Acknowledgements

General Motors, the IAGMASEP Association Board of Directors, and Raytheon Professional Services, GM's training partner for GM's Service Technical College wish to thank all of the people who contributed to the GM ASEP/BSEP curriculum development project 2002-3. This project would not have been possible without the tireless efforts of many people. We acknowledge:

- The IAGMASEP Association members for agreeing to tackle this large project to create the curriculum for the GM ASEP/BSEP schools.
- The IAGMASEP Curriculum team for leading the members to a single vision and implementation.
- Direct contributors within Raytheon Professional Services for their support of translating a good idea into reality. Specifically, we thank:
  - Chris Mason and Vince Williams, for their leadership, guidance, and support.
  - Media and Graphics department under Mary McClain and in particular, Cheryl Squicciarini, Diana Pajewski, Lesley McCowey, Jeremy Pawelek, & Nancy DeSantis.
  - For his help on the Heating, Ventilation, and Air Conditioning curriculum volume, Subject Matter Expert, Brad Fuhrman, for his wealth of knowledge.

Finally, we wish to recognize the individual instructors and staffs of the GM ASEP/BSEP Colleges for their contribution for reformatting existing General Motors training material, adding critical technical content and the sharing of their expertise in the GM product. Separate committees worked on each of the eight curriculum areas. For the work on this volume, we thank the members of the Heating, Ventilation, and Air Conditioning committee:

- Steve Ash, Sinclair Community College
- Warren Farnell, Northhampton Community College
- Rick Frazier, Owens Community College
- Marvin Johnson, Brookhaven College
- Chris Peace, J. Sargeant Reynolds Community College
- Vince Williams, Raytheon
# Contents

## Module 1 – Fundamentals of HVAC

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>2</td>
</tr>
<tr>
<td>Objectives</td>
<td>4</td>
</tr>
<tr>
<td>Lesson 1. Fundamentals</td>
<td>6</td>
</tr>
<tr>
<td>Objective</td>
<td>6</td>
</tr>
<tr>
<td>Principles of Refrigeration Introductions</td>
<td>11</td>
</tr>
<tr>
<td>Refrigerant System Capacities Guidelines</td>
<td>28</td>
</tr>
<tr>
<td>A/C System Components</td>
<td>30</td>
</tr>
<tr>
<td>Leak Detection</td>
<td>32</td>
</tr>
<tr>
<td>Refrigerant Safety</td>
<td>37</td>
</tr>
<tr>
<td>Refrigerant Handling</td>
<td>37</td>
</tr>
<tr>
<td>Cooling System Components</td>
<td>42</td>
</tr>
<tr>
<td>Manual HVAC Systems</td>
<td>43</td>
</tr>
<tr>
<td>Refrigerant Recovery and Recharging</td>
<td>44</td>
</tr>
<tr>
<td>Leak Detection Worksheet</td>
<td>46</td>
</tr>
<tr>
<td>Performance Test Worksheet</td>
<td>50</td>
</tr>
</tbody>
</table>
Objectives

The objectives of this module are introductions, which include the principles of refrigeration, heating, ventilation and A/C subsystems, refrigeration systems, cooling systems, and air distribution systems. Also in this module we will cover safety precautions, environmental concerns, the handling of refrigerant 134a, and refrigerant R12, tools and system identification.

NATEF Area A.7

• Research applicable vehicle and service information, such as heating and air conditioning system operation, vehicle service history, service precautions, and technical service bulletins.
• Locate and interpret vehicle and major component identification numbers (VIN, vehicle certification labels, calibration decals).
• Leak test A/C system; determine necessary action.
• Inspect the condition of discharged oil; determine necessary action.
• Determine recommended oil for system application.
• A/C compressor and mountings; measure oil quantity; determine necessary action.
• Determine need for an additional A/C system filter; perform necessary action.
• Remove and inspect A/C system mufflers, hoses, lines, fittings, O-rings, seals, and service valves; perform necessary action.
• Inspect A/C condenser for airflow restrictions; perform necessary action.
• Remove and reinstall receiver/drier or accumulator/drier; measure oil quantity; determine necessary action.
• Remove and reinstall evaporator; measure oil quantity; determine necessary action.
• Remove and reinstall condenser; measure oil quantity; determine necessary action.
• Perform correct use and maintenance of refrigerant handling equipment.
• Identify by label application or use of a refrigerant identifier) and recover A/C system refrigerant.
• Recycle refrigerant.
• Label and store refrigerant.
• Test recycled refrigerant for non-condensable gases.
• Evacuate and charge A/C system.

