed in this section:

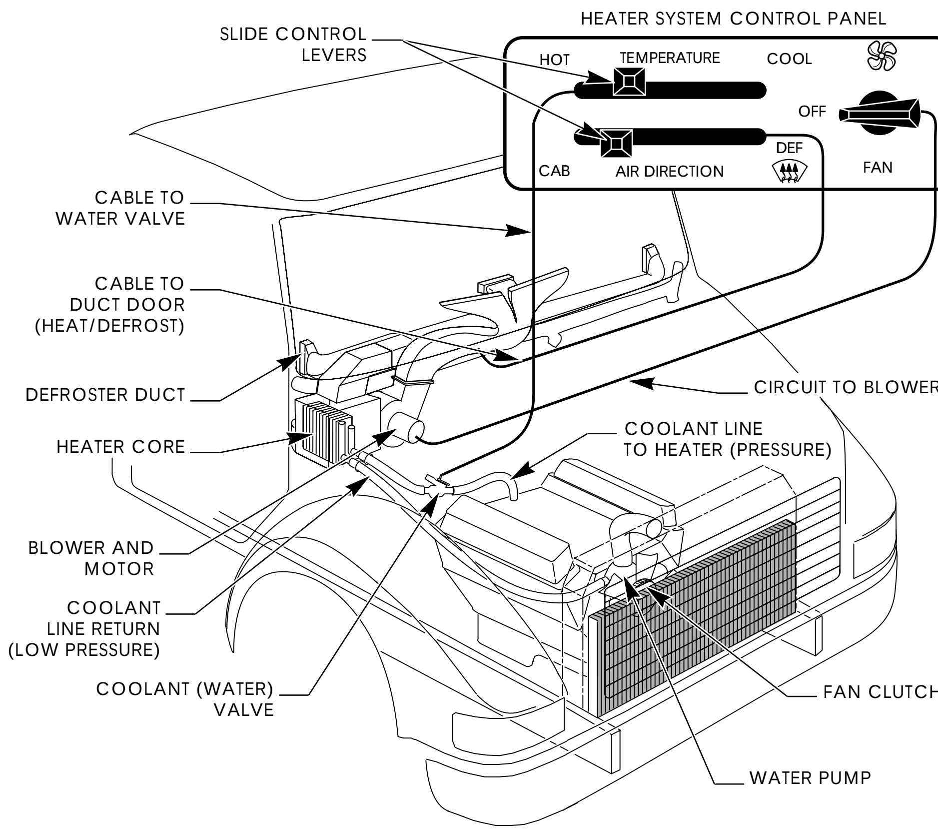
1. Active Heater Controls
2. Vacuum Controls
3. Passive Heater Controls

1. Active Heater Controls

Let’s look at a typical heater control panel. There are a couple of slide bars connected to cables or air lines. The blower (or fan) motor control knob is attached to a four position switch. Figure 5-5 shows the panel connected to system components. System design and component locations will vary from one vehicle to another.

Figure 5-5

Typical heater system controls and locations are shown and described in this drawing.



A water valve is the primary control for a basic heater system. When the valve is open, hot engine coolant flows through the heater core and back to the engine. The driver can adjust the control to modulate coolant flow through the heater core.

In some heater system designs, temperature control is achieved by allowing part of the air moving through the heater duct system to bypass the heater core. The amount of bypass air is controlled by a door. This design is commonly called a blend air system. A water valve is sometimes included in the design and directly linked to the door control.

Another cable operates a door inside the duct system and directs air flow through defroster ducts to the windshield. The knob controlling the blower motor switch may be set to one or more speed positions, or off. This switch controls the air velocity (CFM) through the duct system and heater core.

Note: Air pressure, electric actuators or vacuum may be used in place of cable controls. The air pressure or vacuum do not automatically adjust system function. Manual controls, air switches or other automatic electrical controls regulate vacuum and control air pressure to adjust system function.

2. Vacuum Controls

Heavy trucks with diesel engines do not have a ready source of vacuum. When vacuum components or controls are used, a separate vacuum pump must be driven by the engine.

3. Passive (Automatic) Heater Controls

Various devices are used to control heater operation. These devices are described below:

Water Valves

Some heater systems have an "H" type water valve design. Coolant flows to and from the heater core through separate passages in the valve. Means are provided to block coolant flow to the heater core and bypass or route coolant back to the engine. A pressure valve in the "H" opens when coolant flow to the heater is blocked. Figure 5-6 illustrates the "H" type coolant valve.

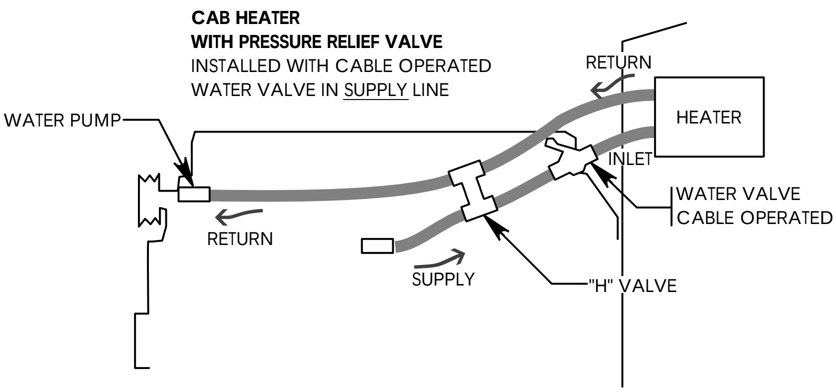


Figure 5-6

This plumbing shows how an "H" type water valve may be used to allow coolant to flow through or to bypass the heater core.

Heater A/C (CTC II™) & Heater (CTC™) Systems

The CTC™ (Constant Temperature Control) system maintains a preselected temperature in the cab. This is accomplished through a controllable circuit board and variable resistor. Changes in the air temperature activate the circuit board, which energizes or deenergizes an air solenoid valve. The solenoid valve controls the air supply to open and close the water valve and pulse hot engine coolant through the heater core. In the AC mode, the thermostat is cycled to hold a constant output temperature. Figure 10-3 shows how the CTC II™ components work together to control heat energy movement into cab air and maintain cab temperature.

HVAC Control Variations

Control variations include one, two or three speed blower/fan motor switches to vary air velocity. Air or electrical toggle switches and rocker switches may be used in system control to replace cable control. Air cylinders open or close duct doors and radiator shutters. Air pressure hoses and fittings have a long service life and are easy to repair. The following controls are discussed in this section:

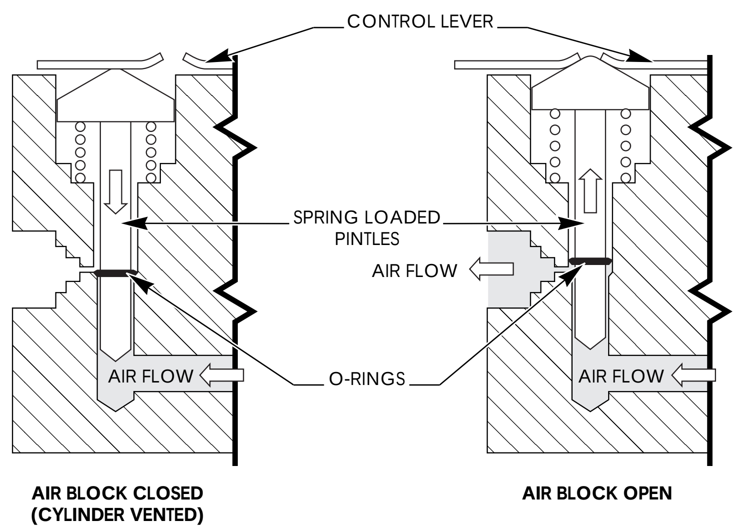
1. Air Controls
2. Electrical Devices and Schematics
3. Combination and Supplemental Controls
4. Fan Clutches, Radiator Shutters, and Override Controls

1. Air Controls

The development of air controls has improved the operation and function of HVAC systems. A basic form of air control may use a single switch and cylinder to operate a duct door. In more complex systems air cylinders are used to control fresh and recirculating air, heat/defrost and air conditioner vents. A pressure switch is often used to control the compressor clutch.

The most common air control system is a modular design. Modular units are simple and compact as illustrated in Figure 5-7. An air block uses a pintle and programmed control lever to control air cylinders.

Figure 5-7
This cutaway view of an air block shows the components and describes their function. The air cylinders are not shown.



In air control systems a Legris push-on fitting has gained popularity with manufacturers. The Legris design speeds air tube installation and provides a positive leak free air seal where tubing is attached.

Some Frigidaire AC systems have a **thermal limiter and superheat switch** combination to protect the compressor when system pressure is too low. A low system pressure can mean there is not enough refrigerant inside the system and/or insufficient refrigerant oil circulation to properly lubricate the compressor. Figure 5-8 illustrates the function of the thermal limiter and superheat switch. When the fuse in the thermal limiter melts, the clutch circuit is broken to stop the compressor. The thermal limiter must be replaced when this happens.

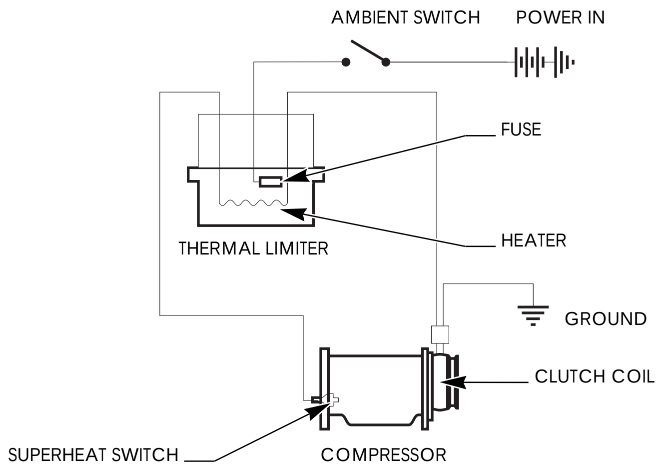


Figure 5-8

This drawing shows a Frigidaire thermal limiter and superheat switch schematic. It works by interrupting the circuit (electrical power) to the clutch and stops the compressor.

There are a variety of other heat, air and pressure activated valves or switches. These are shown in Figure 5-9 and described in the paragraphs that follow.

Figure 5-9

Various types of heat, air and pressure valves and switches are illustrated.

A **pressure relief valve** may be installed on or near the compressor high side or on the receiver-drier fitting. This valve “bleeds” excess refrigerant pressure when malfunction or restrictions inside the system increase pressure to dangerous levels.

A **low pressure cutout switch** may be installed in either the high or low pressure side of the system. It is designed to sense low pressure due to refrigerant loss or system restriction. It is wired into the clutch circuit, and interrupts clutch operation to protect the compressor.

A **low side low pressure switch** is preferred, especially with axial compressors having little or no oil storage capacity. A low side low pressure switch is much more sensitive to problems such as a blocked expansion valve or other situations involving a lack of refrigerant and oil circulation.

High pressure cutout switches are frequently installed to protect the compressor. They are positioned on the high side to sense pressure inside the system, and are wired into the compressor clutch electrical circuit. These switches complete the circuit to the clutch when “closed.” They “open” when preset pressures are reached. Opening shuts the system down by breaking the circuit to the clutch.

Heat and air sensing switches and solenoids are some of the other control devices used to open or close electrical circuits to control or protect system components. These switches are frequently used as override controls in electric or air controlled engine fan and radiator shutter applications.

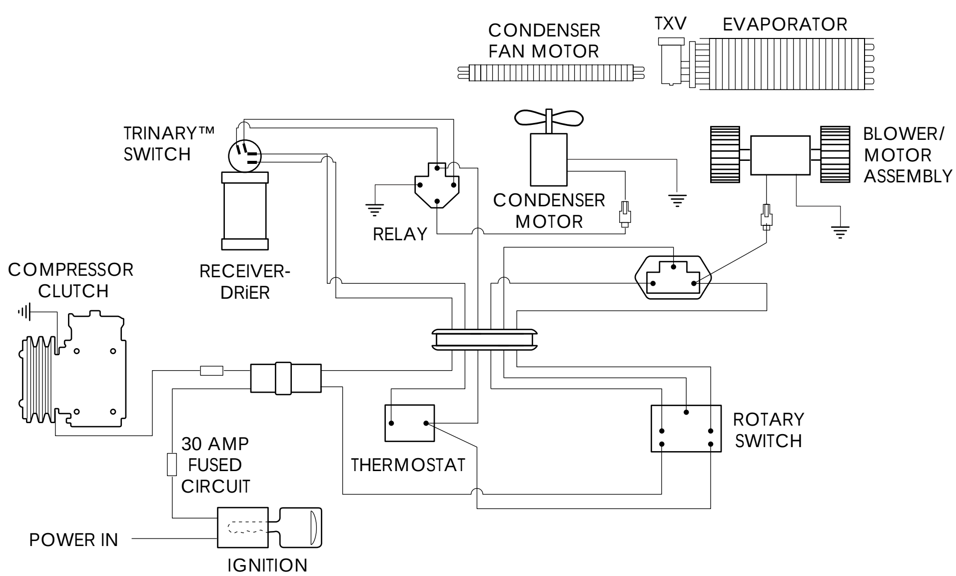
2. Electrical Devices and Schematics

Relays and resistors are electrical controls. They are normally not controlled by pressure or temperature except for the CTC™ system. A relay is included in a circuit to divide power when the demand for it exceeds the capacity of the control switch. A resistor is a voltage dropping (or controlling) device used to control fan or blower speed. Variable resistors are used to control temperature. Figure 5-10 illustrates a relay and resistors.

Figure 5-10
An electrical relay and two types of resistors are shown.

Figure 5-11
This electrical schematic shows how the rotary switch (system on-off) is connected to the thermostat and blower motor assembly. The condenser motor is wired to the thermostat and Trinary™ switches through a relay. The resistor controls voltage to the blower motor assembly.

The electrical schematic (wiring diagram) for a roof top air conditioner shows how electrical components and controls are connected. The diagram used for Figure 5-11 is clear and easy to read. All major AC components in the refrigerant system are also shown. The wiring diagram and AC part locations are not to scale.



3. Combination and Supplemental Controls

Combination and supplemental controls may protect the major components (primarily the compressor) from damage, control engine temperature and insure condenser efficiency.

When used in system design, combination and supplemental controls help maintain the pressure and temperature balance inside air conditioner and heater systems. They can make safe system operation possible in severe or varied climate conditions, and maximize heat energy movement under less than ideal conditions.

Two or three function pressure switch assemblies (Red Dot Binary™ or Trinary™ switches) may be installed on the liquid side of the AC system between the condenser and expansion valve. Both switches are illustrated in Figure 5-12.

Figure 5-12

Red Dot Binary™ and Trinary™ switches with switch operating pressures given.

RED DOT BINARY™ SWITCH

	OPENS	CLOSES
Low pressure protection	Between 3-15 PSIG (falling pressure)	40 PSIG maximum (rising pressure)
High pressure protection	Between 270-330 PSIG (rising pressure)	80-120 PSIG below open pressure

RED DOT TRINARY™ SWITCH

	OPENS	CLOSES
Low pressure protection	22.5 ± 7.5 PSIG (falling pressure)	40 PSIG maximum (rising pressure)
High pressure protection	Between 270-330 PSIG (rising pressure)	80-120 PSIG below open pressure
Shutter fan/override	Opens 35-60 PSIG below closing pressure	200-230 PSIG (rising pressure)

The **two function Binary™ switch** prevents the compressor from operating if there is no refrigerant in the system. It also stops the compressor if head pressures increase to unsafe levels. The switch resets when pressure drops to normal.

Red Dot's **Trinary™ pressure switch** performs three distinct functions to monitor and control pressure inside the AC system. The switch is installed between the condenser and expansion valve, usually on the receiver-drier. All three functions automatically reset when the proper pressure is achieved.

- The low-range pressure function prevents compressor operation if the refrigerant charge has been lost or ambient temperature is too cold.
- A mid-range pressure function activates the engine fan clutch or radiator shutter assembly. As system pressure reaches mid range, the switch engages the fan clutch (fan motor on roof top condenser units) and/or opens the radiator shutter. This increases air flow to the condenser and stabilizes or lowers system operating pressures. The switch cycles on and off to maintain operating pressures.
- A high-range pressure function turns off the compressor if pressure is to high.

- Multi function switches other than Red Dot's are being used in some applications. The concept is the same as described above.

4. Fan Clutches, Radiator Shutters & Override Controls

An engine fan clutch and radiator shutter assembly may be used to control and maintain engine (coolant) temperature. Engine fan and radiator shutter operation are closely related to radiator mounted AC condenser efficiency (heat energy movement). This is the main reason for fan clutch and radiator shutter override controls.

There are three types of fan clutches:

- Viscous Drive
- Air Actuated
- Electric

All but the viscous type may have a fan override control as part of the AC system. The **viscous drive fan clutch** has a high viscosity silicone fluid that moves inside the clutch to increase or decrease fan speed. The fluid is controlled by a temperature sensor, valve and centrifugal force.

Air actuated fan clutches are either on or off. Control is by a thermostatic valve which measures engine coolant temperature. When coolant is hot, the valve opens and air pressure enters the fan body causing the clutch to engage. Some air actuated clutches use air pressure for the off condition.

The electric fan clutch has a preset engine coolant temperature sensor. When the set temperature is reached, the clutch is engaged for increased air movement through the condenser and radiator. When coolant temperature drops the clutch disengages the fan.

Radiator shutters control air (outside air) flow through the radiator. These shutters are opened and closed by thermal or air activated spring loaded valves. Both types of valves sense and maintain engine coolant within a narrow temperature range (4 to 6 degrees). The narrow 4 to 6 degree Fahrenheit temperature range selected may fall anywhere between 160 to 220 degrees Fahrenheit. Thus, override controls are required to bypass radiator shutter controls for efficient or safe condenser function and AC system operation.

Chapter Review

- Basic system controls begin at a control panel inside the cab or sleeper compartment. We can decide on heating or cooling and where and how much air flow we want. We can select a temperature range for the inside of the cab or sleeper.
- When a heater, air conditioner or HVAC system is turned on, the automatic control devices take over system control. They are designed to keep the system in balance and maintain the operator selected temperature range inside the vehicle.

- A balanced system is more efficient in moving heat energy into or out of the air in the cab than an unbalanced one. Balance means maintaining pressures and temperatures inside the system so that heat energy moves easily and efficiently from one area to another.
- In most systems one or more heat or pressure sensitive switches may be installed. These usually protect the compressor if something goes wrong inside the system or the refrigerant leaks out.
- The more advanced system designs use air pressure or vacuum for system and component control. Electronic controls are also used. The advantages of advanced controls are more even cab temperature and faster control response.
- The engine fan clutch and radiator shutter are controlled by engine coolant temperature. In an AC system with an underhood condenser, override controls are used to govern fan clutch and radiator shutter operation.

Chapter 6

Service Tools and Their Use

Click on any of these subject headings to go directly to the page

The basic air conditioner and heater service tools include some special tools and test equipment as well as normal tool chest items. In this section we describe and explain the use of basic tools, test and other equipment, and safety. Some of the special equipment described is expensive but is often justified in a busy shop. Actual system test and service procedures are covered in *Chapter 8* and *Chapter 10*.

Safety is important to you as well as to others in your working environment. The air conditioner and heater system are as safe or safer to work on as other vehicle systems, engines, etc.—but they are a little different. We will stress safety in this chapter and have used **CAUTIONS and WARNINGS in bold print** all through the manual to alert you to potential hazards.

Safety & Safety Equipment

- In servicing HVAC systems you will be exposed to high pressures, temperatures and several chemical hazards. Moving belts and pulleys are normal shop hazards.
- In addition to exercising caution in your work, **ALWAYS WEAR SAFETY GOGGLES OR A FACE SHIELD** when you are using refrigerant or a Halide leak detector, adjusting service valves or the manifold gauge set connectors. Safety goggles or a transparent face shield are practical safety items. **ONE OR THE OTHER IS ABSOLUTELY REQUIRED.**
- Refrigerant inside a container and in parts of the AC system is a liquid under pressure. When refrigerant escapes or is released to the air, **ITS TEMPERATURE DROPS *INSTANTLY.*** If it spills on your skin or in your eyes, flood the area with cool water and **SEEK MEDICAL ATTENTION IMMEDIATELY.**
- The compressor creates pressure when it runs. If pressures get too high in the system, the weakest point may separate or blow out. A system restriction, too much refrigerant, or improper charging procedures are all potentially dangerous.
- Someone else may have serviced the system before you and put too much refrigerant in the air conditioner. The only way to know how much refrigerant is in the system is to take it all out. Then evacuate the system and charge it with a weighed amount of refrigerant yourself, based on manufacturer specs. If too much refrigerant is in the system for proper cooling, and you add more, you may have a potentially ruptured component and serious injury.
- Keep in mind the fact that R-12 refrigerant becomes a poison gas when it burns. **DO NOT SMOKE AROUND REFRIGERANT.**

- Do not grab hold of a clutching fan to stop it when it is disengaged but turning at low RPM. **THE FAN CAN SERIOUSLY INJURE YOUR HAND.**
- Be sure the area you are working in has plenty of ventilation and that no gas or other fumes are present. **DO NOT USE A HALIDE LEAK DETECTOR OR REFRIGERANT WITHOUT ADEQUATE VENTILATION. DO NOT RUN THE VEHICLE ENGINE DURING A PERFORMANCE INSPECTION OR WHEN CHARGING THE SYSTEM WITHOUT ADEQUATE VENTILATION.**

WARNING

Fire or explosion hazards exist under certain conditions with R-134a. A combustible mixture can form when air pressures are above atmospheric pressure, and a mixture of air and R-134a exist. For this reason do not pressure test air conditioning systems with compressed air.

Air Conditioning System Service Tools

The basic AC tools that are discussed in this section include:

1. Recovery/Recycling Station
2. Refrigerant Dispensing Valves & Containers
3. Manifold Gauge Set
4. System Service Valves
5. System Service Valves
6. Vacuum Pumps
7. Leak Detectors
8. Flushing Kit
9. Heater System Service Tools
10. Other Equipment

1. Recovery/Recycling Station

The recovery/recycling station performs two closed loop processes. The station removes the refrigerant from an AC system in the **recovery** mode. The refrigerant is contained in an external cylinder for storing, recycling, reclaiming, or transporting. Typically, the refrigerant is not reusable until it is recycled. Contaminants in the refrigerant are reduced in the **recycle** mode. The contaminants could include moisture, acidity, and particulate matter. *Chapter 9* contains more detailed information on the recovery and recycle processes and necessary equipment.

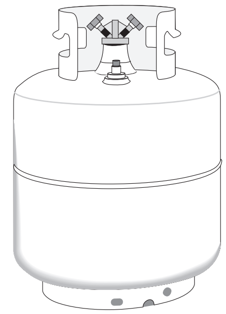
Note: Separate stations are required for R-12 and R-134a.

2. Refrigerant Dispensing Valves & Containers

Bulk containers should always be used with a scale or charging station capable of measuring the refrigerant put into the system. Figure 6-1 illustrates the most common refrigerant container.

Figure 6-1

Refrigerant comes in a standard size container and may be dispensed with single or dual dispensing valves.



20 POUND CYLINDER

WARNING	All containers with refrigerant are under pressure (to contain the refrigerant). Any heat will increase that pressure. The containers are not designed to withstand excessive heat even when empty, and should never be exposed to high heat or flame because they can explode. Containers must be certified as meeting DOT CFR Title 49 requirements.

There are several other tools that could be used when charging an AC system with refrigerant. These are a charging meter (refrigerant scale) or a charging station. They will be described later.

3. Manifold Gauge Set

The manifold gauge set is the tool used for internal system diagnosis and service. A typical manifold has two screw type hand valves to control access to the system, two gauges and three hoses. The gauges are used to read system pressure or vacuum. The manifold and hoses are for access to the inside of an air conditioner, to remove air and moisture, and to put in or remove refrigerant from the system. Shutoff valves are required within 12 inches of the hose ends to minimize refrigerant loss.

Figure 6-2 illustrates a basic manifold gauge set and explains how it works.

Manifold gauge sets are color coded. An R-12 gauge set normally has a blue low side hose, a red high side hose, and a yellow or white utility (center) hose. An R-134a gauge set will have a blue hose with a black stripe for the low side, a red hose with a black stripe for the high side, and a yellow hose with a black stripe for the utility (center) hose.

Different style end fittings are used on R-12 and R-134a hose sets. R-12 hose sets use a 1/4 female refrigeration flare (FFL) on all hose ends. A shutoff valve is required on all three hoses within 12 inches of the end connected to the AC system or service equipment. R-134a hose sets use a 1/2 ACME female nut on the gauge end. Special quick disconnect couplings are normally combined with a shutoff valve on the high and low side hoses. The free end of the utility hose contains a 1/2 ACME female nut and a shutoff device within 12 inches of the hose end.

These special hoses and fittings are designed to minimize refrigerant loss and to preclude putting the wrong refrigerant in a system.

Two hoses (left and right) connect to the low and high sides of the system, usually at the compressor on R-12 systems. The center (utility) hose is used to remove refrigerant from the system, evacuate air and moisture, or add refrigerant. Gauges are calibrated for either high or low pressure and vacuum. The term compound gauge set is often used because the low pressure gauge responds to pressure and vacuum. Separate gauge sets are required for R-12 and R-134a.

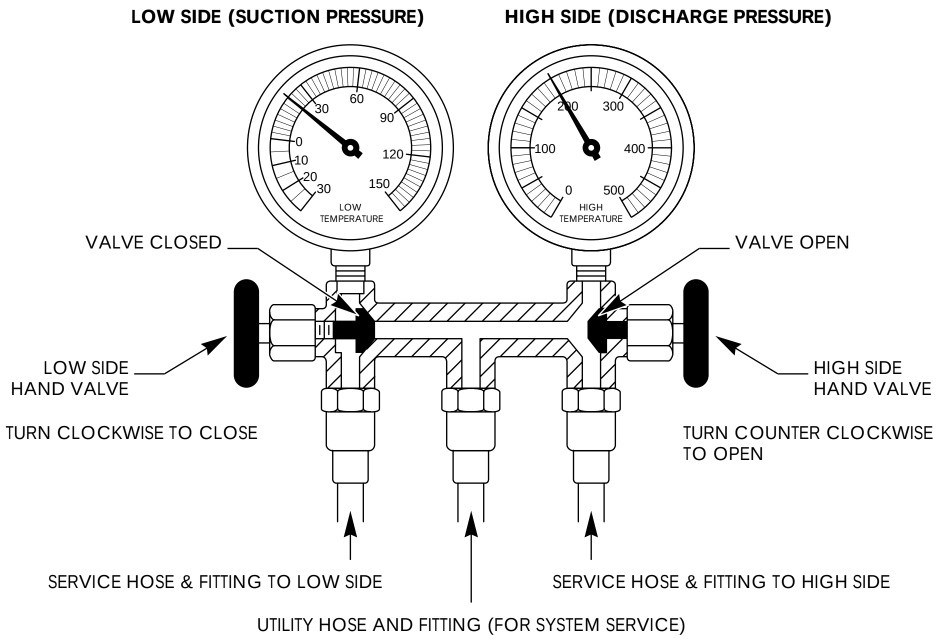


Figure 6-2

The basic manifold and gauges are illustrated. The low pressure gauge displays pounds per square inch (PSI) and inches of mercury (in. Hg). Hg is the chemical symbol for mercury. The high pressure gauge reads in pounds per square inch.