**STC Tasks:**
• Identify safety procedures to be followed when working with refrigerants and refrigeration systems
• Vapor Cycle and Principles of Refrigeration
• Describe the principles of refrigeration and how they are utilized within automotive systems
• Describe A/C systems currently used in General Motors' vehicles
• Describe the CCOT system
• Describe the VDOT system
• Describe the CCTXV system
• Describe the VDTXV system
• Describe refrigerant system components
• Describe the proper use of AC service equipment utilizing approved service procedures.
• Describe approved HVAC servicing procedures
• Describe refrigerant leak detection procedures
• Describe refrigerant leak detection using electronic leak detectors
• Environmental Concerns
• Describe the impact of refrigerants on the environment
• Identify the laws and regulations regarding approved handling of refrigerants
Lesson 1. Fundamentals

Objective

Describe the theory and operation of:

- HVAC Systems
- Cooling Systems
- Air Distribution Systems
- Principles of Refrigeration
- Air Conditioning and Comfort
- Properties of Heat and Temperature
- Vaporization and Condensation
- Basic Refrigeration Cycle
- Factors Affecting Heat Transfer.

Figure 1-1,

A Heater, Ventilation and Air Conditioning (HVAC) system can be divided into the following three sub-systems:

- Refrigeration
- Cooling
- Air Distribution

This lesson deals with the principles of operation and components used for the refrigeration sub-system. The refrigeration sub-system transports refrigerant throughout the HVAC system. It is composed of refrigerant lines, pressure control devices and heat transfer components.

The cooling sub-system is used to cool the hot refrigerant entering the condenser. The cooling sub-system directs cool air entering the engine compartment through the condenser.

The air distribution sub-system directs air through the ventilation system.
Refrigeration Systems

Some of the more popular refrigeration systems that General Motors uses are the following:

- **CCOT** stands for cycling clutch orifice tube
- **VDOT** stands for variable displacement orifice tube
- **CCTXV** stands for cycling clutch expansion valve
- **VDTXV** stands for variable displacement expansion valve

The types of refrigerant used are R 12 and R134A.

Refrigeration systems are used to transfer heat from the air in the passenger compartment to the outside air. The refrigerant is the medium used to transfer heat through the system. All refrigerant systems have certain components in common for performing this task. The evaporator transfers heat from the air entering the passenger compartment to the refrigerant. Accumulator drier or receiver dryer stores the refrigerant and removes any moisture. The compressor is used to compress vaporized (low pressure) refrigerant to a high pressure vapor. The orifice tube or thermostatic expansion valve provides control of refrigerant flow and separates the high-pressure side of the refrigerant system from the low-pressure side of the system. The condenser transfers heat from the refrigerant to the outside air.

*Figure 1-2,*
Cycling Clutch Orifice Tube

The cycling clutch orifice tube refrigeration systems have a fixed displacement compressor that may be controlled by the PCM. The PCM or a pressure switch cycles the compressor on and off to maintain the refrigerant pressure within predetermined limits. The CCOT systems use and orifice tube to control the refrigerant flow and separates the high-pressure from the low-pressure.

The CCOT refrigeration system also uses the following components:

- condenser
- accumulator drier
- evaporator
- muffler
- pressure cycling switch
- thermostatic switch
- pressure cutoff switches
- pressure sensors

Variable Displacement Orifice Tube

The variable displacement orifice tube refrigeration systems have a variable displacement compressor with a PCM controlled clutch. Internal pressure control's within the compressor maintains the low-pressure within predetermined limits. Internal pressure control's eliminates the need to cycle variable displacement compressors. Pressure switches on the high side of the compressor protects the compressor from damage if the refrigerant is not within operating specifications. The VDOT system uses an orifice tube to control refrigerant flow and separates the high side pressure from the low side pressure.