CAUTION Many gauges have dials with metric and US scales to measure pressure. The more expensive manifold gauge sets have liquid filled gauges and additional valves and fittings incorporated in the manifold. All gauges are breakable and should be handled with a reasonable amount of care.

The high pressure gauge registers system pressure from 0 to 500 PSI. The low pressure gauge registers pressure from 0 to 150 PSI clockwise, and vacuum from 0 to 30 inches Hg counter-clockwise.

There are a few important rules and procedures you must follow concerning gauge set hookup. Both the rules and procedure are for your safety and to protect the AC system. The basic rules are covered briefly here. Gauge set hookup should not be done until after you have made a complete visual and performance inspection of all AC system components. These inspections are described in detail in *Chapter 7*. In addition you should inspect the engine, cooling system and other engine driven devices. Engine cooling system problems can cause false gauge readings and incorrect AC system diagnosis. Worn drive belts or hoses are dangerous to work around.

CAUTION	Never attempt to hook up the manifold gauge set with the engine running. Never hookup the gauge set until you have checked to be sure the hand valves on the manifold are closed. Never hookup the gauges to the AC system until you have made a visual and performance inspection.

Figure 6-3 shows the typical gauge set hookup location on a truck. Note that the gauge set hoses are connected to system service valves.

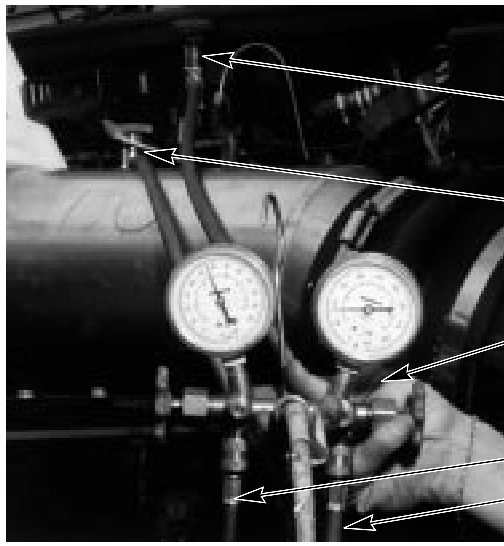


Figure 6-3
This illustration shows the typical manifold gauge set hookup location.

4. System Service Valves (R-12 Only)

System service valves allow safe access to the system inside of an AC system through the manifold gauge set. There are usually two (2) service ports mounted in an easily accessible area for access to the low and high pressure sides of the system.

Two types of service valves are in common use today—stem type and Schrader. The stem type valve stems screw in and out. They may be used to isolate the compressor from the rest of the system for fast compressor replacement. The Schrader type valve functions like a tire air valve. They are easy to incorporate in other locations in the system. Figure 6-4 shows both types of valves and how they work.

Note: Many systems have extra service valves (Schrader) in the system. These valves accommodate pressure switches or provide another service port. The new R-134a refrigerant uses special service fittings to prevent the mixing of refrigerants and oil.

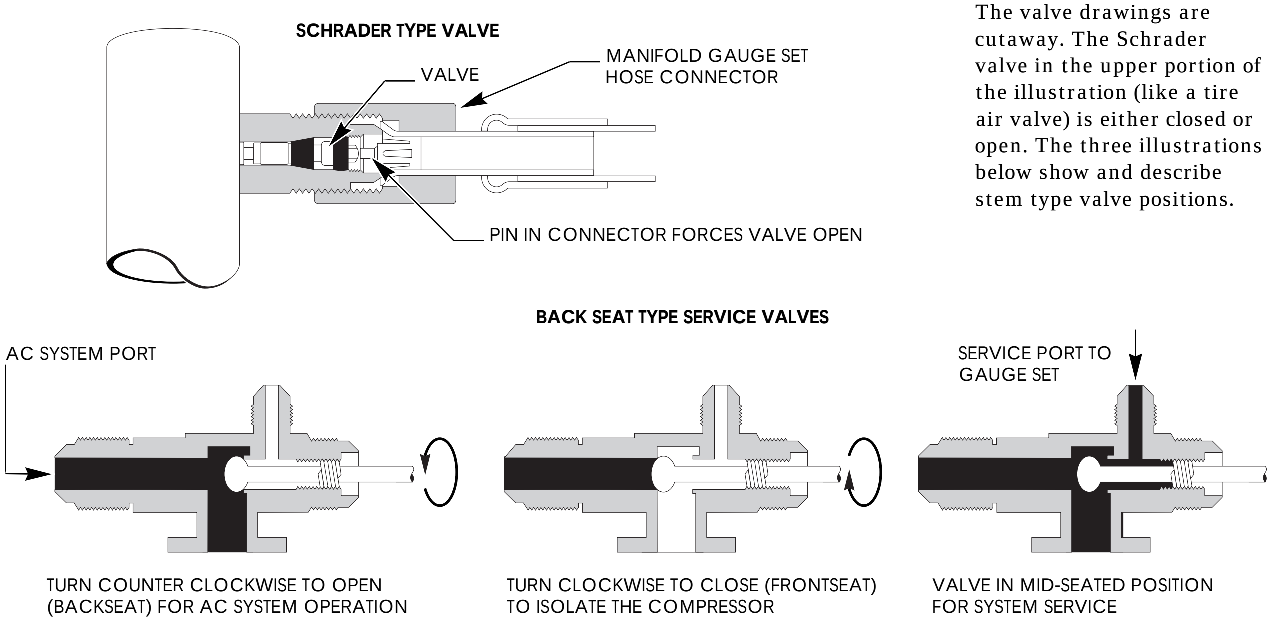


Figure 6-4

The valve drawings are cutaway. The Schrader valve in the upper portion of the illustration (like a tire air valve) is either closed or open. The three illustrations below show and describe stem type valve positions.

5. System Service Valves (R-134a only)

New and unique service hose fittings have been specified for R-134a systems. Their purpose is to avoid cross-mixing of refrigerants and lubricants with R-12-based systems. The service ports on the system are quick disconnect type with no external threads. They do contain a Schrader type valve as shown in figure 6-5. The low side fitting has a smaller diameter than the high-side attachment.

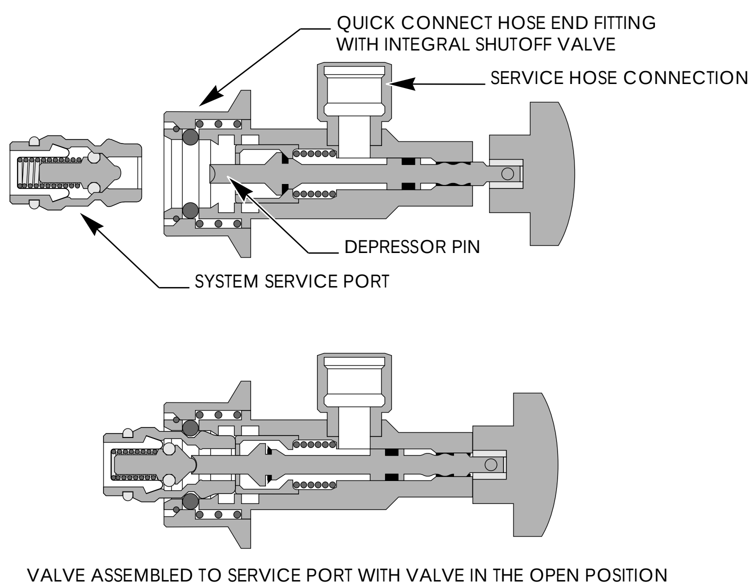


Figure 6-5

This illustration shows R-134a service ports and hose end fittings.

6. Vacuum Pumps

Air and moisture inside an air conditioner contaminate the system. They combine with refrigerant and refrigerant oil to form acid and sludge. Moisture inside a system can freeze at the expansion valve orifice, blocking the flow of refrigerant temporarily. The result is erratic system function. A vacuum pump is used to remove air and moisture from the inside of hoses and components of the air conditioner, but special care must be taken to keep components clean and moisture free.

When the vacuum pump is hooked up to the system through the manifold gauge set (and the service valves are open), the pump sucks air out. The result is a negative pressure or vacuum. The air is removed quickly, in just a few minutes. However, the humidity in the air may condense inside the system and this moisture must be removed.
Moisture will vaporize in a vacuum when a sufficient vacuum level is reached. Vacuum level is measured in inches of mercury. The vacuum pump must operate long enough to cause any condensed moisture inside to vaporize so the pump can suck it out of the system.

In truck and other heavy duty applications it is most difficult to remove the moisture. The hoses used to connect the AC components in a truck may be ten times longer than in a car AC system and may have more bends and connections where moisture can hide. For this reason, vacuum pump capacity and how long you use the pump are important. A higher pump capacity and longer pumping time help insure that all moisture is out of the system. There are two types of vacuum pumps, rotary vane and piston type. They require an electrical source for power. Each is illustrated in Figure 6-6. The rotary vane pump is thought by many to be superior because it is powerful and quiet. We will describe how to use a vacuum pump to evacuate (remove air and moisture from) the system in *Chapter 8*.

ROTARY VANE PUMP

TWO STAGE PISTON PUMP

Figure 6-6
Two types of vacuum pumps are illustrated and described. Both evacuate air and moisture from the air conditioning system through the service valves, manifold gauge set and hoses.

7. Leak Detectors

There are two types of leak detectors in popular use. The least expensive is called a Halide leak detector and is made from a propane torch. The other is called an electronic leak detector. Electronic detectors operate on one of two principals, positive ion or negative corona.

Halide Leak Detector (R-12 Only)

A Halide propane torch leak detector can be used to find system leaks as low as five ounces per year. It includes a propane tank and torch assembly. The torch assembly includes a control valve and tube, pickup hose, orifice at the top of the tube, and copper reactor plate. A chimney surrounds the orifice and copper plate and has a window cut out. The chimney shields the propane gas flame. You can analyze flame color through the window.

In use, ignite the propane and adjust the flame to heat up the reactor plate. The burning propane gas sucks air up the pickup tube (the oxygen in the air also burns with the propane). To detect leaks, move the pickup tube slowly about the AC system. Take care to move the tube **below** potential leak points because R-12 is heavier than the air. Any R-12 present is drawn up the tube and burned. When R-12 is present in the flame, the copper reacts with it and the flame changes color. Figure 6-7 illustrates this leak detector and method. The flame colors are described.

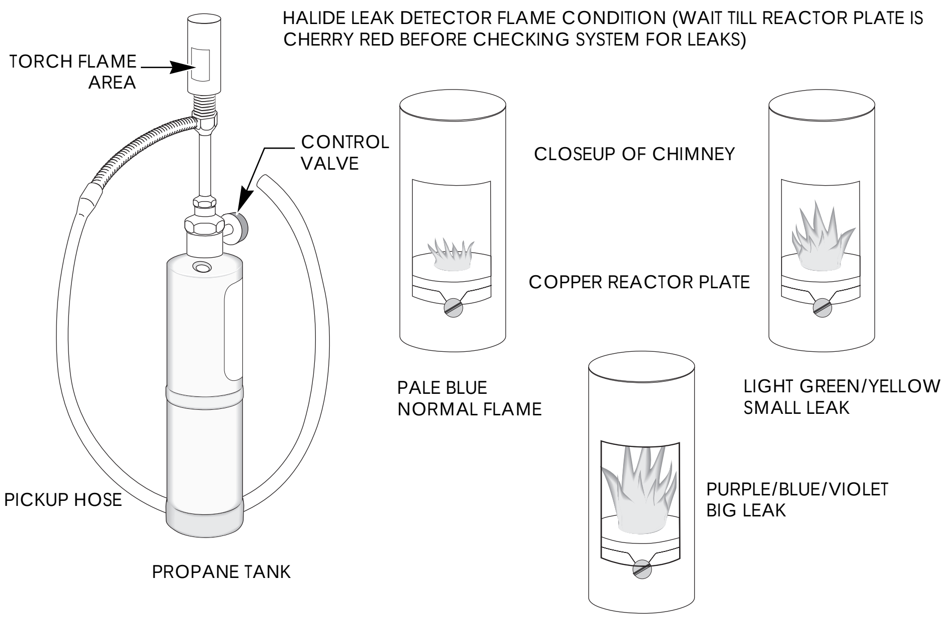


Figure 6-7

The halide leak detector and parts are described. You can use it to detect R-12 leaks as low as five ounces per year. There are three drawings of chimney/reactor plate/flame conditions to show you how the detector works to indicate a leak.

WARNING An open flame in your shop is dangerous. The Halide leak detector should be used with care. Be sure there is adequate ventilation to carry away any fumes from the torch. Remember that refrigerant changes to a poison gas when burned.

Electronic Leak Detector

Electronic leak detectors are safer than the Halide system and about ten times more sensitive. Some designs can detect an R-12 or R-134a leak as low as one half ounce per year. There are two types of electronic detectors, positive ion and negative corona. These technical terms, positive ion and negative corona, are used in describing the electronic elements and their function in these detectors. The negative corona type detector has a longer service life and requires less power.

Electronic detectors have a probe that is moved around the AC system. Where refrigerant is present, a change in current flow inside the probe is sensed by an electrical circuit. This activates a buzzer which signals the user about the presence of a refrigerant leak. Figure 6-8 shows an electronic leak detector of the negative corona type.

Figure 6-8
The electronic leak detector is a small hand held device that is easy to use. It detects R-12 and R-134a leaks as small as one half ounce per year.

8. Flushing Kit

A flushing kit is used to remove contaminants from AC system hoses, evaporator and condenser. Any other components should be bench checked or replaced as flushing is either not effective or will cause damage. Flushing these components is recommended when you replace the compressor or find contamination in other system components (receiver-drier, expansion valve, or at connections). Flushing must be done with a "closed-loop" flushing kit using the Recovery/Recycle station.

Figure 6-9
Flushing kit to use with one brand of recycling station (Sercon).

9. Heater System Service Tools

In addition to normal tool box items, several test devices are required for effective cooling system service. These are a pressure tester, hydrometer and thermostat tester. The **pressure tester** is a simple hand pump with a pressure gauge, hose, and adapters. The adapters are used to connect the tester to the radiator filler neck or to the pressure cap. You use the pump to apply pressure to the cooling system or cap. Then you check for system leaks or for cap function.

A **special cooling system hydrometer** is used to draw coolant from the radiator into a clear tube containing a float. The float has a scale you read and relate to a scale on the hydrometer. The hydrometer scale corresponds to a temperature level at which the coolant will freeze.

A **thermostat tester** has a built in thermometer and a heating element. You put water and the thermostat in the tester, turn on the heating element and observe the thermostat to see if it functions. The thermostat should begin to open at from three to nine degrees Fahrenheit below it's rated temperature and should be fully open at the rated temperature.

Other Equipment

The pulley alignment bar and belt tension gauge may already be a part of your normal tool chest items. They are good tools to have for other service work. In AC systems, belt alignment and tension are important for efficient compressor clutch operation and belt and clutch bearing service life.

A fin comb is used to clean bugs and debris from the condenser and evaporator fins and straighten them if they are bent. These combs are made of molded plastic with a series of grooves to correspond with condenser and evaporator fin spacing.

The dial-type or digital thermometer is used to measure the temperature at evaporator fins or the air coming out of ducts. Figure 1-6 in *Chapter 1* illustrates and describes a typical dial type thermometer.

A variety of compressor service tool kits are available. These contain special tools needed for clutch removal, compressor tear down, service and repair. To check compressor oil level you can make your own oil dipsticks or purchase one for each type of compressor. Three of these and their uses are illustrated in Figure 6-10.

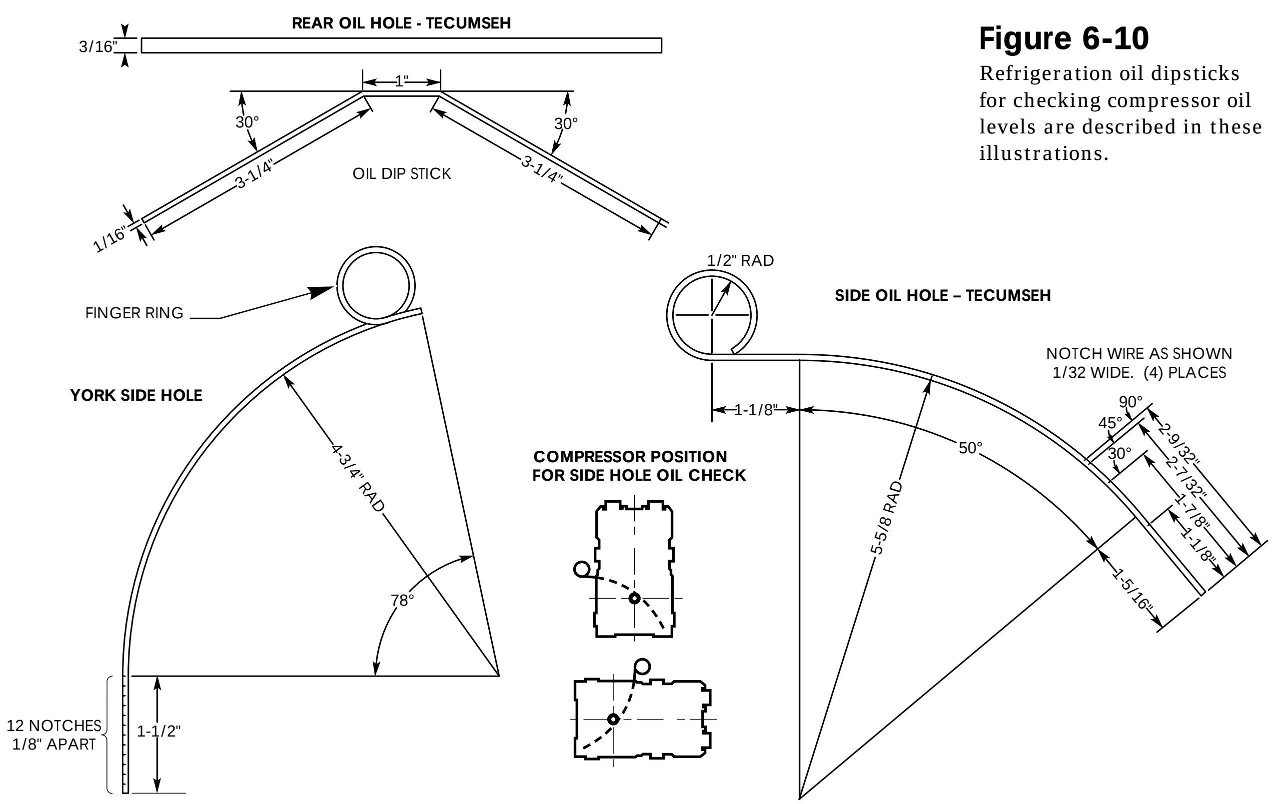


Figure 6-10

Refrigeration oil dipsticks for checking compressor oil levels are described in these illustrations.

Compressor oil injectors are available that connect to the manifold gauge set or charging station to dispense refrigeration oil.

It's a good idea to have a torque wrench, a vacuum tester, a Schrader valve core remover/installer and any other special system testers you would need if you are going to service specific systems.

Earlier we mentioned refrigerant scales or charging meters and charging stations. They are all designed to provide an accurate measure of the refrigerant you use when charging the AC system. The more elaborate charging stations combine the refrigerant supply, manifold, gauges, a heated charging cylinder, hoses and vacuum pump on an easily moved cart or stand. Some even have refrigeration oil dispensing and leak detection capability built in. The more expensive units have electronic controls. Figure 6-11 illustrates some of these devices.

Charging Stations, Basic Description of Use

(Refer to Fig. 6-11.)

a. After repairing the AC system use this station to evacuate air and moisture from it. The station adds the recovered/recycled refrigerant to the AC system. A metering device is used in conjunction with this station to monitor the amount of refrigerant added.

b. This all purpose recovery/recycling/recharging station provides all necessary service features in one package. This station recycles the refrigerant during the evacuation cycle. A microprocessor control allows automatic recovery shutoff, programmable evacuation and charging cycles.

Figure 6-11

Basic and electronically controlled charging stations and a charging meter are pictured.

a.) CHARGING STATION WITH A VACUUM PUMP AND CHARGING CYLINDER

b.) ALL PURPOSE CHARGING STATION INCLUDES AUTOMATIC EVACUATION, OIL INJECTION, RECHARGING, ELECTRONIC CONTROLS TO ADJUST VACUUM PUMPING TIME AND LEAK DETECTION

Other electronic devices you may want to consider are an electronic digital thermometer or electronic sight glass. The advantage of the electronic thermometer is reading speed (it will give you a reading in a few seconds or less), accuracy, and temperature range, all in one unit.

Note: Separate charging stations are required for R-12 and R-134a.

The electronic sight glass is an ultrasonic device with two sensors. The sensors are clamped to a metallic tube (not a hose) carrying refrigerant inside the system, and connected to an electronic signaling device. The type of refrigerant metering device used in the system and where you clamp the electronic sight glass affect how the tester signals to tell you system charge condition.

Chapter Review

- Before servicing an HVAC system, safety must be taken into account. Be aware of what safety precautions must be followed at any time during the servicing of an HVAC system.
- Basic AC tools consist of a recovery/recycle station, refrigerant dispensing valves and containers, a manifold gauge set, system service valves, vacuum pumps, leak detectors, a flushing kit, and heater system service tools.
- Other equipment used to service air conditioners includes a pulley alignment bar, a belt tension gauge, a fin comb, a dial-type or digital thermometer, a compressor service tool kit, a compressor oil injector, a torque wrench, a vacuum tester, other special system testers, a refrigerant scale, a charging meter, a charging station, and electronic devices such as electronic digital thermometers/pyrometers, and an electronic sight glass.

Chapter 7 Inspection and Maintenance– *without gauges*

Click on any of these subject headings to go directly to the page

Discussion of Inspection & Maintenance Survey Results

There are three reasons for regular inspection and maintenance procedures:

1. They save money in the long run by reducing down time and often prevent more costly repairs.
2. They help to insure driver comfort and safety.
3. They add to your store of knowledge about these systems and maintain your level of efficiency.

About half of all heavy duty vehicles have air conditioners. Surveys of AC system owners find that over 30% of the systems are serviced every six months or less, and another 62% are serviced at least once a year.

The survey also covered how often the different components required maintenance. Figure 7.1 below shows survey finding percentages. Failure of any of the AC components listed in the survey could cause a system to malfunction or stop cooling.

Figure 7-1

This chart shows maintenance frequency, lists key parts and how often they require maintenance.

INSPECTION & MAINTENANCE SURVEY

How often are your air conditioners serviced?				
	1 to 6 months	7 to 12 months	More than 12 months	Never
Average	30%	62%	6%	2%

Which AC components require frequent maintenance?					
Belts	Compressor Clutch	Condenser	Add Refrigerant	Refrigerant Lines	Valves
32%	26%	12%	12%	11%	7%

Note: The above survey results may not apply to your situation. Actual operating conditions for the vehicles you service will determine or influence maintenance frequency and requirements.

The following inspection procedures should take about 15 to 20 minutes, longer if corrective steps, part replacement or adding refrigerant is necessary. There is a "Preventive Maintenance Worksheet" you may use at the end of this chapter, Figure 7-9.

Visual Inspection - System Off

Your observations and the corrective measures you take may be different depending on circumstances. The following inspection procedures are explained in more detail below:

1. Observe the System
2. Inspect Parts
3. Check Hoses and Fittings
4. Check for Refrigerant Leaks

Use the following procedures as a general rule in performing a visual inspection with the AC system off:

1. Observe the System

Your first inspection step is to answer the following question if you can:

- Has the vehicle just come in off the road and has the HVAC system been in use?
- Did the operator or work order explain or describe any problems about the system?
- Did someone else work on the system yesterday, 700 miles down the road? Your first inspection step is to answer these questions if you can.

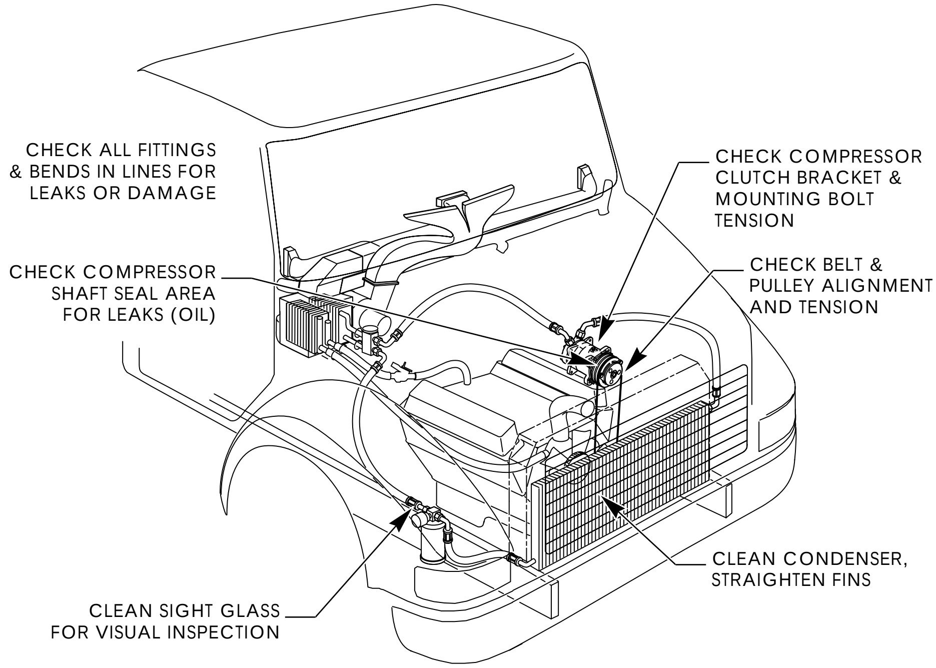
CAUTION	Even when someone has told you what is wrong with an HVAC system, you should perform a visual inspection. Always make a visual inspection before you hook up the manifold gauge set. Never add refrigerant to a system until you have made a complete visual and performance inspection.