The VDOT refrigeration system also uses the following components:

- Condenser
- Accumulator drier
- Evaporator
- Muffler
- Pressure cutoff switches
- Pressure sensor
Variable Displacement Thermostatic Expansion Valve

The variable displacement thermostatic expansion valve refrigeration systems have a variable displacement compressor with a PCM controlled clutch. Internal pressure control's within the compressor maintain the low side pressure within predetermine limits. Internal pressure control's eliminates the need to cycle variable displacement compressors.

Pressure switches on the high side of the compressor protects the compressor from damage if the refrigerant pressure is not within operating specifications. The VDTXV system uses a thermostatic expansion valve to control refrigerant flow and separates the high-pressure side from the low-pressure side. The TXV meters the amount of refrigerant entering the evaporator to more accurately control heat absorption.

The VDTXV refrigeration system also uses the following components.

- Condenser
- Receiver dryer
- Evaporator
- Muffler
- Pressure cutoff switches
- Pressure sensor

Figure 1-5, Variable Displacement Thermostatic Expansion Valve

Cycling Clutch Thermostatic Expansion Valve

The Cycling Clutch Thermostatic Expansion Valve refrigeration systems have a fixed displacement compressor with a PCM controlled clutch. The PCM or pressure switch cycles the compressor on and off to maintain the refrigeration pressure within predetermine limits. The CCTXV system uses a thermostatic expansion valve to control refrigerant flow into separate the high side pressure from the low side pressure. The TE asked the meters the amount of refrigerant entering the evaporator to more accurately control heat absorption. The CCTXV refrigeration system also uses the following components.

- Condenser
- Receiver dryer
- Evaporator
- Muffler
- Thermostatic switch
- Pressure cutoff switches
- Pressure sensor

Figure 1-6, Cycling Clutch Thermostatic Expansion Valve
Cooling Systems

The cooling sub system of the HVAC system directs air through the fins of the condenser. Passing air through the condenser allows heat transfer of the hot refrigerant cooler air. Cooling systems are composed of the following components.

- Air intake
- Condenser
- Radiator
- Fans
- Seals and Shrouds

Figure 1-7, Cooling System

Air Distribution Systems

The air distribution sub system of the HVAC system directs conditioned air through the air outlets. Air distribution systems are composed of the following components:

- Blower
- Evaporator
- Heater
- Air door/valves
- Air ducts
- Control system

Figure 1-8, Air Distribution System

The blower generates an air current to flows through the air ducts. Air current is directed by various air door/valves. Control of the air doors/valves is accomplished by three methods: mechanical, vacuum and electronic. A combination in these three methods can also be used within an air distribution system. Lower speed and air/door valve control are combined to provide the desired air temperature at the correct air outlets.
Principles of Refrigeration Introductions

Automotive A/C systems are designing based on the laws of physics, chemistry, and electronics. A basic familiarity with these laws together with an understanding of A/C components and their operation provide the skills necessary for quick, accurate A/C systems diagnostics diagnosis.

Physics isn't the science of matter and energy. Simply put, it teaches us how things interacted are universe. Several laws of physics apply to automotive refrigerant systems:

- Behavior of heat
- Properties of liquids and gases
- Behaviors all refrigerant R12 and R134a
- Affects of heat and pressure on liquids and gases

Air Conditioning and Comfort

The sole purpose of an AC system is for customer comfort. The AC system achieves customer comfort by cooling the air temperature inside the passenger compartment and removing moisture, dust and pollen particles. By removing moisture and lowering the humidity, the AC system can achieve customer comfort at a higher temperature. Laboratory tests show that people feel just as cool at 79°F with 30 percent humidity as they do at 72°F with 90 percent humidity. The reason for this is that the human body cools itself by allowing moisture on the skin to evaporate. When the moisture evaporator a cools the skin.

The relative humidity governs how quickly evaporation occurs:

- High relative humidity equals low evaporation rate.
- Low relative humidity equals high evaporation rate.

When the A/C system removes moisture from the air, the relative humidity in the passenger compartment decreases. By reducing the relative humidity, the A/C system increases the rate at which the moisture on the passenger skin will evaporate.
Heat vs. Temperature

AC systems operate by removing heat from the air entering the passenger compartment. The result of this is a lower temperature. Temperature and heat are not interchangeable terms. Heat is the energy in a substance. Heat can be measured by British Thermal Units the (BTUs). One BTU is the amount of heat needed to raise 1 pound of water 1°F at sea level. He is independent of temperature. The cup of coffee and the coffee pot are both the same temperature but have different amounts of heat. Temperature is the intensity level of the heat. Temperature can be measured in degrees Fahrenheit. An object that is hot has a high intensity of heat. An object that is cold has a low intensity of heat. Cold objects have a lower intensity level of heat. The cold pool has a greater quantity of heat than the hot barbecue even though the barbecue has a much higher intensity of heat.

Due to the fact that refrigeration was first produced by ice, the rate of removal of heat in a cooling operation is expressed in terms of pounds or tons of ice needed per unit of time (usually per day). 1 lb. of ice absorbs 144 BTU when it melts; 1 ton of ice absorbs 2000 x 144 or 288,000 BTU. When 1 tone of ice melts in 24 hours, the rate is 288,000/24 or 12,000 BTU per hour (or 12,000/60 = 200 BTU per minute). This rate has been officially called 1 ton of refrigeration and is the basis for rating all refrigeration systems.
Heat Transfer

The law of heat transfer states:

- Heat always flows from an area of higher temperature to an area of lower temperature.

Just as water flows downhill, heat always flows down the temperature scale. Thus, when holding a glass of ice water, heat flows from the warm hand to the cooler glass. The law of heat transfer also states:

- The greater the difference in temperature, the faster heat flows.
- Heat continues to flow until both temperatures are equal heat transfer tries to equalize intensity.

An automotive engine cooling system is an excellent example of the different types of heat transfer: conduction, convection, and radiation. The heat transfer process occurs throughout the system. Inside the engines cylinders, burning fuel generates tremendous amounts of heat. However, because the engine coolant system keeps the cylinder walls cooler than the temperature of the burning fuel, heat flows from the combustion chamber to the cooler inner cylinder wall. This heat is then transferred to the outer cylinder wall into the liquid coolant. The outer cylinder wall is hotter than the coolant, so heat transfers to the lower temperature coolant. This type of heat flow is called conduction the flow of heat through a substance. The water pump circulates the saturated cooling away from the engine cylinder walls to the radiator. This movement of heat from one place to another uses a liquid transfer path known as convection. Conductive transfer again or occurs at the radiator. Where the heat energy moves to the cooler radiator surfaces. Then, as the air flows through the radiator walls, the heat radiates to the cooler air. The law of heat transfer, along with the design of the cooling system, prevents engine overheating. Each time heat flows, the law as upheld: heat flows from areas of higher temperature to areas of lower temperature. In principle, and A/C system does the same job as the engine cooling system. An engine cooling system carries heat away from the engine via coolant, while the AC system carries heat away from the air and the passenger compartment via refrigerant. Both systems release stored heat to the outside air.

![Figure 1-12](image-url)
Conduction: heat movement through a solid
Heat transfers through metal parts of a vehicle: gearshift rod, bulkhead, etc.

Convection: heat movement using a gas or liquid
The water in a pan on a stove heats up and rises; the cooler water on the surface sinks to the bottom. The coolant circulating in the cooling system transfers heat from the engine to the radiator and the warm or cool air circulating through the vehicle are all examples of convection.