2. Inspect Parts

Look at the system for what might come loose, leak, wear out or become dirty and not function the way it should. The main points for visual inspection of the system are emphasized in Figure 7-2.

Figure 7-2

This system illustration notes the main points for visual inspection.



A. Condenser – Is it free of leaves, bugs, bird feathers or mud? The condenser must be relatively clean to work well as a heat exchanger. How you clean the condenser depends on where it is mounted. The condenser fin comb, air hose and nozzle, or soap and water may be used. Where possible, check condenser mounting bolts or screws and tighten them if necessary.

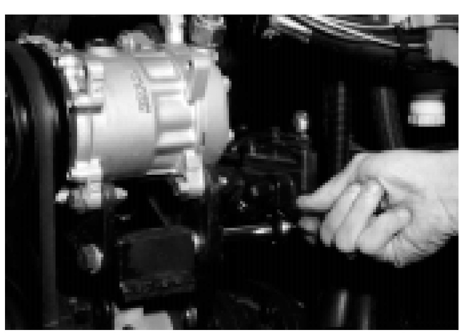
Condenser failure often results from loose hoses. Hose movement will cause fatigue failure of condenser tubing adjacent to the fittings. Make sure the hoses are securely clamped.

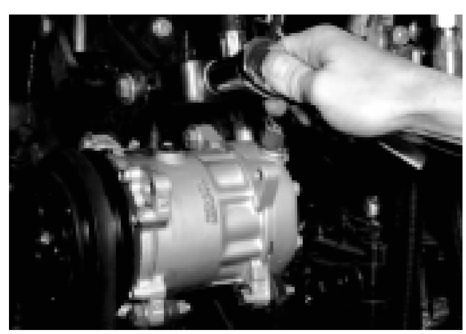
While inspecting the condenser check the receiver-drier sight glass and connections. Look to see if the sight glass has a moisture indicator that is showing moisture in the system.

B. Components Under the Hood – Tip the cab or raise the hood. Look at the compressor mounting bracket, compressor clutch assembly, drive belt and pulley alignment. The mounting bracket, compressor, clutch and drive pulley should be fastened securely, and a clutch groove (there may be two groves) should be in line with the drive pulley. Tighten all bolts shown in Figure 7-3, as you inspect.

Figure 7-3

Engine and compressor vibration can work mounting bolts loose. Tighten all mounting bolts as you inspect the system. Slots in the mounting bracket are used to move the compressor clutch assembly in order to adjust belt tension or alignment.





C. Drive Belt – The drive belt should be tight and in good condition. Use a belt tension gauge to check tension (120 pounds maximum). With experience, you can feel belt tension by twisting the belt. Try feeling belt tension after using the gauge, when you know the tension is correct. Replace belts if they are frayed or look worn.

If the clutch pulley/belt alignment is obviously off, you need to loosen the compressor or mounting bracket, or both—and use the alignment bar to line up the clutch pulley with the drive pulley. Tighten compressor mounting bolts first, then the bolts holding the bracket. The mounting bracket should have slots or other means of adjustment to allow you to adjust the tension of the drive belt. When you use a pry bar to apply tension, be sure you do not pry against the compressor. Pry against the mounting bracket.

3. Check Hoses and Fittings

Check all hoses and fittings. Look for places where hoses flex when the cab is tilted. Any places the hoses or fittings are fastened, clamped, connected, bent or secured are potential wear points. This also applies to places where hoses are not clamped or supported but should be (often near the condenser). All of these spots are potential leak or damage points. Tighten, re-fasten, add, or replace as indicated by your inspection.

4. Check for Refrigerant Leaks

System refrigerant leaks can be anywhere but there are obvious places. You can spot some by looking for signs of refrigerant oil forced out with refrigerant leakage. One location leaks frequently occur is the compressor shaft seal. The shaft and seal are hidden behind the clutch assembly, but centrifugal force will throw the oil off the shaft and against the engine, bracket or whatever is close. Check these points when you examine the compressor clutch and mounting bracket. A solution of soap and water applied around potential leak points works well for detecting leaks. A leak in the evaporator may be indicated if you feel around the condensate drain hole and find oil present.

Note: You can add inexpensive dry nitrogen gas to the system instead of R-12 if system pressures are low. Dispense the gas at no more than 200-250 PSI as this is sufficient pressure to cause or indicate a leak point in the AC system. AC service procedures for complete system recovering of refrigerant, evacuating, and recharging are covered and illustrated in *Chapter 9*.

Note: A leaking heater core could also result in coolant at the condensate drain.

You can feel for oil at the bottom of all connections (see Figure 7-4) if the system is not too hot. Of course, a few minutes with an electronic leak detector is the best way to check for leaks. Keep in mind that pressure is different in a system at rest, so small leaks may be hard to find. Pressure in a system at rest, will equalize at from 60 to 95 PSI, depending on outside air temperature. This means there is more pressure in the low side of the system at rest than during normal system operation. Just the opposite is true of the high side; at rest, high side pressure is lower. You may want to use the detector to check for leaks in the high side when the air conditioner is operating, if you suspect a leak and can't find it when the system is at rest.

Figure 7-4
This illustration shows a potential refrigerant leak point at the condenser fitting.

Electrical System Inspection

The two stages of an electrical inspection are explained in more detail below:

1. Inspect Electrical Connections
2. Check Electrical Current Flow and Device Functions

Use the following procedures to perform an electrical system inspection:

1. Inspect Electrical Connections

First, while you are making your visual inspection under the hood (cab) and/or at the roof top condenser, take a moment and check all electrical connections visually and by feel. Look for any corrosion on leads or connectors and clean them. Make sure all leads and wires are properly supported and securely connected.

2. Check Electrical Current Flow and Device Functions

Perform the following steps to check current flow and electrical device functions:

A. Turn the Ignition On – To check current flow the ignition must be on.

B. Turn the AC System On – This will power the thermostat and clutch. If it does not come on, use the AC mode switch to check the leads to the switch. You should be able to hear a “click” from the thermostat and hear the clutch drive plate “snap” against the clutch pulley. You can not check thermostat cycling on and off until you do the performance inspection. Figure 7-5 illustrates a typical AC electrical system and the places you should inspect.

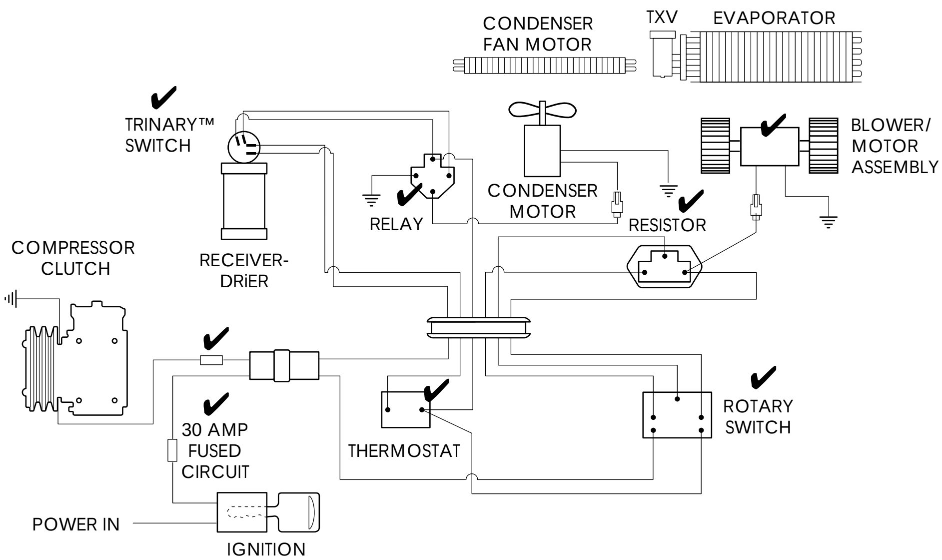


Figure 7-5

The electrical system inspection points are noted with check marks (✔) on this wiring diagram (electrical schematic).

C. Check Fuses – If there is a failure and you have made sure all connections are clean and tight, you need to check fuses—in-cab as well as in-line.

D. Check Clutch Engagement – Since you can’t see and may not hear the clutch engage, get out and look at the clutch. If it’s engaged, you will see that the drive plate is against the pulley and not slightly spaced from it. If you are not sure the clutch is engaged, look for the lead wire connector near the clutch. Break and close that connection. The clutch will disengage and engage again.

E. Test Blower Speed Operation – Some systems have a common switch that turns on the air conditioner and powers the blower motor. Test blower speed operation by adjusting this or the separate blower control switch. Feeling the air flow from the ducts or note blower sound (speed) changes.

F. Inspect Roof Mounted Condensers – Don’t forget to inspect roof mounted condensers and AC systems for dirt and debris. Be sure the condenser fan(s) are working properly and all parts and electrical connections are securely fastened. The roof mounted condenser fans may come on when the system is turned on. Like the thermostat and most clutches, the normal on-off cycling action can not be observed until the engine is running with the AC system on.

Performance Inspection – Engine Running

The purpose of visual and electrical inspection is to detect obvious problems and assure AC system function for an accurate performance inspection. If you do the performance inspection first, you could be mislead. Problem areas discovered during the performance inspection can give you false clues or symptoms, and result in repair errors and come-backs. The following performance inspection procedures are explained in more detail below:

1. Inspect System Component Cycling and Cab Temperature Levels
2. Check Clutch Cycling Under Load
3. Check Sight Glass

The performance inspection does not cover pressure and temperature sensitive safety devices (cutout switches, fan control, Trinary etc.). Testing these devices requires the use of the manifold gauge set for observation of internal system pressures during tests. These are explained in *Chapter 8*.

Use the following procedures as a general rule in a performance inspection:

1. Inspect System Component Cycling and Cab Temperature Levels

A. Turn On the Engine and Air Conditioner – Inspect for system component cycling and cab temperature levels.

Note: **System performance testing will be much faster if all doors and windows in the cab are closed.** The cab air must cool down to thermostat control setting levels before system components will cycle on and off, indicating correct function. This is called ‘stabilizing the system’ and takes about five minutes of operation. In very hot weather the system may not cycle.

B. Check Thermometer Readings – In the cab you can use your thermometer to measure air temperature at the vents. When the evaporator is easy to reach with a thermometer probe without removing some of the dash or duct work, use the probe to measure evaporator temperature. When the AC unit is on and working correctly, you can see the thermometer dial needle move down to about 32 degrees, then rise six to ten degrees and move back down again. The movement up and down indicates that the cycling clutch and thermostat, or orifice tube and accumulator pressure switch (to the clutch) are functioning correctly. In systems with a non-cycling clutch, this movement indicates correct function of the refrigerant metering device.

The needle movement is called “temperature swing.” When you can adjust the thermostat setting, the range of swing should change. For example, from full cooling (cold) to moderate (between cold and warm), the swing may change from 32-38 to 32-42 degrees.

These readings at the vents will be higher and temperature swing slower and not as obvious. Also blower speed will cause the temperature, levels to read higher (high air speed) or lower (low air speed) at the same thermostat setting. When you measure air temperature, an electronic thermometer/pyrometer is a great tool to have. You can easily measure cab air temperature at several locations quickly.

Swing temperatures vary depending on where you measure temperature, and on outside temperature, humidity and altitude. The chart in Figure 7-6, shows some examples of typical temperature variables. Don't forget that cab and sleeper area temperatures can vary within the same vehicle. Also, electronic controls used in newer HVAC systems often keep the temperature spread within a narrower range.

AIR TEMP. DEGREES F.	70°		80°		90°		100°	
AIR QUALITY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY
CENTER OUTLET AIR TEMP. DEGREES F.	43° to 47°	40° to 44°	44° to 48°	40° to 44°	47° to 51°	40° to 44°	52° to 56°	41° to 45°
LEFT & RIGHT AIR OUTLET TEMPERATURE WILL VARY								
	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
OUTLET AIR TEMP. RANGE DEGREES F.	40° to 41°	41° to 44°	41° to 45°	43° to 47°	46° to 52°	47° to 54°	48° to 55°	50° to 56°

Figure 7-6

The chart of AC system and cab temperature range shows you typical variables.

2. Check Clutch Cycling Under Load

The following operating inspections, visual and by feel, are done outside the cab while you wait for the system to stabilize.

A. Lift hood – With the hood up (or cab tilted) observe the clutch cycling under load.

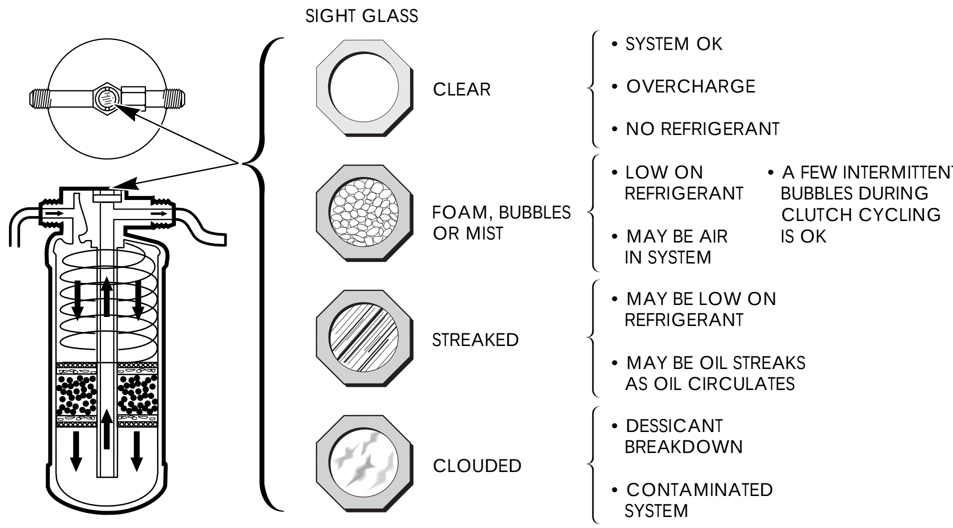
Note: If the condenser is hood mounted you may not have adequate air flow through it.

B. Touch suction and discharge lines – Soon after system start up you can safely feel the suction and discharge lines and note their change in temperature. The discharge line will get hot (after a while it may be to hot to touch) and the suction line will get cooler.

3. Check Sight Glass

The sight glass is the only point where you can actually see inside the air conditioner during operation. Check the sight glass through the window on the top of the receiver-drier (or the separate in-line sight glass). If the system is functioning properly and cooling the cab adequately, the sight glass should be clear (you will not see anything in it). If it is not clear when the system is first turned on, wait a few minutes for the system to stabilize, then look again. Figure 7-7 illustrates and explains what you may observe in the sight glass. Roof mounted condenser fans may run continuously or cycle on and off. If you can't tell by sound you may have to climb a ladder and observe the fan blades.

Figure 7-7
These drawings illustrate conditions you may observe in the sight glass window.



Note: A roof mounted condenser or AC unit assembly often includes a roof mounted receiver-drier (and sight glass) close to the condenser.

Heater System Inspection

A heater system inspection is really a combination engine cooling system and heater inspection. All heater/cooling system rubber parts deteriorate due to the air (ozone), heat, coolant and oils. They should be replaced at regular intervals to prevent breakdown on the road. Metal parts and gaskets are subject to malfunction or breakdown due to fatigue and corrosion.

Coolant has a limited life and should be replaced regularly. If it is dirty, the cooling system should be drained and flushed or back flushed (using special equipment) before refilling with clean water and anti-freeze. Coolant must be hot when using the hydrometer to check protection (freeze-up) level. The following inspection procedures are explained in more detail below:

1. Check Heater Control Valve Function
2. Inspect Other Functions

1. Check Heater Control Valve Function

Many air conditioner/heater systems depend on the heater control valve for temperature control and positive closure. You can easily check heater control valve function as follows.

A. Cool engine – Start with the engine cool, set the temperature to cold and leave the fan off. As the engine warms up, feel the heater return hose. If the hose feels warm or hot, the heater control valve is leaking internally. This type of leak can seriously reduce air conditioning performance.

B. Warm up engine – Next, let the engine warm up to normal operating temperature and set both fan and temperature on high. Feel both heater supply and return hoses. If there is a noticeable difference in their temperature, it indicates a low flow of coolant through the heater core (a partially closed or blocked heater control valve). This could result in poor heating performance during cold weather conditions.

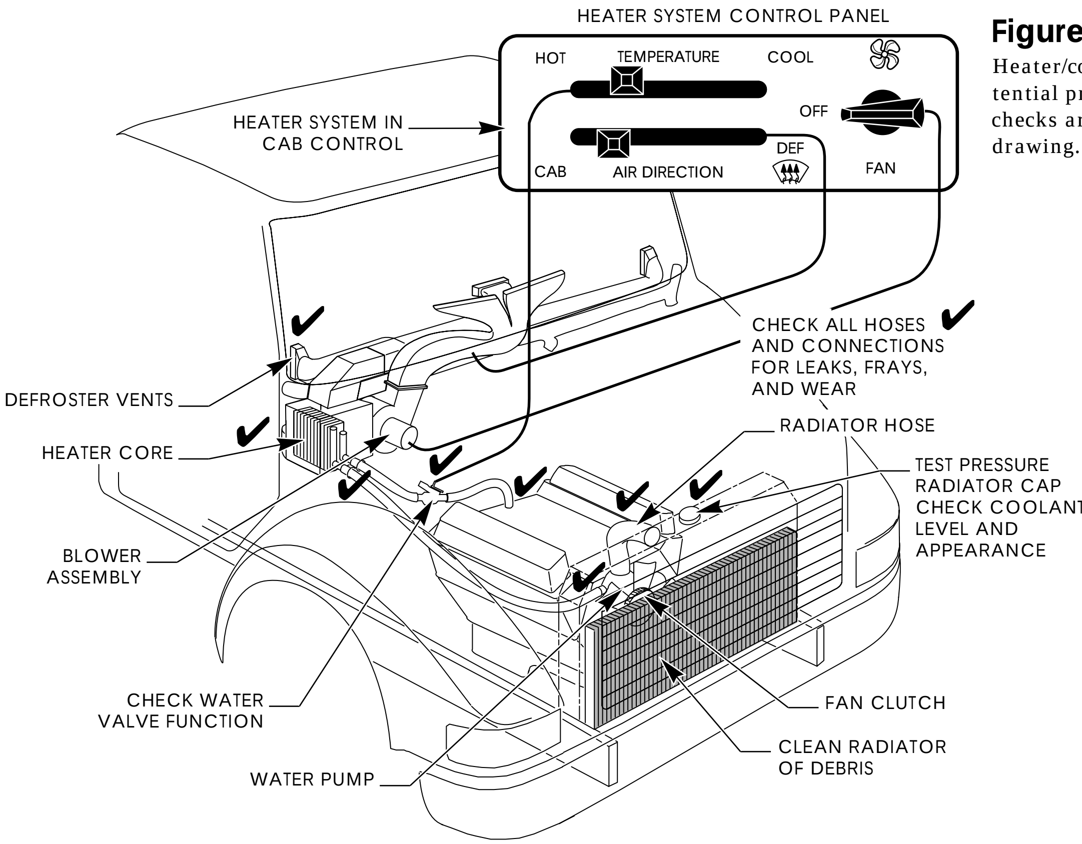


Figure 7-8

Heater/cooling system potential problem areas and checks are indicated in this drawing.

2. Inspect Other Functions

There are some things you can't see or feel when you inspect the thermostat, heater core, radiator pressure cap, electrical switch and control valve functions. Some of these can be checked with the pressure and thermostat testers as described in *Chapter 6*. A hand pump pressure tester can also be used to check for coolant leaks. This is done by using the pump to raise the pressure inside the system above normal operating pressure to force small suspected leaks to show up.

Heater/cooling electrical and valve component inspection is the same as air conditioner inspection. The controls are operated to see if they function correctly to maintain or vary cab temperature and air flow.

Preventive Maintenance Worksheet

Please feel free to modify or copy the worksheet in Figure 7-9. Actual vehicle use, mileage, operating conditions and maintenance budget may influence service frequency.

Chapter Review

The purpose of these brief inspection procedures is for vehicle system maintenance and to determine if further, more detailed service is required. The uses of a manifold gauge set, system troubleshooting, recovery, flushing, evacuating and charging are explained in the next chapter.

High usage and operating condition variations are tough on air conditioning and heater components. You should establish and follow regular inspection and maintenance procedures to improve overall system function and component service life.

The typical inspection should not take more than 15 to 20 minutes unless component replacement and/or complete system evacuation and recharging is warranted. The survey results shown in Figure 7-1, indicate belts, compressor clutch assembly, condenser and the refrigerant lines are the most frequent problem areas. However, your own experience with service and maintenance may vary from survey results.

Inspection should first be visual and by feel. Some of your electrical system inspection will be done as you inspect other components (checking leads, connections and for loose wires). When you check the electrical circuit, begin with the engine off but ignition on. A system performance inspection with the engine running and system on really combines electrical and AC or heater system function.

Figure 7-9 Preventive Maintenance Schedule.

RED DOT Custom HEATERS AND AIR CONDITIONERS ®

PREVENTIVE MAINTENANCE SCHEDULE FOR AIR CONDITIONING SYSTEMS

NOTE: Typical Maintenance Schedule: 3 months or 15,000 miles, 6 Months or 30,000 miles, 12 Months or 60,000 miles

Installation Date: ______________________ Mileage: ____________

Last Maintenance Check: ______________________ Mileage: ____________

Checked by ______________________ Mileage: ____________

COMPONENT	MAINTENANCE INTERVAL (months)			
	3*	6*	12*	DONE
1. COMPRESSOR				
Check noise level	•			❑
Check clutch pulley	•			❑
Check oil level	•			❑
Run system 5 minutes	•			❑
Check belts for tension (120 lb max.)	•			❑
Inspect shaft seal (leakage)		•		❑
Check mounting bracket (tighten bolts)		•		❑
Check alignment to clutch w/crankshaft drive pulley		•		❑
Perform manifold gauge check			•	❑
Verify clutch is engaging			•	❑
CONDENSER				
2. Clean dirt/bugs/leaves from coils (w/compressed air)	•			❑
Check inlet/outlet for obstructions/damage	•			❑
RECEIVER-DRIER				
3. Check inlet line from condenser (hot to touch)	•			❑
Check sight glass (streaks or cloudiness)	•			❑
Replace if system is opened			•	❑

COMPONENT	MAINTENANCE INTERVAL (months)			
	3*	6*	12*	DONE
4. EXPANSION VALVE				
Inspect capillary tube (leakage/damage/looseness)			•	❑
5. EVAPORATOR				
Clean dirt/bugs/leaves form fins/tubes (w/compressed air)			•	❑
Check solder joints on inlet/outlet tubes (leakage)			•	❑
Inspect condensate drain (R-12 or oil leak)			•	❑
6. OTHER COMPONENTS				
Check discharge lines (hot to touch)	•			❑
Check suction lines (cold to touch)	•			❑
Inspect fittings/clamps/hoses		•		❑
Check thermostatic switch (proper operation)			•	❑
Outlets in cab (temperature check; 40 to 50°F)		•		❑
Check fan clutch (proper operation)		•		❑
Inspect all wiring connections		•		❑
Operate manual controls through full functions	•			❑

The following require monthly maintenance:

*Compressor – run system at least 5 minutes (40 degrees Fahrenheit minimum outside temp.) in order to circulate oil and lubricate components.

Maintenance notes: ______________________

Chapter 8

Troubleshooting & Service Procedures

Click on any of these subject headings to go directly to the page

Can you fix an air conditioner or heater system without finding and correcting the cause of the problem? You bet you can! It happens every day and it's not good for business. Here is an example. A truck pulls in off the road and the operator asks to have his rig serviced in a hurry. He tells you the air conditioner isn't cooling like it should and dashes into the restaurant for lunch.

You tip the hood, and check the sight glass on top of the receiver-drier. You see bubbles, not a lot but a fairly constant stream of them. It is obvious the system is low on refrigerant so you hook up the manifold gauge set, purge the gauge set hoses of air, and add refrigerant until the sight glass clears. Then you check evaporator temperature and it's OK. **The air conditioner is repaired right?** Wrong! What you did is add refrigerant and the problem went away. You did not find and fix the cause of the problem.

Component failure in an air conditioning system may be the result of a problem elsewhere in the system. For example, a belt or clutch failure might be caused by a dirty condenser restricting air flow and increasing head pressures. High head pressures commonly create problems with other system components. **Take time to look beyond the obvious for a potential hidden problem.**

Troubleshooting Overview

Troubleshooting includes collecting enough information to locate the cause of the problem, then correcting the problem and its cause by replacement, adjustment, and/or repairing. You begin by gathering information from the most to the least important sources.

Starting with the most important:

1. Your personal knowledge and experience with AC systems.
2. The vehicle operator's knowledge and experience—question him or her.
3. The work order.
4. Good test equipment and the HVAC system

The routine you follow when troubleshooting should proceed from the most to least productive way of locating the problem and fixing the cause.

Experienced troubleshooters talk to the operator if they can, then personally verify the symptoms of the problem whenever possible. They attempt quick fixes on the basis of their knowledge of common system problems and causes when appropriate. They know where components are located, and make repairs when they have a good idea of what the problem is. They fix the cause or causes as well as the problem. They are confident of their knowledge and ability.

Note: **The best troubleshooters all know who to call when they get stuck.** They know someone who knows more than they do and are not too proud to ask for help or suggestions when needed. The key—understanding system function

The Key–Understanding System Function

Your complete understanding of AC and heater systems and how they work, plus what can go wrong, is the key to troubleshooting and repair. We have talked about components and system function before. Now let's take a little different approach in describing what happens when the air conditioner is turned on. In Figure 8-1 we have used numbers on the illustration to track normal air conditioner function.

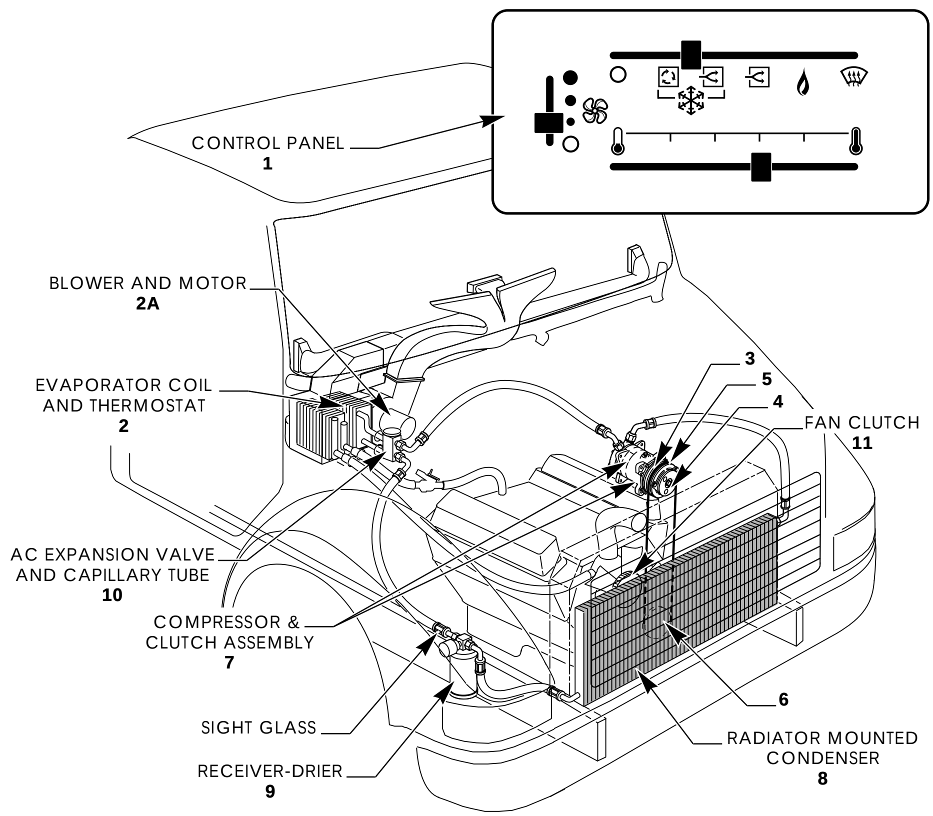


Figure 8-1

An illustration of the typical HVAC system. The numbers follow the action when the AC part of the system is working properly (moving heat out of the cab and into the outside air).

When you turn on the air conditioner at the control panel (1), the thermostat (2), is supposed to sense a warm temperature at the evaporator. A circuit in the thermostat should close, allowing current to flow through the thermostat to the compressor clutch field coil (3). When this happens, the clutch field coil becomes an electromagnet and pulls the clutch drive plate (4) tight against the clutch pulley (5).

Note: The same AC switch (1) may also turn on the fan or blower motor (2a) to circulate air in the cab. The air feels warm at first but will cool quickly.

A belt connects the clutch pulley to a drive pulley (6) on the engine. The engine provides the power to turn the clutch pulley and drive the compressor (7) when the clutch is engaged. When operating, the compressor compresses and pushes refrigerant gas to the condenser (8), through the receiver-drier (9), and to the expansion valve (10) orifice. When it does, it puts a lot of pressure on the gas. The compressor raises the temperature and pressure of the refrigerant inside the high side of the system.

At the same time, the compressor is also sucking in low pressure refrigerant gas from the expansion valve orifice, evaporator and through the low side of the system. The movement of the refrigerant inside the system transfers heat energy from the cab to the outside air for occupant comfort.

The automatic functions of the thermostat (or the pressure valve on some accumulators), and the expansion valve, help maintain pressures and temperatures inside the system at safe and efficient operating levels. Pressure and temperature are constantly changing due to compressor and expansion valve action, the amount of heat energy being moved and the environment or weather conditions.

The engine cooling system fan and clutch (11), and the evaporator blower motor (2a), move a sufficient amount of air through the condenser and evaporator. On the road, vehicle speed provides most of the (ram) air required for the condenser to work right. In a parked or slow moving vehicle the engine fan (or roof or remote mounted condenser and fans) moves sufficient air through the condenser fins.

Note: Clean refrigerant and refrigeration oil should be inside the system in the amount specified by the manufacturer. Moisture, sludge (moisture combined with refrigerant oil or desiccant), or desiccant particles will prevent the correct performance of the system and may cause component damage.

A Troubleshooting Example

Remember the story at the beginning of this chapter? The vehicle operator pulled in off the road and asked you to repair the rig. He was in such a hurry he didn't tell you anything except that the air conditioner wasn't cooling. Here is the best way to handle that kind of situation.

Use your knowledge and experience. Ask yourself what could have caused a lack of cooling in that rig! Did the compressor drive belt break? Did a pressure switch or relief valve cutout the compressor because of high or low system pressure? Does the switch or valve in this type of system reset itself? Could there be a superheat switch and thermal limiter with a melted fuse. Did someone else service the system recently and put in too much refrigerant?

Could there be contaminants in the system blocking the expansion valve (expansion tube)? If there is a leak, why and how did refrigerant get out of the system? You know if refrigerant can get out, air and moisture may get inside as well, especially if the leak is on the suction side of the system. Could there be a restriction to refrigerant flow in one of the high pressure lines because of a kink? From your knowledge and experience, you already know about these possibilities and others when you talk to the operator (before he has the chance to leave).

The right kind of questions can speed up troubleshooting and your service work by pinpointing the problem(s) that needs fixing. Your conversation with the operator might be as follows:

- *How long ago did the AC system stop cooling?*
  Answer: About an hour ago.

- *What steps did you take when you noticed the lack of cooling?*
  Answer: I put it on maximum cool.

- *Then what did you do?*
  Answer: When it wouldn't cool, I opened the window and turned the air conditioner off.

- *Is this problem new or has it happened before, and when?*
  Answer: In the last few days I've had problems with cooling off and on—this is the first time it's happened when I was close to a place that did AC service.

- *Do you get any cooling at all?*
  Answer: Yes but it seems to quit after a while.

- *Do you still get air flow at the vents from the blower?*
  Answer: Yes.

- *When was your air conditioner checked thoroughly?*
  Answer: Before I bought the rig last May (a year ago).

- *Has the heater been used recently and did it work OK?*
  Answer: Yes.

- *Have you had other service problems in the last few months?*
  Answer: No.

- *(If the answer was yes, you should ask—When? Where? What was fixed or replaced?).*

- *Finally, ask the operator if he or she has a wiring diagram for the system.*

Now let's look at the information you have gathered from the operator and what you know from experience. He believes the problem is that the AC system quits cooling after it has been on for a while! You know that the AC system has not been maintained since the rig was purchased a year ago. Because of that, there could be several causes for the problem (lack of cooling) and there may be other potential problems about to develop.

It is possible that some refrigerant has leaked. Moisture and other contamination may be inside the system. You have been told there are no heater problems, but that doesn't mean there are none that might affect AC system operation. The AC system has quit cooling several times in the last few days. The problem may have become more severe than when it quit cooling the first time.

If enough refrigerant or oil has leaked out, a low pressure cutout switch may have cut the circuit to the clutch, protecting the compressor. Because the system has not been maintained in a year, there may be other components that should be serviced. You could fix the probable causes, and the system might work and then break down again as the rig drives out of your place. From your knowledge and what the operator has just told you, you know this may not be a quick fix problem.

It's up to you to describe the service situation to the operator. Tell him you need to do a complete system maintenance inspection to find and correct the problem or other potential problems. He can give you the go ahead for full service and repair now, wait till you have inspected the system to determine cause and cost, or delay repair until he has some down time available.

Normally when the operator can tell you what the problem is, you would first operate the system to verify the problem. In this situation your troubleshooting (your own knowledge added to what the operator told you), indicates the next step. You need to do a complete maintenance inspection instead! Proceed as described in *Chapter 7*. Correct any obvious problems and check carefully for leaks. Leak testing should be visual, by feel and with a leak detector. Next, do your performance test with the engine running and the AC system on.

Note: Don't forget to check the heater system too! If the water valve is not closed, then hot engine coolant flowing through the heater core would warm the air at the same time the evaporator was trying to cool it. The result would be the appearance of an AC problem.

If your AC and heater visual, electrical and leak inspections don't turn up any problems, save time by hooking up the manifold gauge set before you make the performance test. If you find a leak and can correct it easily by tightening a connection, do so. But if too much refrigerant leaked out, you may have to add some refrigerant to the system for an effective performance test. We will get into detail on troubleshooting with gauges after we explain manifold gauge set installation and adding refrigerant.

Manifold Gauge Set Installation

CAUTION Never hook up the gauge set when the engine and air conditioner are running. Be sure all the valves on the manifold are closed all the way (turn them clockwise). Check the hose connections on the manifold for tightness.

Locate the low and high side system service fittings and remove their protective caps. Position or hang the manifold gauge set in a convenient location. Figure 8-2 illustrates a good example of manifold gauge set hookup in one service situation.

Figure 8-2
A typical manifold gauge set hookup is shown in this illustration. The center hose on the gauge set is connected to the vacuum pump.

The manifold gauge set is a necessary tool in troubleshooting AC system problems. The following steps are performed during and after installing the manifold gauge set:

1. Purging Air from the Gauge Set Hoses
2. Adding Refrigerant to the System
3. Stabilizing the AC System.

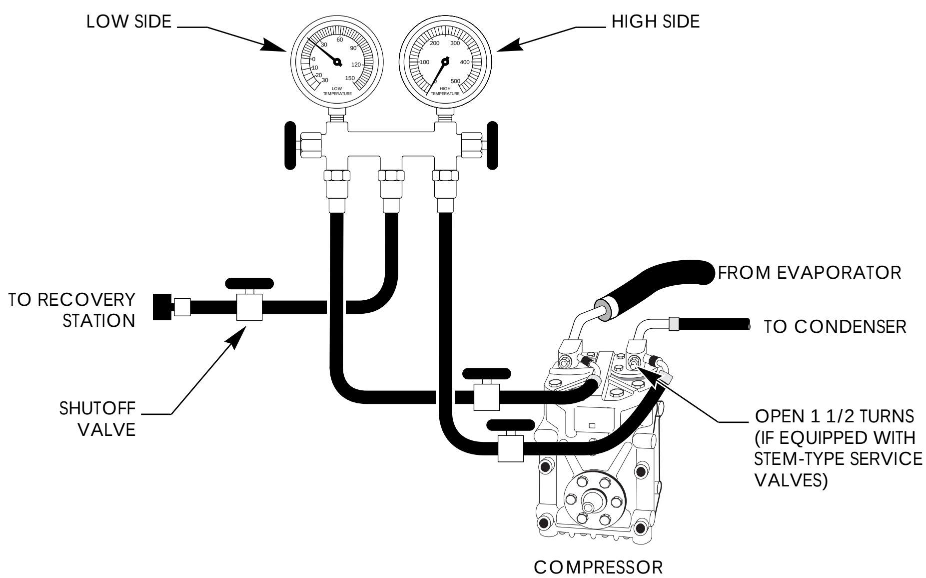
1. Purging Air From Gauge Set Hoses

Environmental regulations require that all service hoses have a shutoff valve within 12 inches of the service end. These valves are required to ensure only a minimal amount of refrigerant is lost to the atmosphere. R-12 gauge set hoses have a valve near the end of all three hoses. R-134a gauge sets have a combination quick disconnect and shutoff valve on the high and low sides. The utility (center) hose also requires a valve.

The initial purging is best accomplished when connected to recovery or recycle equipment. Figure 8-3 illustrates the gauge set connections for purging and refrigeration recovery.

Figure 8-3

The purging setup for manifold gauge set and compressor service valves are shown here.



Note: The manifold gauges read system pressure when the hand valves are closed if the hose end valves, and the stem type service valves (if included) are open.

2. Adding Refrigerant to the System

Now that the gauges are connected, you may need to add some refrigerant to the AC system before you can do an effective performance inspection. However, if leaks are obvious they should be repaired prior to adding refrigerant.

Note: Loss of some refrigerant is not unusual over an extended period of time. Adding refrigerant is a typical procedure when the AC system is maintained on a regular basis.

When adding refrigerant to the system, connect the center hose from the manifold gauge set to the refrigerant dispensing valve on the container. Figure 8-4 illustrates this connection.

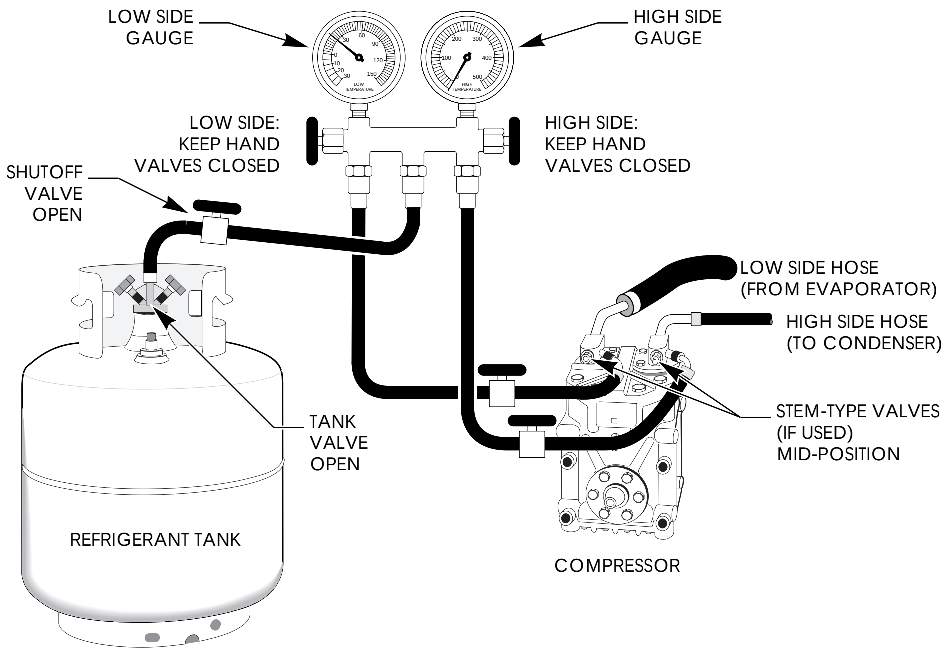


Figure 8-4

In this illustration we have noted how refrigerant is added to the air conditioner.

Before adding refrigerant to the system you should study the sight glass while the engine is running and the air conditioner is on. Even if you found a leak during the system inspection and corrected it, you have no way of knowing how much refrigerant has leaked. You will not be able to tell how much refrigerant is in there, but you can see if bubbles are present.

Then check the gauges for unusually high or low readings, or a lack of pressure. Following this procedure, and using your knowledge and experience, decide if it is safe and makes sense to add refrigerant in order to make your full performance inspection.

You are now ready to add refrigerant to the system. For your safety and to prevent system damage use the following procedure.

1. Turn on the engine and set the idle at 1200 to 1500 RPM and then turn on the air conditioner.

CAUTION Do not open the high pressure hand valve on the manifold gauge set. The compressor could pump refrigerant into the container and cause it to BURST. Be sure to keep the refrigerant container upright to prevent liquid refrigerant from entering the compressor.

2. Open the refrigerant dispensing valve on the container and then the low pressure hand valve on the manifold. This allows refrigerant to enter the system as a gas on the low pressure or suction side of the compressor. The compressor will pull refrigerant into the system.

3. Add refrigerant until the gauges read in the normal range and the sight glass appears clear. The sight glass may not be clear for a moment just before or after the clutch cycles on and off but should generally be clear. Gauge readings will fluctuate as the compressor cycles on and off.

Note: Pressures within the air conditioning system vary with ambient temperature. A normal pressure range is defined as follows:

Low side	15–30 PSIG
High side	150–280 PSIG

If R-134a is used in place of R-12 the high side readings will be about 20 PSI higher. For this reason many OEMs are recommending an increase in condenser capacity when retrofitting to the new refrigerant, R-134a.

CAUTION If the gauges show any abnormally high or low pressures as you are adding refrigerant, stop and investigate for probable cause. Never add more than one pound of refrigerant. If the system is low enough on refrigerant to require more than that amount you should stop and check again for leaks. Then recover all of the refrigerant, repair, evacuate and recharge the air conditioner. (See *Chapter 9*). You may want to add dry nitrogen gas to the AC system instead of R-12 if pressures are below normal and a leak is suspected. Nitrogen gas is sold in cylinders under high pressure, 1800 to 2000 PSI. Be sure the cylinder has a pressure regulating valve to control the pressure when dispensing nitrogen gas. Dispose the gas at no more than 200-250 psi, as this is sufficient pressure to cause or indicate a leak point. See note under *Troubleshooting by Manifold Gauge Set Readings* in this chapter.

4. When the gauges show normal, close the hand valve on the manifold, the hose end shutoff valve, and the valve on the refrigerant container. You can now proceed with the performance inspection.

3. Stabilizing The AC System

For reliable gauge readings as an aid in troubleshooting, the AC system must be stabilized.

CAUTION Be sure your tools and test equipment are clear of all moving parts of the engine and air conditioner.

Start the engine and set to a fast idle of 1200 to 1500 RPM. Turn on the air conditioner. After a quick in-cab performance test of control function, blower speeds and air flow, set the AC system controls to maximum cooling and blower speed on high. All windows must be closed. If cab temperature is hot (rig has been sitting in the sun with the windows closed), open the windows for a minute or so to let the hot air out. Run the engine and air conditioner about five minutes for the system to stabilize. In hot humid weather or where the AC condenser can't receive adequate air flow from the engine fan you may have to use a floor mounted fan to force sufficient air flow through condenser fins. This helps to stabilize the system by simulating ram air flow found under normal operating conditions.

When a vehicle has a tilt cab or hood and the condenser is part of the grill, you must use the floor fan to get air to the condenser. You could tilt the cab or hood back to normal position, carefully routing the manifold gauge set and hoses away from moving parts. Then place the gauges so you can read system pressure.

Troubleshooting by Manifold Gauge Set Readings

The series of figures that follow (Figures 8-6 through 8-15) show gauges with typical readings indicating AC system problems. Each figure is followed by troubleshooting tips, probable causes for the gauge readings shown, and appropriate service and repair procedures.

Low Refrigerant Charge in the System

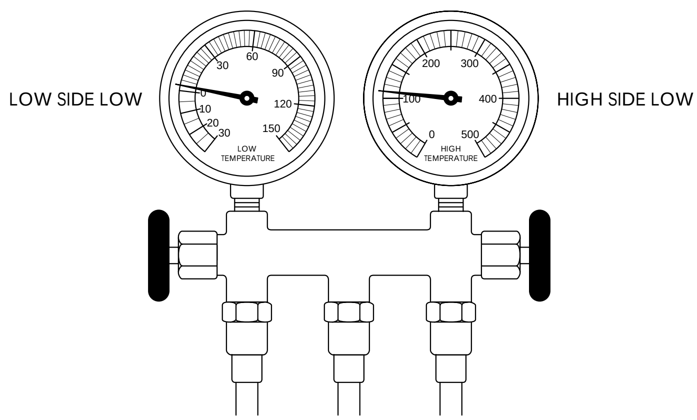


Figure 8-5

Gauge reading, low refrigerant charge in the system.

Tip:	You see bubbles in the sight glass. The air from vents in the cab is only slightly cool.
Cause:	Insufficient refrigerant (charge) in the system.

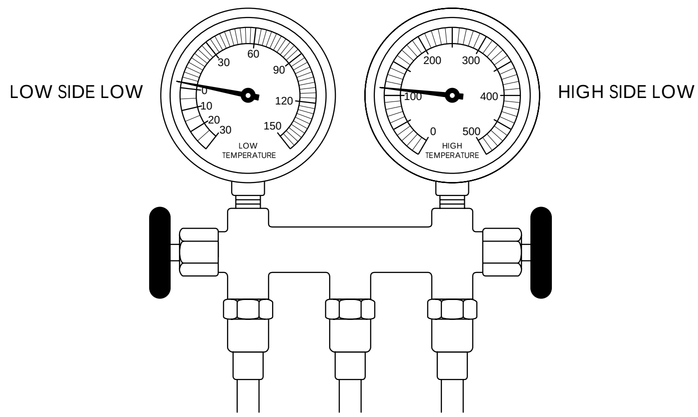
Repair Procedure:

Check for leaks with your leak detector. If you find a leak at a connection, tighten it then add refrigerant as necessary. If a component or line is leaking (defective), recover all refrigerant from the system. Replace the defective part and then check the compressor oil level and replace missing oil. Evacuate and recharge with refrigerant, then check AC operation and performance.

Figure 8-6

Gauge reading, extremely low refrigerant charge in system.

Extremely Low Refrigerant Charge in the System



Tip: The sight glass is clear or shows oil streaks. The air from vents in the cab seems warm. If there is a low pressure or Trinary™ switch in the system it may have shut off the compressor (clutch).

Cause: Extremely low or no refrigerant in the system. There is a leak in the system.

Repair Procedure:

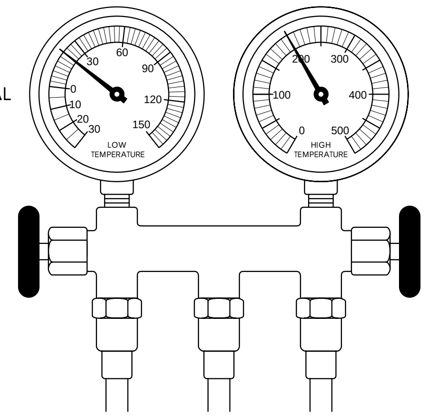
Add refrigerant to the system, at least half of the normal full charge amount. Then perform your leak test. As an alternative to a refrigerant, add dry nitrogen gas to the system and then test for leaks.

Note: It may be necessary to use a jumper wire to bypass some types of low pressure cutout switches to operate the compressor (clutch) when you add refrigerant to the system.

After finding a leak, recover all refrigerant from the system and repair the leak. Check the compressor and replace any refrigeration oil lost due to leakage. Evacuate and recharge the system with refrigerant, then check AC operation and performance.

Air and/or Moisture in the System

LOW SIDE NORMAL



HIGH SIDE NORMAL

Figure 8-7

Gauge reading, air and/or moisture in the system.

Tip: The sight glass may be clear or show some bubbles. The air from vents in the cab is only slightly cool. In a cycling clutch type system with a thermostatic switch, the switch may not cycle the clutch on and off, so the low pressure gauge will not fluctuate.

Cause: Air and/or moisture in the system.

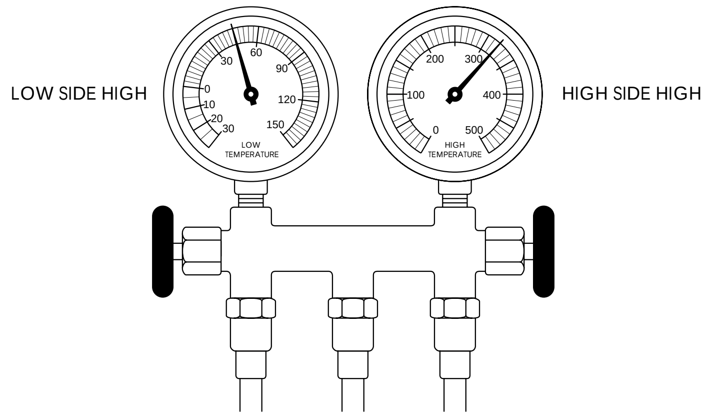
RepairProcedure:

Test for leaks, especially around the compressor shaft seal area. When the leak is found, recover refrigerant from the system and repair the leak. Replace the receiver-drier or accumulator because the desiccant may be saturated with moisture (there is no way to tell). Check the compressor and replace any refrigeration oil lost due to leakage. Evacuate and recharge the system with refrigerant, then check AC operation and performance.

Figure 8-8

Gauge reading, excessive air and/or moisture in the system.

Excessive Air and/or Moisture in the System



Tip: There may be occasional bubbles in the sight glass. Air from vents in the cab is only slightly cool.

Cause: System contains excessive air and/or moisture.

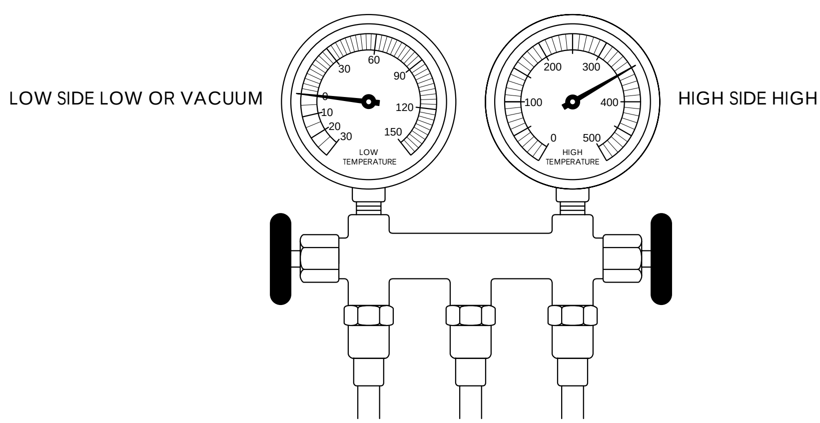
Repair Procedure:

Test for leaks, recover refrigerant from the system and repair the leak. Depending on the type of system, replace the receiver-drier or accumulator. The desiccant is saturated with moisture. Check and replace any compressor oil lost due to leakage. Evacuate and recharge the system, then check AC operation and performance.

Figure 8-9

Gauge reading, expansion valve (TXV) stuck closed.

Expansion Valve (TXV) Stuck Closed or Plugged



Tip: Air from vents in the cab is only slightly cool. The expansion valve body is frosted or sweating.

Cause: An expansion valve malfunction could mean the valve is stuck in the closed position, the filter screen is clogged (block type expansion valves do not have filter screens), moisture in the system has frozen at the expansion valve orifice, or the sensing bulb is not operating. In vehicles where the TXV and sensing bulb are accessible, perform the following test. If not accessible, then proceed to *Repair Procedure.*

Test:

1. Warm diaphragm and valve body in your hand or carefully with a heat gun. Activate system and watch to see if the low pressure gauge rises.

2. Next, carefully spray a little nitrogen, or any substance below 32 degrees Fahrenheit, on the capillary coil (bulb) or valve diaphragm. The low side gauge needle should drop and read at a lower (suction) pressure on the gauge. This indicates the valve was part way open and that your action closed it. Repeat the test, but first warm the valve diaphragm or capillary with your hand. If the low side gauge drops again, the valve is not stuck.

3. Clean the surfaces of the evaporator outlet and the capillary coil or bulb. Make sure the coil or bulb is securely clamped to the evaporator outlet tube and the insulation is in place. Next proceed with recovering refrigerant from the system.

Repair Procedure:

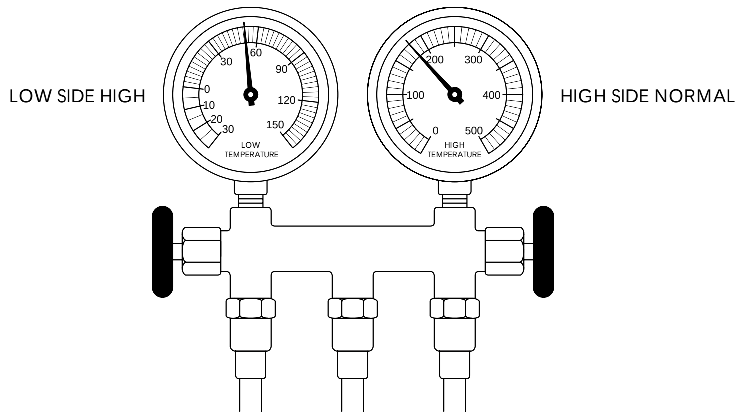
Inspect the expansion valve screen (except block type valves). To do this you must recover all refrigerant from the system. Disconnect the inlet hose fitting from the expansion valve. Remove, clean and replace the screen, then reconnect the hose. Any signs of contamination will **require** flushing the system. Next, replace the receiver-drier. Then evacuate and recharge the system with refrigerant, and check AC operation and performance.

Note: If the expansion valve tests did not cause the low pressure gauge needle to rise and drop, and if the other procedures described did not correct the problem, the expansion valve is defective. You must recover all refrigerant from the system again, and replace the expansion valve and receiver-drier. Evacuate and recharge the system with refrigerant, then check AC operation and performance.

Figure 8-10

Gauge reading, expansion valve (TXV) stuck open.

Expansion Valve (TXV) Stuck Open



Tip: Air from vents in the cab is warm or only slightly cool.

Cause: The expansion valve is stuck open and/or the capillary tube (bulb) is not making proper contact with the evaporator outlet tube. Liquid refrigerant may be flooding the evaporator making it impossible for the refrigerant to vaporize and absorb heat normally. In vehicles where the TXV and sensing bulb are accessible, check the capillary tube for proper mounting and contact with the evaporator outlet tube. Then perform the following test. If the TXV is not accessible, then proceed to *Repair Procedure.*

Test:

1. Operate the AC system on it's coldest setting for a few minutes. Carefully spray a little nitrogen or other cold substance, on to the capillary tube coil (bulb) or head of the valve.

2. The low pressure (suction) side gauge needle should now drop on the gauge. This indicates the valve has closed and is not stuck open. Repeat the test, but first warm the valve diaphragm with your hand.

3. If the low side gauge shows a drop again, the valve is not stuck. Clean the surfaces of the evaporator outlet and the capillary coil or bulb. Make sure the coil or bulb is securely fastened to the evaporator outlet and covered with insulation material. Operate the system and check performance.

Repair Procedure:

If the test did not result in proper operation of the expansion valve, the valve is defective and must be replaced. Recover all refrigerant from the system and replace the expansion valve and the receiver-drier. Evacuate and recharge the system with refrigerant, then check AC operation and performance.

System High Pressure Side Restriction

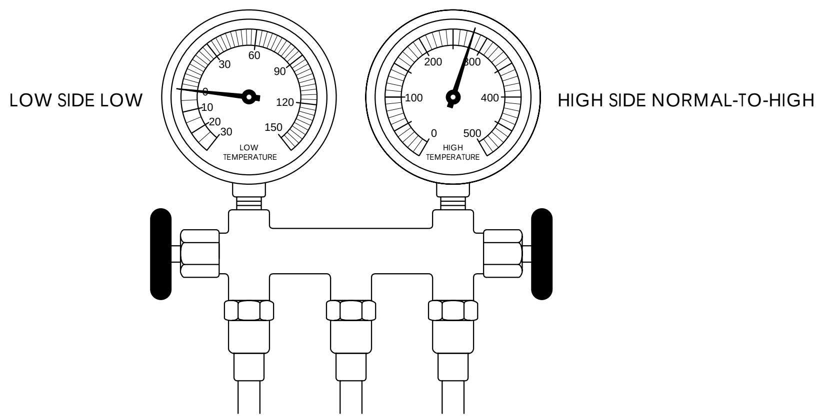


Figure 8-11
Gauge reading, system high pressure side restriction.

Tip: Air from vents in the cab is only slightly cool. Look for sweat or frost on high side hoses and tubing, and frost appearing right after the point of restriction. The hose or line may be cool to the touch near the restriction.

Cause: There could be a kink in a line, or other restriction in the high side of the system.

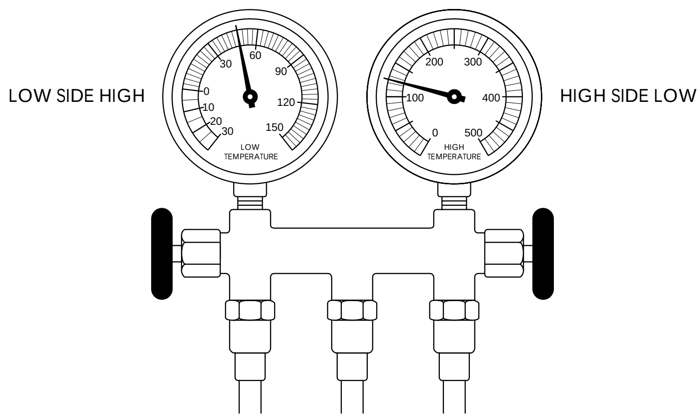
Repair Procedure:

After you locate the defective component containing the restriction, recover all of the refrigerant. Replace the defective component and the receiver-drier. Evacuate and recharge the system with refrigerant, then check AC operation and performance.

Figure 8-12

Gauge reading, compressor malfunction.

Compressor Malfunction



Tip: The compressor may be noisy when it operates.

Cause: Defective reed valves or other compressor components. If the compressor is not noisy, there may be a worn or loose compressor clutch drive belt.

Repair Procedure:

If you find the belt worn or loose, replace or tighten it and recheck system performance and gauge readings. To inspect and service the compressor, you must isolate (front seat the stem type compressor service valves) and recover refrigerant, or fully recover R-12 from systems containing Schrader valves. Remove the compressor cylinder head and check the appearance of the reed valve plate assembly. If defective, replace the valve plate and install with new gaskets, or replace the compressor assembly.

If you find particles of desiccant in the compressor, remove and replace it and the receiver-drier. Before doing so, back flush other system components (except the expansion valve) using a flushing kit. If there are stem type valves and you isolate the compressor, the rest of the system must be purged of refrigerant before you can disconnect and flush system components (*Chapter 9* describes the flushing procedure). After flushing, reassemble the components. Always check the oil level in the compressor, even if you install a new or rebuilt unit. Tighten all connections and evacuate the system. Recharge the air conditioner with refrigerant and check system operation and performance.

Note: Rotary compressors have a limited oil reservoir. Extra oil must be added for all truck installations

Condenser Malfunction or System Overcharge

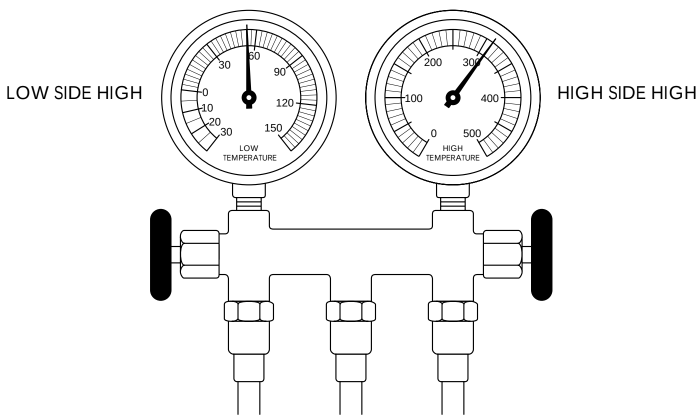


Figure 8-13
Gauge reading, condenser malfunction or system overcharge.

Tip: The air from vents in the cab may be warm. In R-12 systems there can be bubbles in the sight glass. The high pressure hoses and lines will be very hot. Don't forget to check the engine cooling system components—fan and drive belt, fan clutch operation, and the radiator shutter.

Cause: The condenser is not functioning correctly or there may be an overcharge of refrigerant inside the system. Another possibility is lack of (ram) air flow through the condenser fins during testing. Engine cooling system component malfunction can cause high pressure by blocking air flow (radiator shutter) or not providing air flow (fan clutch) in sufficient quantity.

Repair Procedure:

Inspect the condenser for dirt, bugs or other debris and clean if necessary. Be sure the condenser is securely mounted and there is adequate clearance (about 1-1/2 inches) between it and the radiator. Check the radiator pressure cap and cooling system, including the fan, fan clutch, drive belts and radiator shutter assembly. Replace any defective parts and then recheck AC system operation, gauge readings and performance.

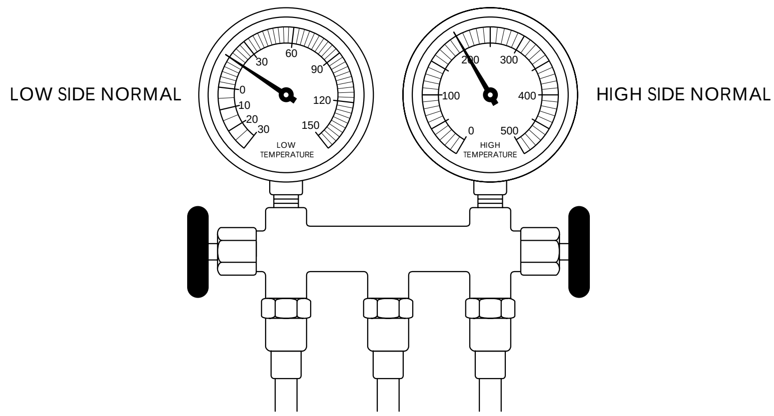
If the problem continues, the system may be over- charged (have too much refrigerant inside). Recover the system slowly until low and high pressure gauges read below normal, and bubbles appear in the sight glass. Then add refrigerant (charge the system) until pressures are normal and the bubbles disappear. Add another quarter to half pound of refrigerant and recheck AC system operation, gauge readings and performance.

If the high gauge readings do not change, you should recover all of the refrigerant and flush (it may be partially plugged) or replace the condenser. Also replace the receiver-drier or accumulator. Then connect the components and evacuate the system. Recharge the air conditioner with refrigerant and check system operation and performance.

Figure 8-14

Gauge reading, thermostatic switch malfunction.

Thermostatic Switch Malfunction



Tip: The low side gauge needle may fluctuate in a very narrow range compared to a normal range. The compressor clutch may be cycling on and off more frequently than it should.

The low side gauge needle may fluctuate in an above normal range as the clutch cycles. This may be an indication that the thermostat is set too high (someone may have attempted to adjust the factory setting). A new thermostat may have been installed incorrectly (capillary tube not inserted between the evaporator fins in the proper position).

Cause: The thermostatic switch is not functioning properly or at all.

Repair Procedure:

Replace the thermostatic switch. When you remove the old thermostat, replace it with one of the same type. (They operate in a factory preset temperature range.) Take care in removing and handling the thermostat and thin capillary tube attached to it. Don’t kink or break the tube.

Position the new thermostat capillary tube at or close to the same location and seating depth between the evaporator coil fins as the old one. Connect the electrical leads.

Note: See the *Thermostat* section in *Chapter 10*. Fan clutch, radiator shutter, condenser, compressor, and the newer air and water valve control systems are covered in *Chapter 10*.

Review of Frequent Problem Areas

In HVAC systems a limited number of things can go wrong. Moving parts of the compressor, clutch, and expansion valve or refrigerant metering device can malfunction or break down from metal fatigue, contamination, abnormal pressure or lack of lubrication. Electrical connections may corrode, become disconnected or break. Fuses blow from shorts or overload. Belts slip or break.

Vibration from the engine or road surface can work bolts and air or vacuum lines loose, or rub and break or wear parts out. Motors may burn out. The inside of the system can become contaminated from moisture, air or desiccant material breakdown. Refrigerant may leak out of the system quickly or very slowly. Moisture in the system can combine with refrigerant to form acid and attack (corrode) metal parts from the inside. Moisture and refrigeration oil can combine to form sludge that may block refrigerant flow.

The following problems are discussed in more detail in this section:

1. Belts and Compressor Clutch
2. Condenser
3. Refrigerant Lines, Hoses, and Fittings
4. Refrigerant Metering Valves
5. Other Problems

1. Belts and Compressor Clutch

Let's review problem areas listed at the beginning of *Chapter 7*. The most frequent repairs are replacing belts and servicing or replacing the compressor or clutch. Heavy duty vehicle operation puts a lot of stress on these parts. There are several main reasons.

There is often continuous operation for long periods of time. There may be frequent sudden RPM variations when shifting gears up or down. For this reason the AC clutches used in heavy duty systems usually have double row ball bearings. Vibration and road shock contribute to loose or broken mounting brackets, electrical connections and fittings. Belts, bearings and compressor reed valves wear out.

Various compressor clutch cutout switches are used because the AC designers know about compressor operating conditions. System leaks, high operating pressures, malfunctioning engine cooling system components—all cause compressor problems and failures. When refrigerant and refrigeration oil leaks out of a system or there is contamination blocking oil flow, the compressor will be starved for oil and seize.

2. Condenser

Condensers get dirty and the dirt reduces heat movement by insulating the condenser. The fittings come loose or break from stress if the condenser or connecting hoses are not secured properly to keep the effects of vibration at a minimum.

Heat transfer efficiency and pressure in the condenser are affected by the amount of outside air flowing through condenser fins. A lack of air flow can mean the refrigerant doesn't give up enough heat energy to the outside air (it doesn't change state). The refrigerant arrives at the evaporator as a gas and can't pick up any heat energy from cab air. In the cab, air from the vents is only slightly cool or warm.

One possible cause of condenser malfunction could be the engine cooling system. This is why fan clutches and radiator shutters are often controlled or overridden by AC switch function. In fact, we can add fan clutch, radiator shutters and also fan motors to condenser problems. If they don't function to allow sufficient air through the condenser, pressure inside the system may become dangerously high. A lack of air through the condenser fins can raise high side pressure and blow out the weakest point in a system, or damage the compressor.

3. Refrigerant Lines, Hoses and Fittings

Problems with these parts may be caused by normal deterioration, vibration damage, lack of maintenance or human error (improper installation or replacement). All rubber parts are attacked by ozone (oxygen) in the air. Rubber parts break down slowly and become more vulnerable to the effects of vibration with the passage of time.

Heavy duty vehicle vibration causes stress on all lines, fittings and connections. Regular maintenance includes checking and tightening any suspect line, or hose retainers, or grommet position where the grommet is protecting a line or hose from abrasion. Any insulating material wrapped around hoses must be in place and securely fastened.

4. Refrigerant Metering Valves

When you consider valve problems there are obvious differences in valve construction and what can go wrong. If a valve is clogged with sludge or other obstruction, the result is a valve problem but the cause is contamination in the system. Valves get stuck open or closed, although most often closed when the gas charge is lost from the diaphragm housing in a traditional TXV. The capillary tube can vibrate loose from the evaporator outlet tube. The capillary can break and the small quantity of temperature sensitive gas can escape. The diagnosis of a valve as defective calls for replacement.

5. Other Problems—Leaks, Moisture, and Adding

Refrigerant

Before any refrigerant was put inside the AC system, someone used a vacuum pump to evacuate any air and moisture. Vacuum is really a force pulling against all hoses, fittings and components from the inside. When the system is charged with refrigerant, the pressure goes from minus (a vacuum) to plus pressure inside the hoses and all components. The refrigerant and refrigeration oil are trying to escape from the system at all times.

Technicians frequently add refrigerant to a system, replacing refrigerant seepage through system connections or fittings. If the system has been maintained regularly (every three to six months), adding a small amount of refrigerant may result in normal system function. However, the best procedure is to check all connections and look for, find and repair any leaks before adding refrigerant.

When your leak detector indicates the presence of a leak, you can't tell how long the system has been leaking. Finding one leak doesn't mean there are not others. Until you have some AC system work experience, it will be hard to guess how much refrigerant may have leaked. If you have to top a system off with a half pound of refrigerant or more, adding refrigerant is not the answer.

Find the leak. Recover all of the refrigerant and repair the system. The moisture absorbing capacity of any desiccant material is limited and cannot be measured. For that reason, replace the receiver-drier or accumulator. Then evacuate the system for an hour and recharge with refrigerant.

When a compressor shaft seal has leaked oil and the refrigerant charge is a little low, the shaft seal may have leaked because the air conditioner was not used. The seal can get a little out of round from the weight of the crankshaft and leak above the shaft. Running the compressor may cause the seal to swell and close up the leak. The shaft rotation exerts force all around the seal and puts life back into it. To prevent this from happening, manufacturers recommend regular AC system operation a minimum of every couple of weeks even in cool weather.

Keep in mind that the compressor can cause a vacuum inside the system if there is a restriction in the system. That means it can suck air and moisture inside under some conditions. It will pull these contaminants in through the same space where refrigerant and refrigerant oil has leaked out.

Conclusion

What could the air conditioning problem and it's cause have been at the beginning of this chapter? The operator was in a hurry, but you were able to start your troubleshooting with the answers he gave you. Problems your inspection may have turned up are a very low refrigerant charge, a contaminated system or defective compressor. Those are not quick fix jobs.

On the other hand, you might have found enough debris on the condenser fin surface to boost high side pressures to an abnormal level during the hottest part of the day. So the Trinary™ or high pressure switch would cut out from high pressure—but reset itself. You cleaned the condenser, added a half pound of refrigerant and AC system pressures and function returned to normal. Service and repair took a half hour. But there was no way to tell without using your knowledge and experience. By now you are pretty familiar with AC system problems, the reasons for some of them, troubleshooting and repair. In *Chapter 9* we will describe complete system purging, evacuation, flushing and recharging.

Chapter 9

Refrigerants

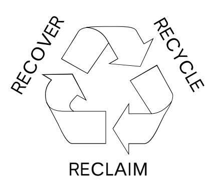
Click on any of these subject headings to go directly to the page

Description and Properties of Refrigerants

Refrigerants are contained in the closed system of an air conditioner and circulate under pressure, moving heat energy from the cab to the outside air. Different refrigerants require different operating pressures, causing the refrigerant to undergo a "change of state" (refer to *Chapter 1 — HVAC Function*).

Changes in Service Procedures

Since the beginning of 1992, the EPA has required that any refrigerant removed from an AC system be recovered and recycled before reuse. Unlike the purging process which releases ozone depleting refrigerant into the atmosphere, the recovery processes allow us to use the same refrigerant over and over.



A major difference between purge and recovery/recycle procedures is the refrigerant is contained in an externally sealed container when undergoing recovery/ recycle procedures in order to ensure environmentally safe processing.

In order to reuse a refrigerant in an AC system, the following steps are required:

1. Prepare the station for the recovery process
2. Recover refrigerant from the AC system
3. Recycle the recovered refrigerant
4. Perform the maintenance or repair the system
5. Flush the AC system when necessary
6. Evacuate the AC system
7. Charge the AC system with recycled refrigerant

Recycling the refrigerant involves the following processes:

- **Recovery** — You recover a refrigerant when you remove it from an AC system (in order to repair or replace a component) and then store, transport, recycle, or reclaim it. This is a closed loop process. The recovered refrigerant may vary in quality. Refer to the *Recovering and Recycling the Refrigerant* section for a complete description of the recovery process.
- **Recycle** — You recycle a refrigerant when you remove contaminants such as moisture, acidity, and particulate matter. Many refrigerants are reusable at this stage. Refer to the *Recovering and Recycling the Refrigerant* section for a complete description of the recycle process.
- **Reclaim** — You reclaim a refrigerant when you send it to an outside facility which can restore it to a new product specification. This reprocessing usually includes both a chemical analysis and distillation of the recycled refrigerant. Refer to the *Reclaiming the Refrigerant* section for a complete description of the recycle process.

Recharging an AC system requires the following procedures:

- **Flush** — You flush certain AC system components and hoses to remove contaminants within them. Flushing prepares the AC system for the new refrigerant. Refer to *Flushing the AC System* section below.
- **Evacuate** — You evacuate the AC system to remove moisture and air. Refer to the *Evacuating and Charging the AC System* section below.
- **Charge** — You charge the AC system by adding new refrigerant to the system.

Recovering and Recycling the Refrigerant

Recovery/Recycle Station

When troubleshooting indicates that a component in a closed AC system be replaced or removed for service, refrigerant must be removed from the system. A handy, dual purpose station performs both recovery and recycle procedures allowing us to follow the new guidelines for handling used refrigerant. The recovered refrigerant can then be recycled to reduce contaminants, and reused.

Equipment is also available to just remove or extract the refrigerant. Extraction equipment does not clean the refrigerant. It is used to recover the refrigerant from an AC system prior to servicing.

To accomplish this, the recovery/recycle station separates the oil from the refrigerant and filters the refrigerant multiple times to reduce moisture, acidity, and particulate matter found in a used refrigerant.

CAUTION	Mixing refrigerant types damages equipment. Dedicate one recovery/recycle station to each type of refrigerant processing to avoid equipment damage.

Figure 9-1 shows a recovery/recycle machine. Recycle equipment must meet certain standards as published by the Society of Automotive Engineers and carry a UL approved label. The basic principals of operation remain the same for all machines, even if the details of operation differ somewhat.

Figure 9-1
Recycle station.

A full system recovery is not necessary when you service or replace a compressor with stem type service valves. These valves may be front seated to isolate the rest of the AC system from the compressor. The refrigerant stays in the system and only the refrigerant in the compressor is recovered, recycled and replaced.

Note: Keep the collection cylinder in an upright position for the duration of the recovery/recycle cycle to ensure no liquid is drawn back into the system.

Draining the Oil from the Previous Recovery Cycle

In preparation for recovery, do the following:

1. Place the power switch and the controller on the recovery unit in the OFF position.
2. Plug in the recovery station to the correct power source.
3. Drain the recovered oil through valve marked OIL DRAIN on the front of the machine.
4. Place the controller knob in the ON position. The low pressure gauge will show a rise.
5. Immediately switch to the OFF position and allow the pressure to stabilize. If the pressure does not rise to between 5 psig and 10 psig, switch the controller ON and OFF again. With practice, this procedure should become easier.

6. When the pressure reaches 5 to 10 psig, open the OIL DRAIN valve, collect oil in an appropriate container, and dispose of container as indicated by local, state, or Federal Regulation. THE OIL IS NOT REUSABLE, DUE TO CONTAMINANTS ABSORBED DURING ITS PREVIOUS USE.

Performing the Recovery Cycle

You are now ready to recover. Follow these steps:

1. Be sure the equipment you are using is designated for the refrigerant you intend to recover.
2. Record the sight glass oil level. Having drained it, it should be zero.
3. Check the cylinder refrigerant level before beginning recovery to make sure you have enough capacity.
4. Confirm that all shut-off valves are closed before connecting to the AC system.
5. Attach the appropriate hoses to the system being recovered.
6. Start the recovery process by operating the equipment as per the manufacturer's instructions.
7. Continue extraction until a vacuum exists in the AC system.
8. If an abnormal amount of time elapses after the system reaches 0 psig and does not drop steadily into the vacuum range, close the manifold valves and check the system pressure. If it rises to 0 psig and stops, there is a major leak. Refer to *Chapter 8* for troubleshooting leak procedures.
9. Check the system pressure after the recovery equipment stops. After five minutes, system pressure should not rise above "0" gauge pressure. If the pressure continues to rise, restart and begin the recovery sequence again. This cycle should continue until the system is void of refrigerant.
10. Check the sight glass oil level to determine the amount of oil that needs to be replaced.
11. Mark the cylinder with a RECOVERED (red) magnetic label to reduce the chance of charging a system with contaminated refrigerant. Keep a record of the amount of refrigerant recovered, if you have the capability.

WARNING Check the sight glass oil level to determine the amount lost during recovery. You must add this amount of oil back into the system.

Performing the Recycling Procedure

The recovered refrigerant contained in the cylinder must undergo the recycle procedure before it can be reused. The recycle or clean mode is a continuous loop design and cleans the refrigerant rapidly. Follow equipment manufacturer's instructions for this procedure.

Purging Non-Condensable Gases (Air)

During purging and refrigerant recovery air can be entrapped in the refrigerant container. Air must not be put into an AC system. The result is higher operating pressures and possible system damage.

A simple check can be performed as follows:

1. Store the recovered refrigerant at constant temperatures above 65° F (18.7° C). The container should include a pressure gauge reading to 1 psi increments. The container should not be in direct sunlight or near a heat source.
2. Use a calibrated thermometer to establish temperature within 4 inches of the container.
3. Compare the pressures for like temperatures in Figure 9-2. Note the separate charts for R-12 and R-134a. If the container pressure is equal to or less than the pressure shown in the table, excess air is not present.
4. If container pressure is greater than shown in the table, connect the container to recovery or recycle equipment with the pressure gauge in place.
5. Bleed a small amount of vapor from the container until the pressure is below that shown on the table, then close the valve.
6. Tank temperature may change during the bleed off process. Mild shaking will assist in temperature stabilizing, but it is a good idea to let it set for several hours before again checking pressure against the table.
7. If the pressure remains above that shown on the table, excess air or another contaminant (i.e., another refrigerant) is still present. This material must be recycled or reclaimed.
8. If the pressure is equal or below that shown on the table identify the cylinder as “recycled.”

R-12 Allowable Container Pressure

°F	Psig	°F	Psig	°F	Psig	°F	Psig	°F	Psig
65	74	75	87	85	102	95	118	105	136
66	75	76	88	86	103	96	120	106	138
67	76	77	90	87	105	97	122	107	140
68	78	78	92	88	107	98	124	108	142
69	79	79	94	89	108	99	125	109	144
70	80	80	96	90	110	100	127	110	146
71	82	81	98	91	111	101	129	111	148
72	83	82	99	92	113	102	130	112	150
73	84	83	100	93	115	103	132	113	152
74	86	84	101	94	116	104	134	114	154

°C	kPa	°C	kPa	°C	kPa	°C	kPa	°C	kPa
18.3	510	23.9	600	29.4	703	35.0	814	40.6	938
18.9	517	24.4	607	30.0	710	35.6	827	41.1	952
19.4	524	25.0	620	30.6	724	36.1	841	41.7	965
20.0	538	25.6	634	31.1	738	36.7	855	42.2	979
20.6	545	26.1	648	31.7	745	37.2	862	42.8	993
21.1	552	26.7	662	32.2	758	37.8	876	43.3	1007
21.7	565	27.2	676	32.8	765	38.3	889	43.9	1020
22.2	572	27.8	683	33.3	779	38.9	896	44.4	1034
22.8	579	28.3	690	33.9	793	39.4	910	45.0	1048
23.3	593	28.9	696	34.4	800	40.0	924	45.6	1062

R-134a Allowable Container Pressure

°F	Psig	°F	Psig	°F	Psig	°F	Psig	°F	Psig
65	69	76	85	87	103	98	125	109	149
66	70	77	86	88	105	99	127	110	151
67	71	78	88	89	107	100	129	111	153
68	73	79	90	90	109	101	131	112	156
69	74	80	91	91	111	102	133	113	158
70	76	81	93	92	113	103	135	114	160
71	77	82	95	93	115	104	137	115	163
72	79	83	96	94	117	105	139	116	165
73	80	84	98	95	118	106	142	117	168
								118	171
74	82	85	100	96	120	107	144	119	173
75	83	86	102	97	122	108	146	120	176

°C	kPa	°C	kPa	°C	kPa	°C	kPa	°C	kPa
18	476	25	593	32	752	39	917	46	1124
19	483	26	621	33	765	40	945	47	1158
20	503	27	642	34	793	41	979	48	1179
21	524	28	655	35	814	42	1007	49	1214
22	545	29	676	36	841	43	1027		
23	552	30	703	37	876	44	1055		
24	572	31	724	38	889	45	1089		

Figure 9-2
The pressures in these English and metric charts refer to recycled R-12 and R-134a refrigerant, respectively.

Flushing the AC System

Flushing has long been recommended as a means of removing contaminants or other debris from certain system components. The normal flushing materials, such as R-11, are now prohibited.

Using compressed air is not a good method of flushing. Air should never be used in an R-134a system. Closed loop flushing kits are now available, although they may not remove all foreign material.

The primary use of a flushing kit is to remove contaminants from the AC system hoses, evaporator, and condenser. Any other component of an AC system should be bench checked or replaced, since flushing may be ineffective or may damage a component. Flushing is usually performed after the recovery process. We recommend it before you replace the compressor, or when you find contamination in other components (receiver-drier, expansion valve, or connections). Some recover/recycle machines have optional “flush kits.” The only proper way to flush system components is to use refrigerant in a closed-loop system.

Evacuating and Charging the AC System

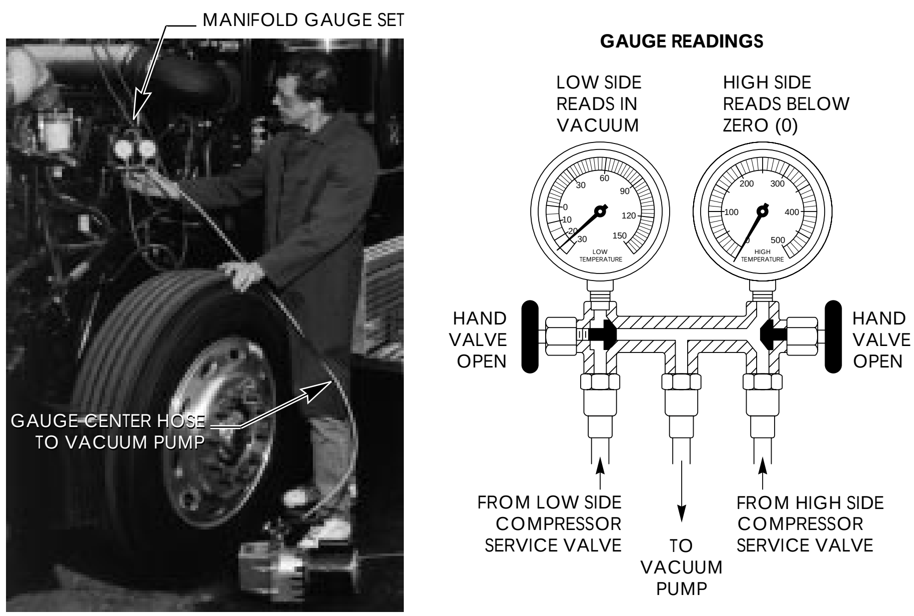
Evacuate the system once the air conditioner components are repaired or replacement parts are secured, and the AC system is reassembled. Evacuation removes air and moisture from the system. Then, the AC system is ready for the charging process, which adds new refrigerant to the system.

Evacuating the System

Follow this procedure:

1. Tighten all connections and attach a vacuum pump to the center hose of the gauge set.

Figure 9-3
This illustration shows evacuation of an AC system before recharging. It is very important to run the vacuum pump long enough to insure the removal of any moisture that may be in the system.



2. Start the vacuum pump and open both the hand valves on the manifold all the way. Run the pump for five minutes, then close the hand valves and shut off the pump.
3. Check the gauge readings for five minutes. If the gauge needles move up, the system is not sealed. There is a leak. Air and moisture are being sucked into the system by the vacuum.
4. Tighten any loose connections. Re-start the pump, and open the hand valves on the gauges again. Repeat the vacuum test.

5. Run the vacuum pump for at least an hour to remove the moisture from the system.

The moisture must turn to gas before the pump can pull it out. The moisture takes time to boil away, so that it can be drawn out of the system.

Your vacuum pump can draw most of the air out pretty quickly. But a deep vacuum requires more time; the deeper the vacuum the longer it takes to get there. To ensure the least possible amount of air and moisture in the system, buy a good quality vacuum pump, take care of it, and use it *for at least an hour*.

Figure 9-4
Vacuum pump.

WARNING Lubricants removed during the recovery process must be replaced with new lubricants.

Charging the AC system

*Use a charging station whenever possible.

When adding a full charge of refrigerant, you can put it in as a gas or as a liquid. Adding refrigerant as a liquid is faster but can damage the compressor if not done correctly. The procedure you use, and where you add the refrigerant in the AC system makes a difference. When using refrigerant as a liquid, never add more than two thirds of system requirements as a liquid. Finish charging the system using gas. Always keep the refrigerant containers in an upright position so that no liquid is drawn into the system.

Refer to the *Charging with Refrigerant Gas* section below for the procedure for gas charging. Refer to the *Charging the System with Liquid Refrigerant* section for the procedure for liquid charging.

Charging with Refrigerant Gas (on the Low Side)

Perform this procedure to charge with refrigerant gas:

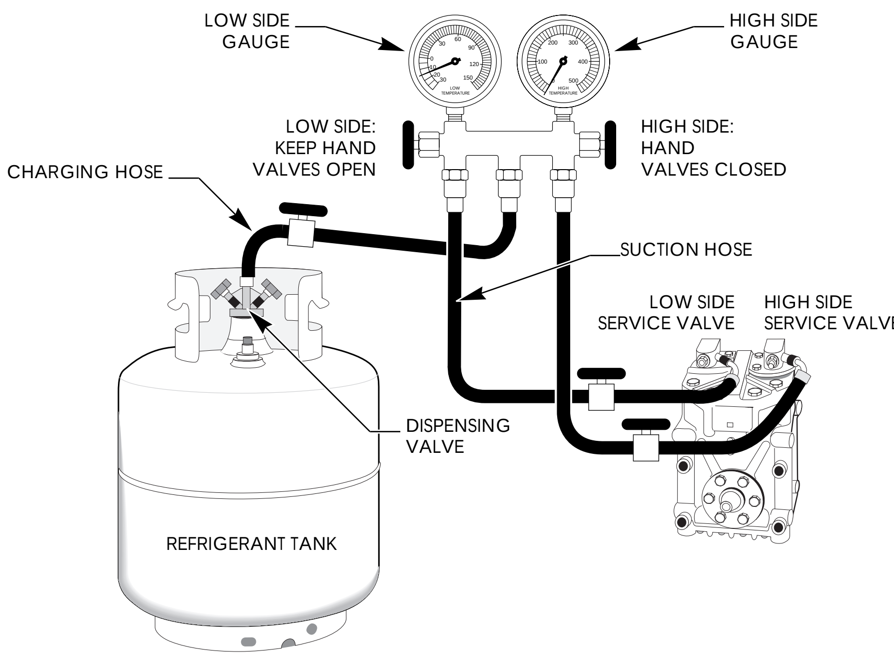
1. Use a charging meter or station to select the exact amount of refrigerant required. Never add more than the amount of refrigerant recommended by the manufacturer (in pounds and ounces). To measure, use a container and scale, or charging station.

2. Connect the center service hose from the gauge set to the refrigerant container dispensing valve. Purge the hose of any air using refrigerant gas pressure from the container.
3. Run the engine at 1200 to 1500 RPM, with the AC unit on maximum cool.
4. Open the dispensing valve, then the low side hand valve on the manifold. Figure 9-5 illustrates system charging with refrigerant gas entering the compressor on the suction (low pressure) side of the system.

Note: If there are no manufacturer's charging specifications, you can watch the sight glass first for bubbles, then clearing.

Figure 9-5

In this illustration, refrigerant is added on the low side of the system as a gas. The engine must be running at 1200 to 1500 RPM to draw the gas in.



5. Check the sight glass when you have added nearly the specified amount of refrigerant. Keep adding refrigerant until the sight glass clears or you have added the specified refrigerant charge. Use an oil injector to replace oil drained from the system. Remember, a large leak may have resulted in nearly all the lubricant being lost.
6. Close the valve on the refrigerant container. Close the hand valve on the gauge set and check the gauge readings. The gauges should read in the normal range.
7. Turn off the engine and AC system. Check for leaks. If the system checks out OK, back seat the service valves. Remove the manifold gauge set hose fittings from the compressor. If Schrader valves are in use, be sure to remove the manifold hose fittings quickly and carefully, using a glove or shop towel to protect your hand. Replace the protective caps on the compressor service valves.

Charging the System with Liquid Refrigerant

This process is used as a time-saver, but requires much more care to avoid compressor damage.

1. Check the amount of refrigerant recovered, and add approximately two thirds of that amount, and no more than recommended by the manufacturer (in pounds and ounces).
2. Connect the center service hose from the gauge set to the refrigerant container dispensing valve.
3. Add refrigerant liquid through the compressor discharge service valve (high side of system). If an accumulator is used, add the liquid refrigerant (and gas during final charging) via a Schrader valve.
4. Open the refrigerant dispensing valves and hand valves on the hose and gauge set. Liquid refrigerant flows into the system.

   Figure 9-6 illustrates how to connect the manifold gauge set when adding liquid at the compressor (or accumulator).

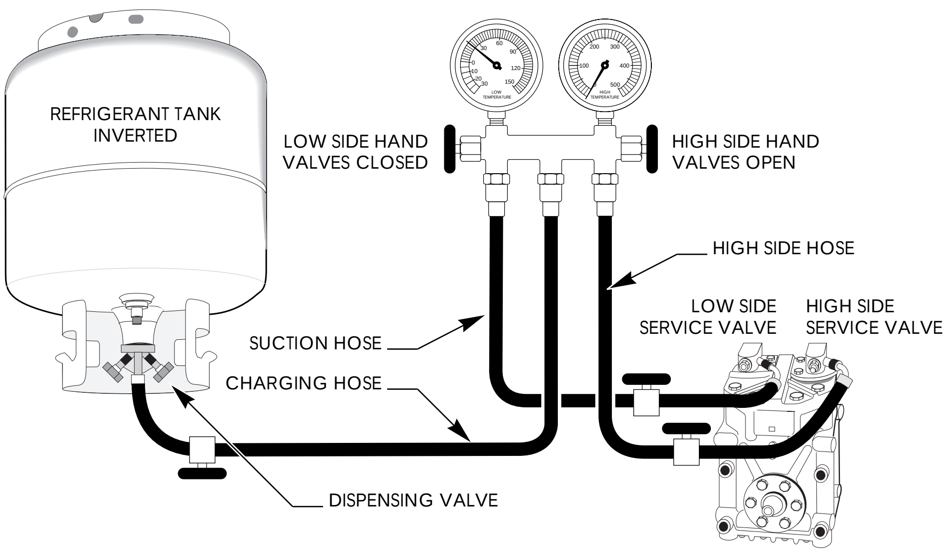


Figure 9-6

Adding refrigerant liquid to partially charge the AC system is illustrated and described.

5. When you have added two thirds of the recorded, actual recovered amount of refrigerant, shut off the refrigerant supply. If you added liquid refrigerant at the compressor high side service fitting, there may be liquid in the compressor. Attach a wrench to the nut holding the clutch the compressor shaft. Turn the compressor shaft a few times in the direction of normal rotation to clear any liquid from the compressor.
6. Finish charging the system with refrigerant gas by starting the engine and AC system. Follow the procedure for charging with gas as shown in Figure 9-5.

Reclaiming Refrigerant

Reclaiming refrigerant reprocesses the material to virgin purity. For sources of reclaimed refrigerant or to send refrigerant for reclamation, contact the EPA, the independent industry organizations, or your state's Department of Ecology.

Chapter Review

- Common refrigerants have varying properties and operating pressures.
- New laws require that we standardize our refrigerant processing methods throughout the industry. This includes the processes that handle refrigerant, including **recovering** and **recycling**, which are the most economic and environmentally friendly ways of handling the refrigerant.
- **Recovery/recycle** processes deal directly with the refrigerant. During **recovery** the refrigerant is removed from the AC system. During **recycling** it is restored to reusable condition by removing moisture, acidity, and particulate matter.
- The **flushing** procedure removes contaminants from the AC system hoses, evaporator, and condenser. The **evacuation** process removes air and moisture from the AC system. This is necessary before adding new or recycled refrigerant. The process of adding refrigerant is called **charging**.
- **Reclaiming** a refrigerant means processing the refrigerant so that it meets standards for new refrigerant.

Chapter 10

Component Repair or Replacement

Click on any of these subject headings to go directly to the page

Tips on Replacing & Repairing AC Components

The following service and repair procedures are not any different than typical vehicle service work. However, AC system parts are made of soft metals (copper, aluminum, brass, etc.). The comments and tips that follow will make your job easier.

CAUTION All of the service procedures described are only performed after the AC system refrigerant has been recovered. Never use regular shop oil or joint compound to lubricate or seal any AC connections.

Note: To help prevent air, moisture or debris from entering an open system, cap or plug open lines, fittings or components as soon as they are disconnected. Keep all connections (also the caps or plugs you might use) clean so no debris can accidentally get inside the system.

As a general rule in AC service, replace any gaskets and O-rings with new ones. Use fresh refrigeration oil to lubricate connections, gaskets and O-rings. The following parts are discussed further in this section:

1. Hoses and Fittings
2. Lines
3. Expansion Valves
4. Expansion Tubes
5. Receiver-Drier and Accumulator
6. Compressor & Clutch

1. Hoses and Fittings

When replacing hoses be sure to use the same type and ID hose you removed. When hoses or fittings are shielded or clamped to prevent vibration damage, be sure these are in position or secured. On R-134a systems make sure replacement hose has been designed for this refrigerant.

Machine crimped fittings are preferred over those fittings which use hose clamps. Properly crimped ferrules make stronger connections than hose clamps, and are recommended by the manufacturers of refrigerant hose. Use crimped fittings on hose brands such as Goodyear Galaxy. Steel fittings are preferred over aluminum in heavy duty applications. Use reusable fittings on the nylon-lined hose brands such as Aeroquip FC 202.

2. Lines

Always use two wrenches when disconnecting or connecting AC fittings attached to metal lines. You could be working with copper and aluminum tubing which can kink or break easily. Tube O-ring type fittings require only 18 foot pounds of torque for correct sealing. When there are grommets or clamps used to prevent line vibration, be sure these are in place and secured.

3. Expansion Valves

When removing the expansion valve from the system, remove the insulation, clean the area, and disconnect the line from the receiver-drier. Detach the capillary (bulb) and external equalizer tube (if present) from their mounting locations. Remove the expansion valve from the evaporator inlet. Expansion valve service is limited to cleaning or replacing the filter screen. If this is not the problem, replace the valve. If there is any debris in a block-type valve, replace it. Secure the capillary and equalizer, if used, and replace any insulating material.

4. Expansion Tubes

A clogged or defective expansion tube must be replaced. There are special tools available to remove and replace tubes at their location. If you don't have one, you may be able to use a pair of needle-nose pliers. Put a little refrigerant oil in the evaporator inlet to lubricate the expansion tube for easier removal. Discard the old tube. Lubricate the new tube and O-ring and insert until it seats against the dimples in the evaporator inlet.

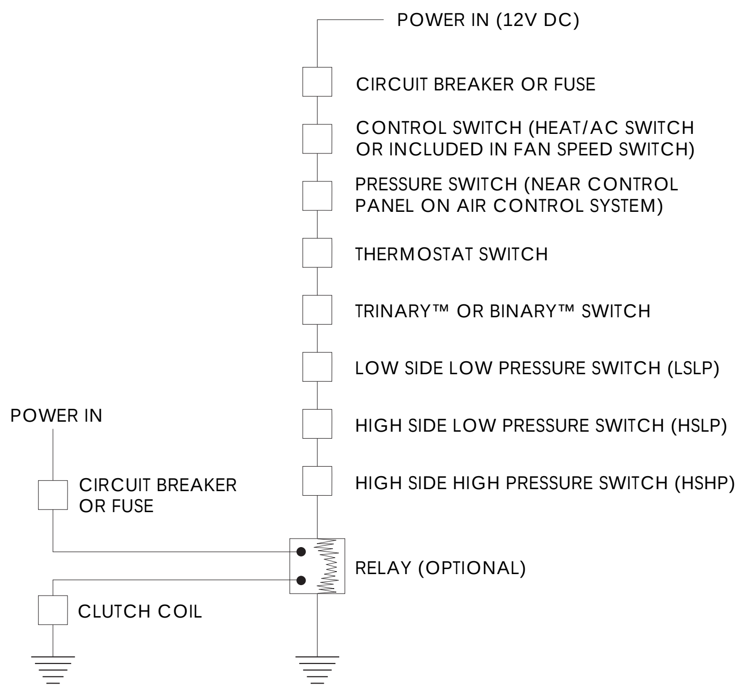
5. Receiver-Drier & Accumulator

The receiver-drier and accumulator can not be serviced or repaired. They should be replaced whenever the AC system is opened for any service. If the receiver-drier or accumulator has a pressure switch to control the clutch, it should be removed and installed on the new unit.

6. Compressor & Clutch

Problems with the clutch assembly can be due to low voltage, electrical failure in the coil, the lead wire or a bad pulley bearing. Check first to see that electrical power is reaching the clutch. The lead wire and bearing can be replaced and the clutch assembly reinstalled. If the coil fails, it must be replaced. If the clutch shows obvious signs of excessive heat, replace the complete assembly. The compressor can fail due to shaft seal leaks, defective valve plates, bad bearings, or problems associated with high pressure, heat or lack of lubrication.

Figure 10-1
Wiring schematic for the clutch circuit. Two or more of these switches may be found in a clutch circuit.



Servicing the Compressor

Every AC system and compressor depends on refrigeration oil for lubrication and safe operation. Whenever an AC system is opened for service, check the compressor oil level and add clean refrigeration oil as required by manufacturer specs. This is especially important with a rotary compressor that has no oil sump.

WARNING Different lubricants are used in R-12 and R-134a systems. They must not be mixed.

Compressor Repair

Vehicle down time or travel delay can be very costly to the heavy duty rig operator. For this reason, compressor service and repair is usually more costly than replacement with a new or rebuilt compressor. We have limited compressor and clutch service and repair coverage because each compressor make (and model) requires special tools and procedures for complete repair capability. Compressor manufacturers publish service manuals for their products.

HVAC Control System Variations—Troubleshooting

We described Binary™ and Trinary™ switches, air operated controls (Air Block) and CTC™ or Constant Temperature Control in *Chapter 5*. These control devices are often specified on heavy duty vehicle HVAC systems. Troubleshooting and servicing are explained here.

Troubleshooting for the following components is discussed below:

1. Binary™ and Trinary™ Switches

2. Air Operated Controls

3. CTC™ System

1. Binary™ and Trinary™ Switch—Troubleshooting

The high/low pressure function of the Binary™ and Trinary™ switches acts as a circuit breaker for the AC system. The switch interrupts current flow to the clutch when there is abnormal pressure in the system. A combination of components or wiring problems could cause the system to malfunction. In many cases, problems associated with these switches are the result of a malfunction elsewhere in the system.

Note: Terminal numbers are molded into the top of the Trinary™ switch. Terminals 1 and 2 control the compressor clutch and are identical to the two terminals on the Binary™ switch.

AC Compressor Clutch Circuit

In normal operation, the Binary™ and Trinary™ terminals, #1 and #2, should form a closed circuit. They supply power to the clutch if the AC system is properly charged with refrigerant, and the outside air temperature is above 40 degrees Fahrenheit.

AC Clutch Does Not Engage.

1. With the system on, check power at Trinary™ switch with voltmeter or trouble light:

a. One of the terminals, #1 or #2, should have power.

b. If there is no power, there is a problem with the AC unit or wiring.

2. Both terminals have power:

a. The problem is either the clutch or the wiring from the switch to the clutch.

3. Power to and from the Binary™ or Trinary™ check out OK:

a. Use the manifold gauge set to check out system pressures. (Outside temperature must be above 40° F).

b. If system pressure is below 40 PSIG, check for refrigerant leaks. If OK, add refrigerant to obtain correct pressure.

4. AC system pressure and power supply to switch check out OK:

a. Connect a temporary jumper wire between terminals #1 and #2.

b. The clutch should engage. Operate the AC system for five minutes at maximum cooling. Disconnect jumper wire and reconnect the switch leads. If the clutch will not engage, and pressure is over 50 PSIG, replace the switch.

CAUTION	Do not operate AC system with incorrect refrigerant charge or compressor damage may occur.

Compressor Cycles, but AC System Does Not Cool.

All electrical components in the clutch circuit appear to be functioning properly. Refer to *Chapter 8* for troubleshooting procedures.

Power to Trinary™ OK and Compressor Still Runs Continuously.

The high side cutout switch may not be functioning, so one of the problems described below is causing the abnormal pressures.

1. Check high side pressure. If it approaches 300 PSIG, a serious problem is indicated.
   a. The AC system may be overcharged.
   b. There may not be enough air flow through the condenser or it may be blocked by debris.
   c. The condenser may be too small for operating conditions.
   d. There may be a restriction inside the system (bent or kinked lines or hoses, sludge or moisture in system, etc.).
   e. The thermostat may not be functioning.

Fan Clutch or Shutter Override Circuit.

Note: In normal operation, Trinary™ switch terminals #3 and #4 are normally open. (Normally closed Trinary™ switches are used with some air-clutching engine fans.) As the system pressure reaches mid-range (200-230 PSIG), the switch closes and supplies power to the fan clutch or shutter control circuits.

Fan Clutch or Shutter Cycles Too Often or Stays On Too Long:

1. Connect gauge set to AC system:
   a. Watch high pressure side increase until mid-range pressure is reached.
   b. If fan engages or shutter opens at the proper pressure, the Trinary™ is OK.
   c. The problem is the condenser—check for debris or lack of air flow through the condenser fins. The condenser may be too small for conditions.

2. Fan or shutter cycles at less than 180 PSIG or remains on below 150 PSIG:
   a. The Trinary™ is functioning below it’s proper operating range and must be replaced.

Fan Clutch Will Not Activate.

1. Check power supply to terminals #3 and #4 with voltmeter or trouble light. System pressure must be above 230 PSIG (restrict air flow through the condenser if necessary to achieve this pressure). Check opposite terminals for switch function. If switch does not close and activate the fan clutch, replace the Trinary™.

Note: Some air-clutching engine-fan systems use normally closed Trinary™ switches (Bendix, Horton, etc.). When the operating pressure is reached, the fan circuit will open and the fan will come on.

2. Faulty solenoid (air-clutching fans) or wiring. If the Trinary™ switch functions in the above test, check wiring to solenoid valve, fan, or relay, and determine if the valve or relay is functioning properly.

Air Operated Controls

Air controls have become important in truck HVAC system operation. In discussing troubleshooting, we will cover the module air control system. The four major components of this system are illustrated in Figure 10-2 and described as follows:

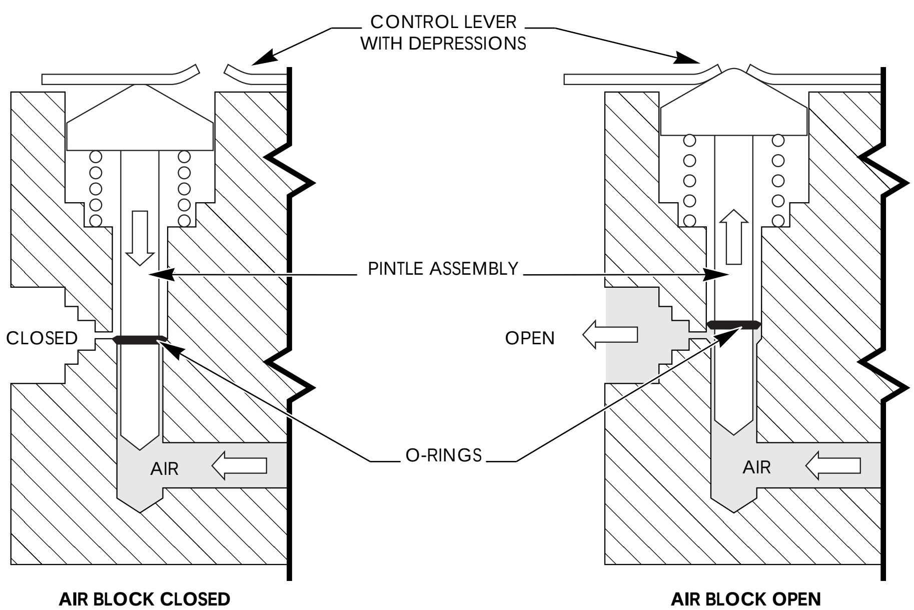


Figure 10-2
The AIR BLOCK is shown and described in this illustration.

Air Block—A molded plastic or machined metal block with air passageways; inlet, outlet and vent ports.

Pintle—A valve stem with head and O-ring seal

Control Lever—A sliding flat metal plate with formed depressions (or cavities) programmed to position the pintles for each mode of HVAC system operation.

Air Cylinder—A single or double action spring return device to position air directional control doors.

Air controls are assembled so the pintles are retained in the passageways of the air block by a mode selector lever. Air control functions (modes) are programmed by the depressions (or cavities) formed in the control lever. As the control lever is moved to an operator selected mode, the pintles slide in and out of the depressions. This action moves the pintles and their O-rings in the air passageways of the air block, allowing air to flow or vent from the air cylinders. Doors located in the AC unit or duct system will open or close as the air cylinders are activated, directing heated or cooled air to the desired outlets.

If the air control panel shows signs of internal leaking, it should be replaced using an air service kit. An air service kit includes the assembled block, pintles and control levers. Do not attempt to replace individual components of the air control panel.

Before replacing any air control system parts look for air leaks in the system.

Air Leaks in System.

Check for loose air fitting connections on the air block and air cylinders. Examine the air hose. NOTE: To remove hose from Legris air fittings, push on the metal ring or color coded button around the hose, and pull hose from fitting.

1. Check for leaks around fitting seals:
   - a. Hose must be cleanly cut at a 90° angle to seal in fitting.
   - b. Hose must be pushed all the way into the fitting (about 9/16").
   - c. Cleaning hose and applying a thin coat of light weight oil will help seal hose in fitting.

2. Inspect hose for cracks:
   - a. Check the air block assembly. If there is a leak around pintles, replace assembly. Do not try to disassemble and repair.
   - b. Check air cylinders for leaks.

Modes do not Function as Control Lever is Moved.

Check air supply to the control panel. Check for sticking doors (defrost, vent, etc.), and jammed air cylinders. Inspect air block assembly.

1. Cycle the control lever and listen for air escaping from exhaust port (vent). The air cylinders will not retract unless the air block vents properly. Replace block if it does not vent.

2. Disconnect air lines going to cylinders. Cycle control lever. Listen for air exiting the ports. If there is no air in at least one lever position, replace assembly.

Problem Activating AC Clutch Circuit.

Inspect the low pressure switch located on the air block. The switch is normally closed. It must have air pressure to disengage the clutch. If there is no power to the clutch proceed as follows.

1. Make sure there is power to the pressure switch—use a voltmeter or trouble light to check.
2. Make sure there is air to the controls.
3. If there is air and power available, place a jumper across the two terminals on the low pressure switch. If the clutch engages, there is a problem with the pressure switch or air block.
4. Remove the switch from the air block, move the lever to heat mode. If air exhausts from the port, replace the pressure switch. If no air is vented from the port, the air block is defective.
5. If the air block and pressure switch check out OK, inspect AC system clutch, thermostat, Trinary™ switch, or other pressure switches, and wiring.

CTC™ (Heater) and CTC™ II (Heater–A/C System)

The constant temperature control systems maintain a pre-selected cab temperature by pulsating the flow of hot engine coolant through the heater core. In the CTC II configuration the compressor is cylced to control temperature in the AC mode. The four major components of the system are illustrated in Figure 10-3 and described as follows:

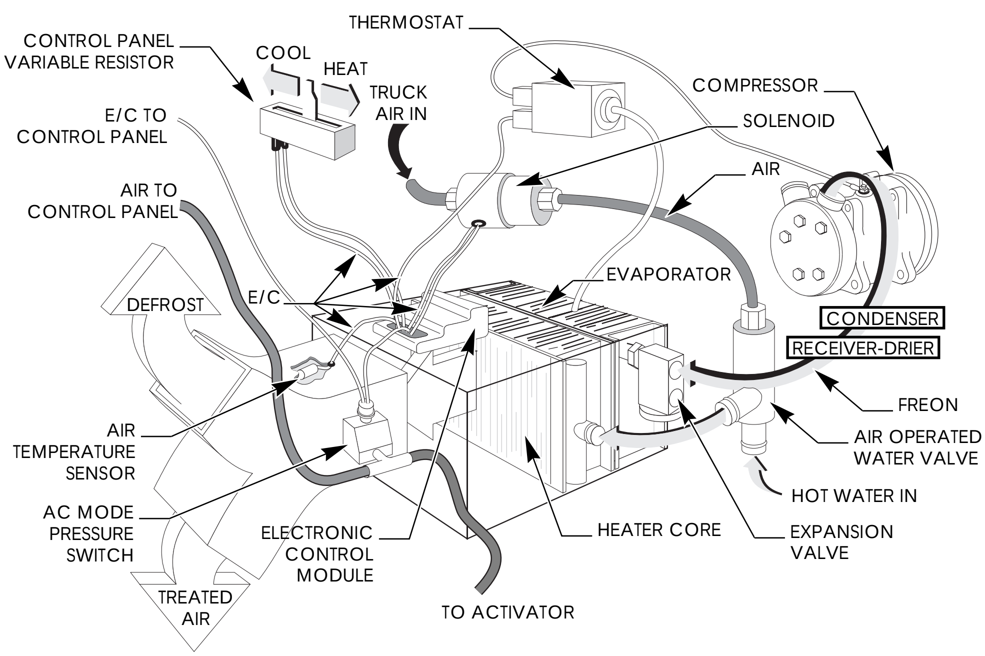


Figure 10-3
The CTC II system is shown in this drawing.

Circuit Board Assembly—The assembly is located on the heater/AC unit. It supplies power to resistor and solenoid, and monitors air output temperature.

Variable Resistor—Located on the control panel and used with temperature control lever to select desired temperature. It translates the desired temperature into a control voltage for the circuit board.

Solenoid Valve—Located on the HVAC unit or near the water valve. It receives power from the circuit board and controls the air supply to the water valve.

Air operated Water Valve—The preferred location is on the engine side of the firewall. Air pressure to the water valve is controlled by the opening and closing of the solenoid valve. When the solenoid valve is open, air pressure closes the water valve. The water valve is located on the inlet side of the heater core.

You will need Constant Temperature Control analyzers to troubleshoot the CTC™ systems. The vehicle must be operating at proper engine coolant temperature, air pressure and voltage output in order to troubleshoot the two possible failure modes.

Servicing and Repairing the Heater

Heater service and repair may be necessary because of lack of maintenance. The rubber parts: belts, heater and radiator hoses all fail in time. Engine coolant should be replaced every year and the whole system should be flushed when this is done. The thermostat and radiator pressure cap may fail from metal fatigue.

Heater valves (water and air), the core, or control devices may malfunction and require adjustment or replacement. In addition to your normal tool chest items, the cooling system test equipment required is described in *Chapter 6*.

Summary

By now you should have a pretty good idea about what is involved in HVAC function, service and repair. With a sound knowledge and understanding of fundamentals and typical problem areas, your experience on the job will quickly add to your ability and confidence. *Chapter 11* gives you a better understanding of where components may be located and how they go together. A series of photos and exploded view illustrations of the typical air conditioner, heater and combo systems are described. Before you study them, you might want to review the photos and drawings in earlier chapters.

Chapter 11 Typical HVAC Systems and Components

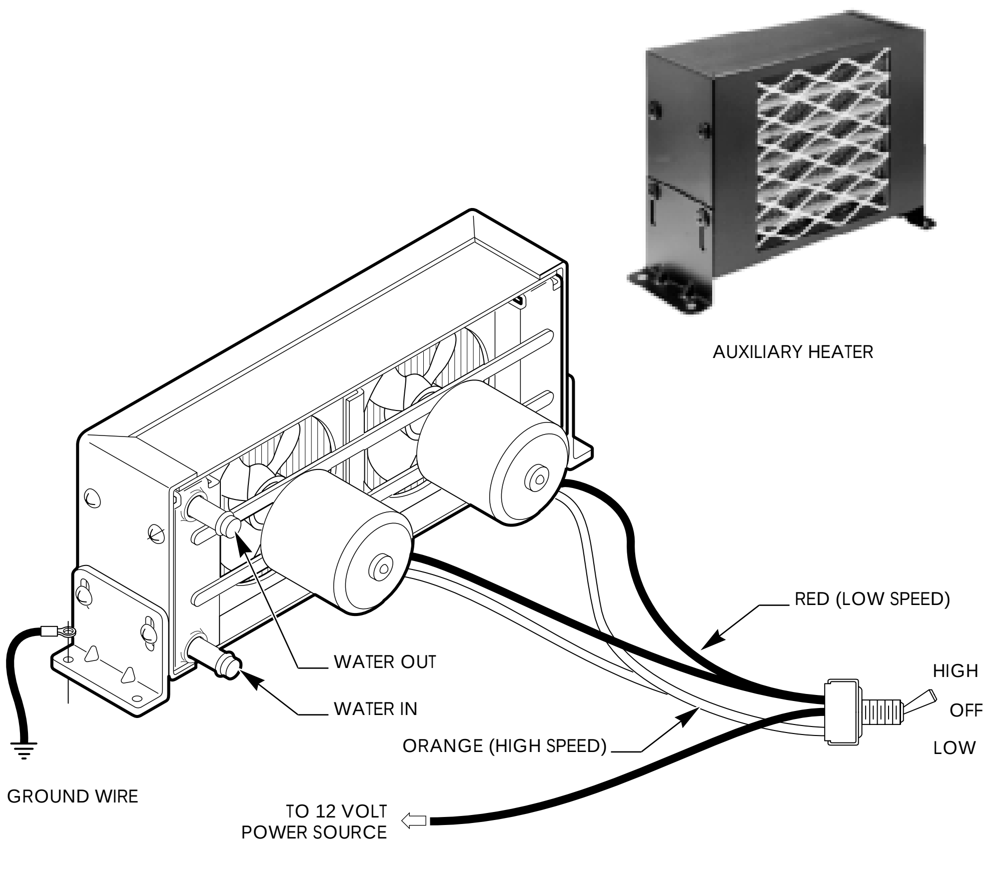
Click on any of these subject headings to go directly to the page

Now it's time to add to your general knowledge about different systems. The series of photos and schematics that follow show typical heater, air conditioner, condenser and combo units. Figures 11-1 through 11-7 are also illustrated in corresponding exploded view drawings. You can see the basic parts and how they go together.

In most of the figures, the underhood components, plumbing, and wiring schematics that go with the units illustrated are not shown. Their actual position varies from one vehicle to another. Your basic mechanical knowledge is sufficient to locate and service any parts not shown.

Figure 11-1

An auxiliary, universal heater. It may be mounted in various ways.



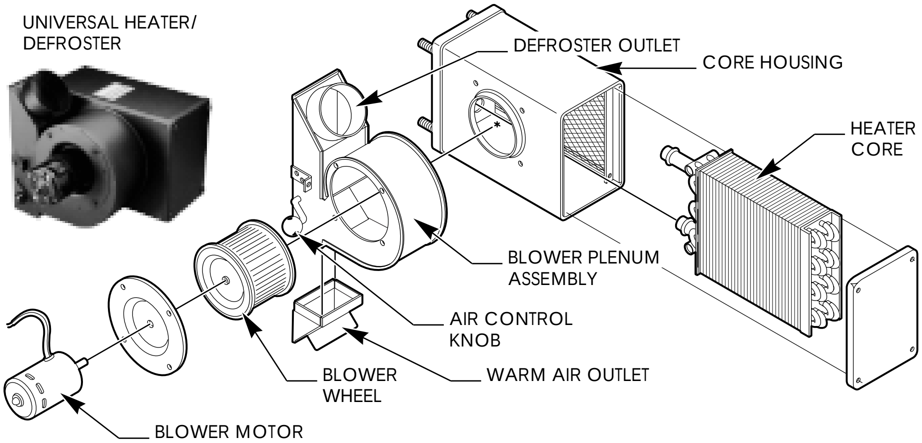
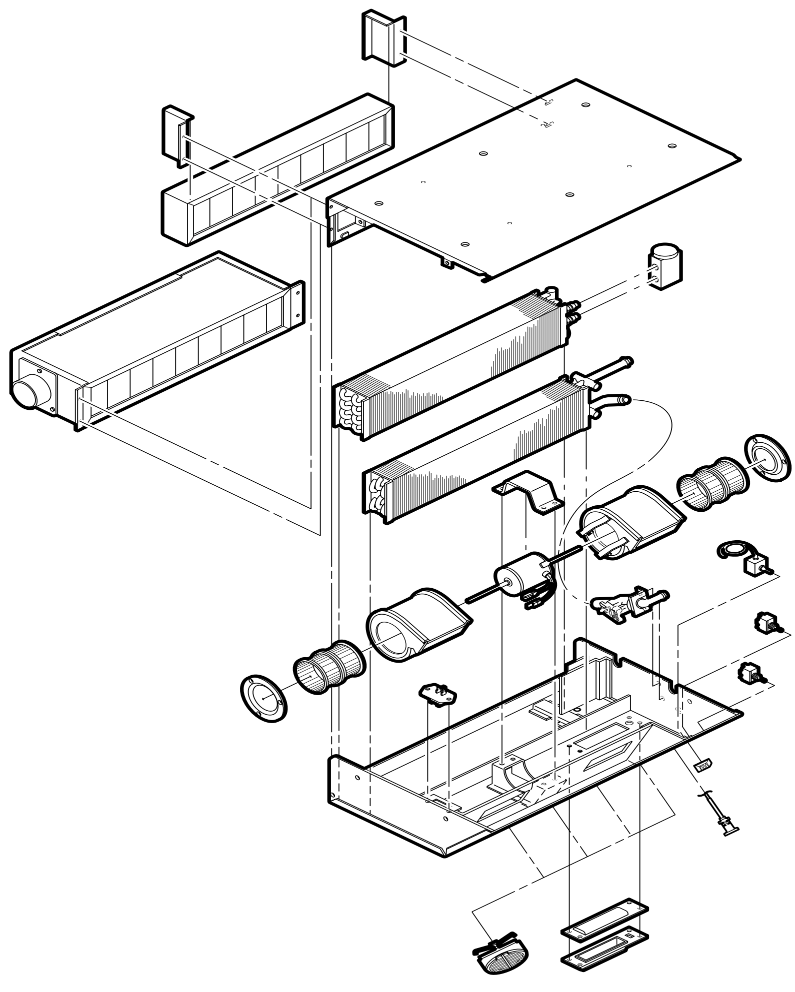


Figure 11-2

A universal heater defroster unit.



UNIVERSAL IN–CAB ROOF MOUNTED AIR CONDITIONER UNIT

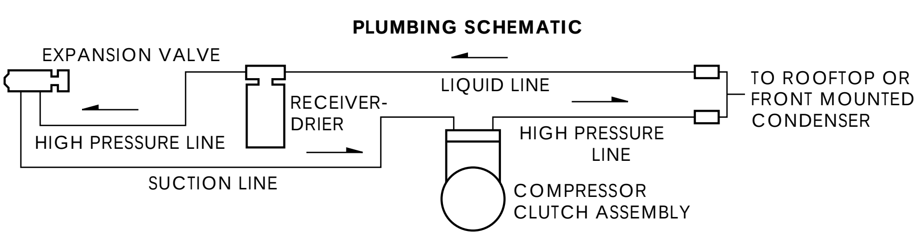


Figure 11-3

A universal in-cab roof mounted air conditioner. The compressor clutch and condenser would probably be mounted under the hood or cab (cab over). Refrigeration hoses would be long compared to in-dash mounted units. System controls are easily accessible for the driver. This system is usually found on off-road vehicles.

Figure 11-4

An HVAC combination unit designed to mount on the panel behind the operators seat. The vents direct air to both the cab and rear compartment. Note how the evaporator coil and heater core are stacked, one over the other. The valves and connections are easy to access for service.

HVAC COMBINATION UNIT

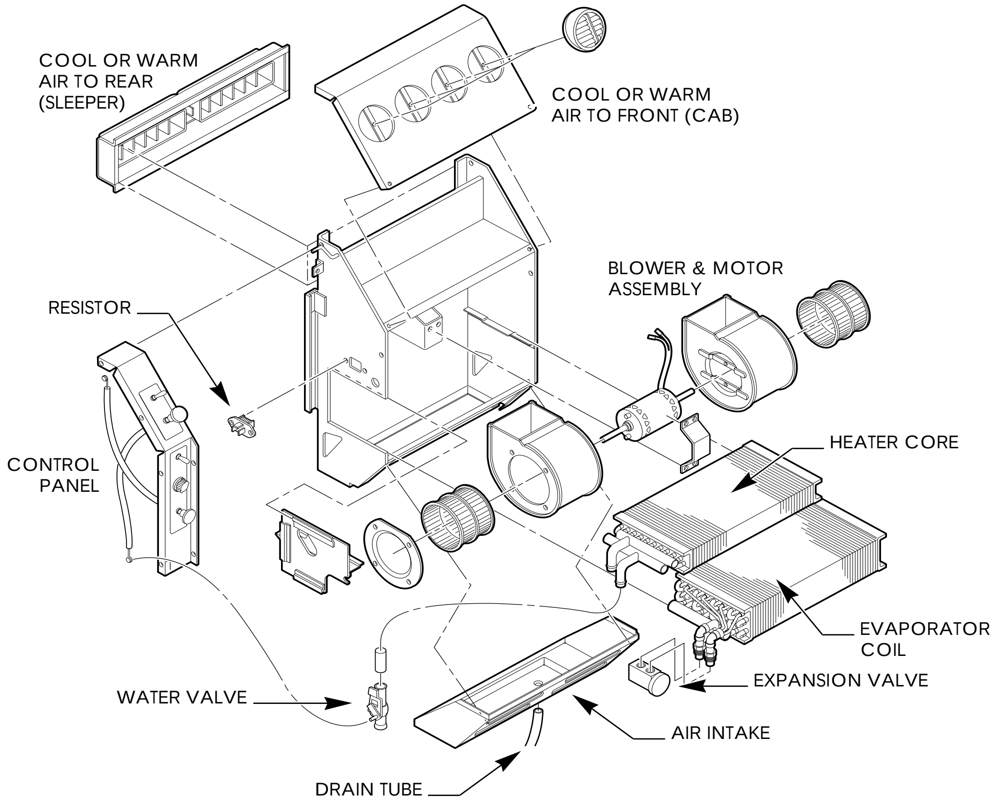
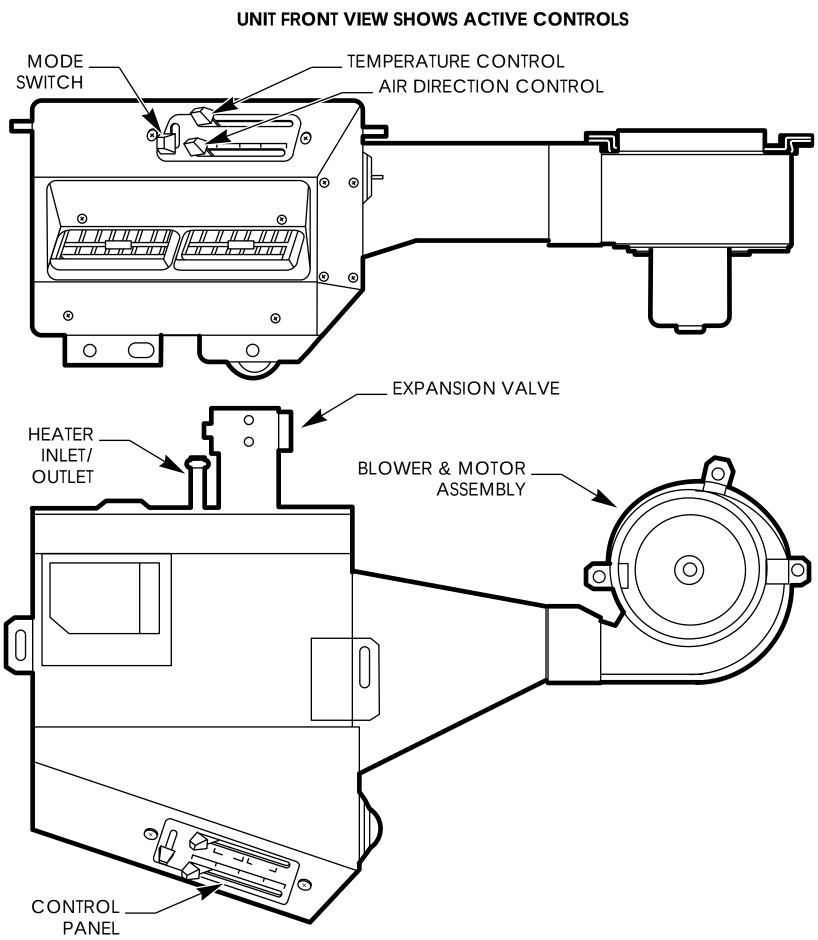


Figure 11-5

This combo HVAC unit is designed to mount under the dash and on a specific truck series. In this case it's for the MACK "R" series. Under-dash units blend into the overall appearance of the dash.

HVAC UNIT



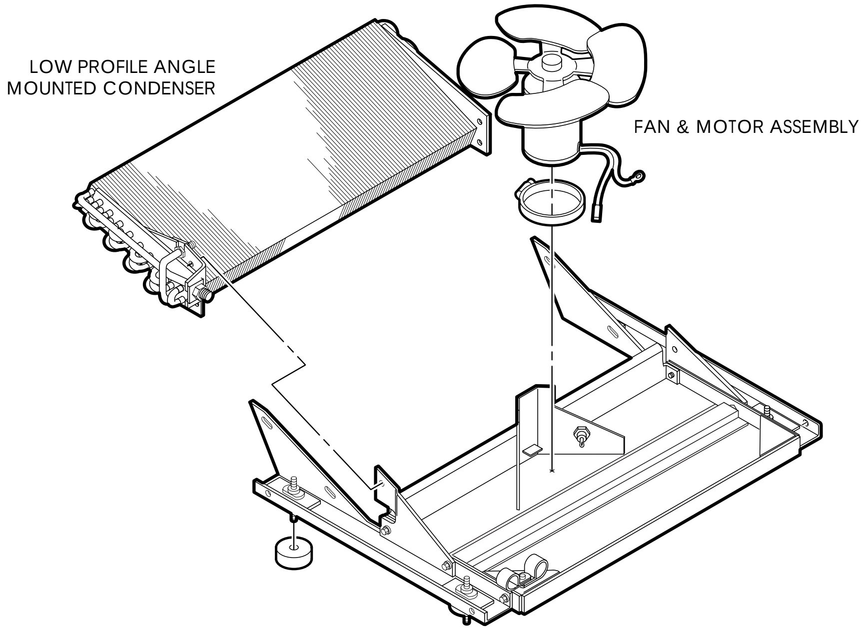
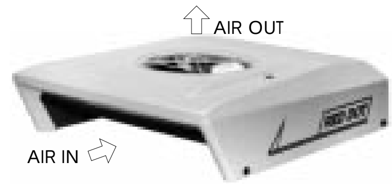


Figure 11-6

A basic low profile roof mount condenser. Hoses must be run to the compressor mounted on the engine, and to the evaporator in the cab.



LOW PROFILE ROOF MOUNT CONDENSER COVER ASSEMBLY WITH FAN GUARD

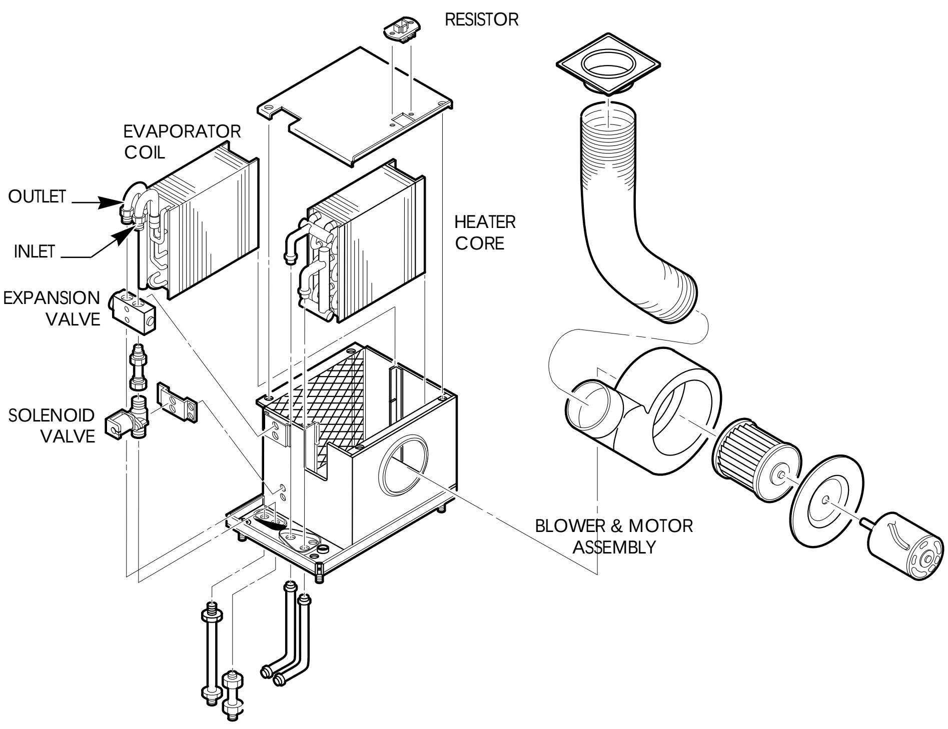


Figure 11-7

This is an auxiliary HVAC unit designed to heat and cool a bunk or sleeper box. It would supplement heat energy movement by an existing HVAC system. To get engine coolant and refrigerant to this auxiliary system, you would “T” off the existing refrigerant lines and plumb the heater in series with the cab unit, or separately from the engine.

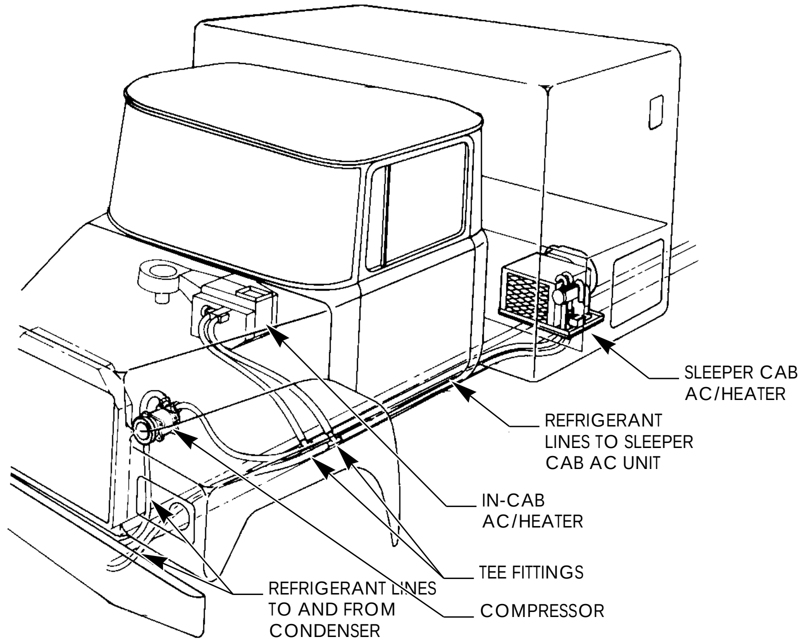
AUXILIARY HVAC UNIT

Sleeper cab AC system refrigerant flow is controlled by an electrically operated solenoid valve. The solenoid is wired to the control panel in the sleeper cab. When the operator turns on the bunk AC system, the solenoid valve opens to allow refrigerant to flow to the evaporator mounted under the bunk. With most installations the fan motor cycles on and off to control temperature. Figure 11-8 shows how the sleeper box and in cab AC units may be positioned and connected.

Note: CTC® systems are used in some applications.

Figure 11-8

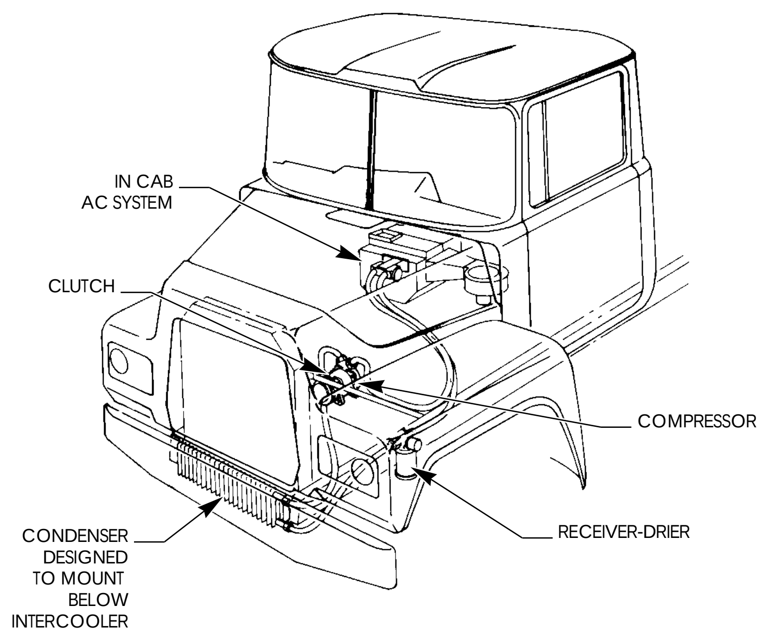
A typical installation schematic that shows component location when under-dash and sleeper box systems are combined. Tee fittings in both high and low pressure AC lines carry refrigerant to and from both evaporators. The heater system is not shown.



Engine intercooler designs often use the space in front of the radiator where an AC condenser would normally be mounted. A roof mount AC system condenser may be the solution. In some cases, there is space to install the condenser below the intercooler. Figure 11-9 illustrates how an AC system design takes advantage of space below the intercooler for condenser installation.

Figure 11-9

This AC system schematic shows how components might be mounted when an engine intercooler (charge-air cooling) has been installed in front of the radiator. The condenser used is designed to fit below the intercooler unit (not shown).



Please take a few minutes to review all illustrations, cautions and notes in this manual. If you would like more information about heavy duty vehicle HVAC system service and repair, check with your supplier. Someone may be holding a service clinic in your area that you could attend and benefit from.

Your own troubleshooting ability and work speed will increase with experience. Remember also, the causes for system failure can often be prevented with a regular system maintenance program.

Chapter 12

Retrofitting an R-12 System

Click on any of these subject headings to go directly to the page

The world supply of R-12 is ever declining. Although many precautions are being taken to contain R-12, it continues to be lost to the atmosphere. At the same time production of this material is being curtailed. Production of R-12 will actually cease at the end of 1995.

As long as a supply exists and the price is reasonable, R-12 systems should be serviced with this refrigerant. However, at some time, you will be retrofitting R-12 systems with R-134a. It would be a good idea to become acquainted with the retrofit process on those vehicles you normally service. This will allow you to discuss the process with your customer and estimate the costs involved.

The most dependable way to retrofit a system is to replace all components in the refrigerant loop. This is costly and time consuming. Many vehicle manufacturers will recommend a retrofit procedure with a kit. Retrofit kits are planned for vehicles produced in high volume.

Retrofit Survey

Survey the system and determine what components need changing. If a kit is available from the original manufacturer your job is made easier. If not, review each component and make a judgment call.

The following parts are discussed further in this section:

1. Compressor
2. Condenser
3. Receiver-Dxrier
4. Expansion Valve
5. Evaporator
6. Hoses
7. Seals and “O” Rings
8. Service Ports

1. Compressor

Some compressor manufacturers are suggesting their products can be used with R-134a after draining out the R-12 mineral oil. Although this may be a recommendation, it may not be backed with a warranty. Use your own judgment here or let the customer make the call.

2. Condenser

When R-134a is used in an R-12 system, operating pressures generally run about 20 psi higher. If this is acceptable, the existing condenser can be used. If operating pressures are already marginal, as in some existing systems, a larger condenser should be added.

3. Receiver-Drier

Always replace the receiver-drier. Many new receiver-driers are being built with XH-7 or XH-9 desiccants which are compatible with both R-12 and R-134a. However, a drier that is in service will have collected moisture, contaminants, and lubricant. It is good insurance to start with a clean component. R-134a is more sensitive to the presence of free moisture. A receiver-drier with more desiccant (such as 15 cubic inches in place of 12 cubic inches) is a great idea.

4. Expansion Valve

Beginning in 1993, many expansion valves are being charged with a gas that works equally well with R-12 and R-134a. Even a TXV charged with R-12 will work fairly well with the new refrigerant. If the valve is clean and functioning, it can be reused with little risk.

5. Evaporator

The evaporator coil can be used although it should be drained of lubricant.

6. Hoses

R-134a will permeate through rubber hose much faster than R-12. A nylon barrier hose is much better for either refrigerant but essential with R-134a. Nylon barrier hose has been used on many heavy duty R-12 systems. There have been continued improvements in both hoses and fitting crimp designs. Hose replacement is costly but the customer should be advised of the risk of possible replacement at a later date.

7. Seals and “O” Rings

Certain seals and “O” rings in older systems are not compatible with PAG lubricants. The best bet is to change “O” rings with a known material such as neoprene or HNBR. The systems manufacturer should be able to advise you on compressor and other system seals.

8. Service Ports

The R-12 service ports, most often Schrader type fittings, must be removed or converted to R-134a service ports.

General Retrofit Procedure

Now it’s time to make the changeover. Before starting, be sure all the new materials are at hand. They could well be in short supply.

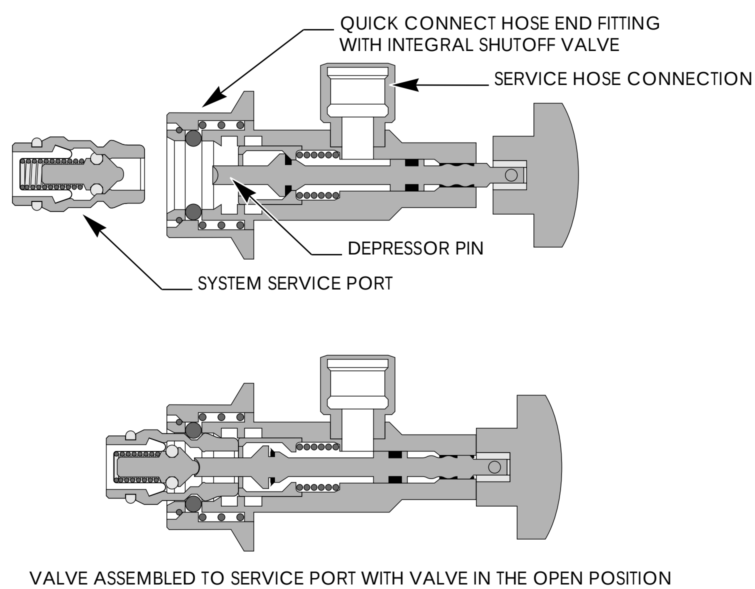
1. Using your R-12 recovery/recycle equipment, remove the R-12.
2. Remove mineral oil. Removing as much mineral oil as possible is very important, although some tests indicate a residual amount of oil can be tolerated.
3. Discard the receiver-drier.
4. Make efforts to drain those components where lubricant may collect. This would include evaporator coils and the lowest hoses such as those routed to a sleeper box evaporator.
5. If you are reusing the compressor, it should be removed and drained. Measure the amount of oil removed.
6. Power flushing with R-12 might be considered, but to be successful, system restrictions (compressor, receiver drier, and expansion valves) must be isolated. Other solvents may not be compatible with system components, R-134a or the new lubricants. Know for sure what you are using, and use only what is approved by the system's manufacturer.

WARNING Compressed air should never be used to flush or purge a system. Although compressed air is most dangerous in the presence of R-134a, bad habits could develop with R-12 and carry over to the new refrigerant. Compressed air almost always contains moisture which could result in early comebacks and additional cost.

7. New quick connect service fittings must be installed on an R-134a system. This is done to prevent servicing with refrigerant other than R-134a. Figure 12-1 shows these fittings.

Figure 12-1

This illustration shows R-134a service ports and hose end fittings.



8. Reassemble the system with its new components. Attach a vacuum pump and evacuate for at least one hour. Leak check as discussed in *Chapter 9*.
9. If a label identifies the amount of R-12 and lubricant that was used in the system, replace with that amount.

10. If no label exists, refer to the recovery unit for lubricant withdrawn. Add the amount drained from the compressor and estimate that which was removed from other components. Add the type of lubricant as recommended by the vehicle or compressor manufacturer. Charge with R-134a using the sight glass technique.

11. Leak check with an electronic leak detector.

12. Replace the original system's label with one showing the retrofit to R-134a Include the amount of refrigerant, and the amount and type of lubricant that was added. It is a good idea to label the unique R-134a components if they do not already carry such identification.

Chapter Review

Retrofitting of mobile air conditioning, systems will be a major activity by 1995. The service technician must understand the procedure, and have the necessary equipment and a source for the new components. Understand the step by step procedure and do not deviate from the set plan. Advise your customer of the potential risks of using existing components.

Glossary

accumulator — a refrigerant storage and filtering component used in place of a receiver-drier in CCOT air conditioner systems

activated alumina — one of the chemical agents used in receiver-driers as a desiccant

air block — an assembly used to direct air pressure to control devices

air conditioning — control of air movement, humidity and temperature by mechanical or other means in a vehicle

air operated water valve — a valve in the vehicle cooling (heater) system controlled by air pressure

altitude — a measured height above sea level (where atmospheric pressure is lower than at sea level)

ambient air temperature — air temperature outside the vehicle

ambient switch — used to sense outside air temperature and prevent compressor operation in below freezing weather

atmospheric pressure — the pressure of the air at a given altitude with the normal pressure reference point of 14.7 pounds per square inch at sea level

axial compressor — a type of compressor containing pistons located in an axial design, i.e. Frigidaire, Sanden, or Zexel (formally Diesel Kiki)

back seat — an AC service valve position which closes off the service port and allows free flow of refrigerant in the system

bellows — a chamber used as a control device in an air conditioning system which expands and contracts much like an accordion

bi-level system — a cab HVAC system where the AC output is diverted to both upper (defrost) and lower air outlets

bimetallic — two dissimilar metals joined together to function as a thermostat

Binary™ switch — a two function pressure activated switch used to prevent compressor damage when pressure is to high or refrigerant is lost from the AC system

blends — a refrigerant containing less chlorine than R-12. Proposed as a replacement for R-12, but not a simple “drop in” substitute

blower wheel — wheel used to blow air through the evaporator or heater core causing air to circulate in the cab

boiling point — the point at which liquid changes to vapor

BTU — an abbreviation for British Thermal Unit, a unit of measure of heat quantity equal to the amount of heat energy required to raise a pound of water one degree Fahrenheit

bulk charge — a large container of refrigerant used in air conditioning system servicing, containing 20 or more pounds of refrigerant

CTC™ (constant temperature control), and CTC II™ — an electro-mechanical device used to maintain preselected air temperature

capacity — a measure of unit performance in BTU’s per hour, tons, watts or other unit of measure

capillary tube — a gas-filled tube extending from the thermostat and some expansion valves, senses temperature to close thermostat (clutch) circuit or open expansion valve orifice

Celsius — a temperature scale where zero degrees Celsius equals 32 degrees Fahrenheit (freezing), and 100 degrees Celsius equals 212 degrees Fahrenheit (the boiling point of water)

centigrade — another name for Celsius

change of state — the reorganization of matter which allows a solid to change to a liquid or gas, a liquid to a solid or gas, or a gas to a solid or liquid

charge — term used to describe what happens when refrigerant is added to an air conditioning system

charging hose — a hose connected to a port on a manifold gauge set, used to conduct refrigerant into the AC system from the refrigerant source

chlorofluorocarbon (CFC) — a family of chemicals which includes R-12 and other chemicals. Usage is being phased out under federal law.

clutch — a mechanical device which serves to take the torque in a driving force and transfer it to another force to be driven — used to drive the compressor or engine fan

clutch cycling switch — an electrical switch used to turn the compressor clutch on or off according to temperature or pressure demands (one example is the thermostat)

compressor — the pump (often referred to as the heart) of an air conditioning system which pumps refrigerant through the system and raises the vapor pressure of refrigerant

compressor head pressure — the pressure of refrigerant as it leaves the compressor through the discharge port

compressor shaft seal — a seal located on the output end of the compressor shaft which serves to keep refrigerant oil and refrigerant inside the system

condensate — the water that collects on surfaces like the evaporator fins and other cold surfaces when the air conditioning system is operating

condensation — the process by which gas or vapor changes to a liquid

condenser — a finned tube device (heat exchanger) in which refrigerant loses heat and changes from hot vapor (or gas) to a warm liquid in the system

conduction — the ability of a substance to convey heat from one point to another within the substance (heat movement in refrigerant)

contaminant — any foreign substance (particularly moisture, dirt or air) which enters an air conditioner system and must be removed

convection — transmitting or moving heat within a liquid or gas by moving the heated parts

cutoff switch — a switch on the compressor which cuts the compressor out of the system when full throttle is applied to the engine

cycling clutch orifice tube (CCOT) system — a Frigidaire AC system that uses an expansion tube (fixed orifice tube) and an accumulator in place of the expansion valve and receiver-drier

cycling clutch system — a temperature control system which monitors the operation of the compressor clutch

dehumidify — to remove moisture (humidity) from the air in the cab or defog the windshield

density — the ratio of mass to it's volume

desiccant — an agent used in an air conditioning system to dry or remove moisture by absorption; found in the receiver-drier or accumulator

desiccant bag — the container found inside some receiver-driers and accumulators for the desiccant

diaphragm — a device which acts as a bellows or piston to divide the chambers of a control device

dichlorodifluoromethane — the chemical name for Refrigerant R-12

discharge — in an air conditioning system, refers to bleeding or releasing all refrigerant in a system

discharge line — line carrying refrigerant from the compressor outlet to the condenser inlet connection

discharge pressure — the high side pressure (refrigerant vapor) leaving the compressor

discharge switch (compressor) — switch on the compressor which turns the compressor off when low pressure of refrigerant is sensed

discharge valve — same as high side service valve

drain tube — in an AC system a tube positioned to drain condensation out of the vehicle

drier — normally a part of the receiver-drier, used to absorb moisture in the system using a desiccant as a drying agent

drive pulley — the pulley that drives the compressor clutch

drying agent — same as desiccant

electronic leak detector — a device designed to sense leaks in an air conditioning system with extreme accuracy

electronic sight glass — a device using ultrasonic principals to sense refrigerant inside an AC system and provide audible signals when the AC system has the proper amount of refrigerant

equalizer line — used to control valves in an air conditioning system to equalize pressure or temperature

ester — a type of lubricant that may be found in R-134a systems

evacuate — the process of removing all moisture or air in a system by creating a vacuum in the system

evaporation — the process by which a liquid changes it's state to become a vapor or gas

evaporator — a device with coils and fins through which liquid refrigerant flows, removing heat energy from the air, and changing to a vapor

expansion tube — also called a fixed orifice tube (CCOT system), replaces expansion valve and meters refrigerant to evaporator

expansion valve — same as thermostatic expansion valve (TXV)

external equalizer — same as equalizer line

Fahrenheit — a scale used to measure temperature (heat intensity- how hot something is), and calibrated at 32 degrees Fahrenheit where water freezes and 212 degrees Fahrenheit where water boils

fan clutch — a variable speed or on-off clutch which acts as a coupler (fluid, air or electrical), between engine and the engine cooling fan

filter — a portion of the receiver-drier used to remove solid contaminants from the system

flush — the process of removing all foreign matter from a system by means of pressurized air, refrigerant or dry nitrogen

foaming — when observed in the sight glass indicates low level of refrigerant in the system

foot-pound — a measurement of energy required to raise one pound one foot. In relationship to torque, it is a force that acts upon a body (such as a bolt or nut) to produce rotation

freeze-up — the freezing of water or moisture in the expansion valve orifice or on the fins and coil of the evaporator

freezing point — the point at which a liquid will become a solid

Freon® — Dupont registered trade mark name for refrigerant R-12

front seat — an AC service valve position which isolates the compressor from the system by closing the valve (turning the valve stem all the way to the right)

gauge set — two gauges (sometimes three) installed on a manifold to test and measure conditions inside the AC system

'H' valve — a water valve which returns excess coolant from the heater inlet back to the engine cooling system

Halide leak detector — a propane gas device used to determine the location and severity of an R-12 leak in the system

head pressure — the pressure of refrigerant from where it originates at the discharge valve of the compressor, through all lines and components to the orifice in the expansion valve

heat energy — heat in action; the movement of a quantity of heat measured in BTU's (example, in a change of state)

heat exchanger — a device which enables fluid at one temperature (higher) to move heat to another fluid at a lower temperature

heat intensity — the temperature of a substance or material as measured by a thermometer

heat load — the amount of heat contained in a given situation

heat quantity — the amount of heat measured in BTU's (British Thermal Units)

heater — an apparatus that provides heat

heater core — an assembly of metal tubing and fins used to exchange heat from engine coolant to cab air

Hg — the symbol used for mercury in the Periodic Table of Elements

HVAC — heating, ventilation, and air conditioning

high load condition — the circumstance when the air conditioning system is operating at maximum capacity to cool a given environment

high pressure cutout switch — a switch which cuts out the compressor clutch if pressure in the system rises above a pre-set level

high pressure lines — the lines that carry high pressure refrigerant gas and liquid between the compressor, condenser, receiver-drier and expansion valve

high side — the high pressure side of a system (gas or liquid) from the compressor outlet to the expansion valve orifice

high side low pressure cutout switch — a switch (on the high pressure line) which cuts out the compressor clutch if pressure in the system drops below a pre-set level

high side service valve — a valve on the compressor used to service the high pressure side of the system and permit it to be checked

humidity — the degree of moisture or wetness in the air (atmosphere)

hydrochloric acid — a corrosive chemical created within an air conditioning system when moisture and R-12 combine under pressure

ideal comfort range — a temperature range, generally between 70 and 80 degrees Fahrenheit, where most people are comfortable

in. Hg (inches of mercury) — a unit used to measure vacuum

inch-pound — a measurement of energy required to raise one pound one inch. In relationship to torque, it is the force that acts upon a body (bolt or nut) to produce rotation

in-line compressor — a 2-cylinder compressor whose pistons are side-by-side, i.e.. Tecumseh, York

in-line drier — a drier located after the receiver-drier but before the expansion valve; absorbs and moisture escaping from the receiver-drier

in-line muffler — a device to reduce noise from the high side of the compressor

intercooler — an air-to-air heat exchanger used on some heavy duty vehicles, that mounts in front of the radiator to cool the intake air on a turbo-charged engine. Also called a charge-air cooler

KLEA — Technical Chemical Company trademark for R-134a

latent heat of evaporation — the amount of heat required by a substance to change it's state from a liquid to a gas without raising it's temperature

leak detector — a device which detects any refrigerant leaks in an air conditioning system

Legris air fitting — a patented push-on connector (fitting) used in AC/heater air control systems to attach tubing and designed for a positive leak free seal and quick disconnect

liquid line — the line from the outlet of the receiver-drier to the expansion valve inlet

low head pressure — a system malfunction which causes the high side pressure to be lower than required for proper system operation

low side low pressure cutout switch — a switch (on the suction line) which cuts out the compressor clutch if pressure in the system drops below a pre-set level

low side — the low pressure side of a system, from the expansion valve orifice to the compressor inlet

low side service valve — a valve on the compressor used to service the low pressure side of the system and permit it to be checked

lubricant — refrigeration oil specially formulated to be free of all contaminants and moisture. Note: different for R-12 and R-134a

magnetic clutch — an electrically operated device used to cycle the compressor on and off

manifold — the part of the manifold gauge device designed to control refrigerant flow

manifold gauge hoses — hoses connected to the manifold gauge set used to test, evacuate, recover and charge the air conditioning system

manifold gauge set — a system measuring device containing two (sometimes three) gauges and three or more service connections

melting point — the temperature at which a solid turns into a liquid

mercury — used to indicate the amount of vacuum (a perfect vacuum is 29.92 inches of mercury at sea level)

molecular sieve — a drying agent used in the receiver-drier to absorb moisture and filter contaminants out of the refrigerant

natures laws — the principals of conduct in natural process or function in nature

PAG — a polyalkylene glycol lubricant used in many R-134a systems

parallel flow — a coil design where refrigerant flows through both upper and lower tubing at the same time

phosgene — a poison gas produced when R-12 comes in contact with an open flame

POA valve — a suction throttling valve used in some systems

pressure drop — pressure lost while passing through a component, the difference between pressure in and pressure out

pressure range — a measured spread between a high and low pressure

pressure switch — a pressure sensitive electrical switch mounted at the receiver-drier, on some accumulators or in the suction line to activate or interrupt electrical current cycling the compressor clutch

propane — a flammable gas used in the Halide leak detector

psi — abbreviation for “pounds per square inch”

psig — abbreviation for “pounds per square inch gauge”

purge — to remove the refrigerant from an AC system and hoses by opening the system or using pressure to eliminate the contents

R-12 — the common name of the refrigerant used in vehicle air conditioner systems to move heat energy

R-134a — a new refrigerant which does not harm the atmosphere

radial compressor — a compressor that has pistons in a radial design

radiation — heat waves (heat energy) passing through the air

radiator shutter — a metal vane assembly on some truck radiators where the vanes can be opened or closed to allow or exclude ram air flow to the radiator, radiator mounted condenser and engine

ram air — air through which a vehicle passes, increasing in force as the speed of the vehicle increases

receiver-drier — a container which receives, stores, and removes moisture from refrigerant

reciprocating compressor — a compressor having pistons that move back and forth in cylinders

reclaim – the process of restoring refrigerant to new product specifications

recovery – the process of removing refrigerant from an AC system

recycle — the process of removing contaminants (moisture, acid, particulate matter) from a refrigerant

reed valve — suction and discharge valves located in the valve plate of the compressor

refrigerant — a substance used in HVAC systems to control heat energy

refrigerant cycle — one complete revolution of refrigerant through the system which includes changes of state of the refrigerant from liquid to vapor or gas and back to liquid

refrigeration oil — a specially manufactured oil free from moisture and all contaminants

relative humidity — the amount of moisture in the air as compared to the total amount the air can hold at a given temperature and altitude

resistor — a voltage dropping device, usually wire wound, which provides a means of controlling fan or blower speed

retrofitting — reconditioning an R-12 AC system to use R-134a

rotary vane compressor — a type of compressor which uses internal vanes rather than pistons to operate and pump the refrigerant through the system

rotating coil clutch — an old type clutch where the magnetic coil is part of the clutch pulley — now replaced universally by the stationary coil design where the coil is bolted to the compressor body

Schrader valve — a spring loaded valve inside some service fittings, similar to a tire valve; also found on some accumulators

serpentine — a condenser coil formed from one piece of extruded aluminum tubing

service port — a fitting on control devices and service valves allowing connection of manifold gauge hoses

service valve — see “low side service valve” and “high side service valve”

shaft seal — see “compressor shaft seal”

sight glass — a window usually in the top of the receiver-drier for observing the condition of the refrigerant

silica gel — a type of desiccant which removes moisture from refrigerant

solenoid valve — an electromagnetic valve controlled by electrical current energizing and de-energizing a coil to open or close the valve

specific heat — the amount of heat required to change the temperature of one pound of a substance 1 degree Fahrenheit

stationery coil clutch — the magnetic clutch used to drive the compressor

stem-type valve — a service valve with a threaded valve stem for three position adjustment, back-seated, mid position and front-seated

suction line — the line connecting the evaporator outlet to the compressor inlet; the low pressure lines

suction service valve — see “low side service valve”

suction side — the low pressure portion of the system, from expansion valve orifice to compressor inlet

sump — the portion of a compressor where oil is contained, waiting to be circulated

superheat — heat added to a gas after evaporation from a liquid state (the approximate temperature rise across the evaporator coil)

SUVA — Dupont trademark for R-134a

superheat switch — a switch mounted on the compressor and connected to a thermal limiter and fuse, used in some GM systems to sense low refrigerant and protect the compressor

temperature range — a measured spread between a high and low temperature

thermal limiter — a protective device with a fuse and used with a superheat switch to stop the compressor when low pressure is sensed by the superheat switch

thermistor — a very sensitive electronic temperature sensor

thermostat — a temperature sensitive switch used to control system temperature by cycling the compressor on and off

thermostatic expansion valve — a valve which senses evaporator outlet tube temperature and pressure to regulate the flow of refrigerant into the evaporator

TRINARY™ switch — a three function switch, the first two functions protect the compressor from operating as follows: 1) abnormally low refrigerant or loss of refrigerant, 2) extremely high head pressure. The third function can open the radiator shutter and/or cycle an air or electric operated fan clutch when the system requires more air flow through the condenser

tube and fin — aluminum or copper tubing inserted through individual pieces of fin material

vacuum — expressed in inches of mercury or Hg, a vacuum is a state in which air pressure is below atmospheric pressure

vacuum pump — a pump attached to a sealed system or enclosure (an air conditioning system) to evacuate air and moisture from the system

valves-in-receiver — a receiver-drier which contains an expansion valve and a POA valve in one unit

WANKEL compressor — a type of compressor which uses a triangular gear driven rotor inside a figure eight shaped cavity to operate and pump refrigerant through the AC system

water valve — a mechanical, vacuum or air operated valve used to control the flow of coolant to the heater core

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