Radiation: The heat transfer from the Sun to the Earth is an example of radiation. Heat is transferred, but it does not warm the medium (space) through which it passes. (similar to light waves). A human radiates approx. 75 watts of heat.
States of Matter

Because the A/C refrigeration system and the engine cooling system used different mediums for heat transfer, there are some important differences between the two systems. Engine coolant is an ethyl-glycol based liquid. Ideally it remains a liquid as it transfers heat. Refrigerant, on the other hand, evaporate and condenses each time it absorbs or transfers heat. As a result, it changes from a liquid to a vapor and back to a liquid as it flows through the AC system. In physics, a changes state occurs when the molecular cell structure of a substance is rearranged as it changes between any two of the three physical states: solid, liquid, or a gas. For example, an ice cube is a solid. Yet when dropped onto a hot griddle, the ice undergoes a changes state as it melts into a liquid. And, as water evaporates into a vapor, another changes state occurs. What makes a physical change of state occurs is either adding or subtracting heat.

![Figure 1-13](image_url)
Latent Heat and the Vaporization of Liquids

Another law of physics is the heat of vaporization law. It states: a specific amount of heat is needed to change a liquid into a vapor. The amount of heat needed to change 1 Gram of liquid into a vapor is called its heat of vaporization. The heat of vaporization is also known as latent heat. Latent heat refers to the heat absorbed as a liquid changes state. It is called latent or hidden heat because, even though a lot of heat is absorbed as a change in state occurs, the liquid and vapor remain at the same temperature. When water has absorbed enough heat to boil, it turns to a vapor. Water at 212°F turns into a vapor at the same temperature. Under normal circumstances, adding more heat to the water does not increase the temperature of the water. Boiling water at atmospheric pressure cannot be heated above 212°F. Any heat above the quantity necessary to boil water only produces greater quantities of vapor in less time.

When a vapor changes to a liquid, it is said to condense. A common example of condensation is found on the bathroom mirror during a steamy shower. Moisture from the steamy air condenses as it comes in contact with the cool mirror. This moisture collects on the mirror and drips down the surface in the form of a liquid. When vapor condenses, it releases its latent heat. The latent heat of condensation is the amount of heat released as a vapor changes to a liquid.
Specific Heat:

Each substance has a different capacity for absorbing heat.

If 1 lb of water at 80°F is cooled to 60°F it will emit 20 BTUs.

If 1 lb of iron is cooled over the same range, only 2.6 BTUs will be emitted (about 1/8 of that emitted from water).

All materials absorb heat in different capacities. By comparing heat-absorbing qualities with a standard, a gauge is produced to make comparisons.

The amount of heat, in BTUs, required by 1 lb of a substance to change its temperature 1°F is its specific heat.

Water is used as the 1.00 on the specific heat scale because of its large heat capacity. 1 lb of water requires 1 BTU to raise its temperature by 1°F.

The heat of vaporization of R-12 at 37 psi and 40°F is 64.2 BTUs/Lb. The heat of vaporization of R-134a at 34.5 psi and 40°F is 87.2 BTUs/Lb.

R-12 circulates through the system at approximately 10 pounds per minute. R-134a circulates through the system at approximately 8 pounds per minute.

One cubic ft of R-12 weighs 81.5 pounds at 79°F. One cubic ft of R-134a weighs 75 pounds at 79°F. This is why less (weight) of R-134a is need during a retrofit.

Boiling point and vaporization point are interchangeable terms. As materials are heated they absorb heat (BTUs). In order for a change of state to occur additional BTUs must be absorbed. This additional heat is called the latent heat.

Latent heat is the hidden or non-apparent heat.

• It requires the addition of 144 BTUs to change 1 lb of ice (32°F) to 1 lb of water.

• It requires the addition of 970.4 BTUs to change 1 lb of water (32°F) to 1 lb of steam.

Latent heat of 134A is 93 BTU/lb.
Pressure-Temperature Relationships

The science of physics includes laws describing the relationship between pressure and the boiling points of liquids.

Let's look specifically at two of these laws.

**IF THE PRESSURE ACTING ON A LIQUID IS INCREASED, THE BOILING POINT OF THE LIQUID INCREASES.**

**LOWER THE PRESSURE ACTING ON A LIQUID LOWERS ITS BOILING POINT.**

Thus, water in a vacuum boils at a very low temperature, while water pressurized in an engine cooling system boils at a higher temperature.

An engine cooling system readily demonstrates the effect of pressure on the boiling point of water. As water in the cooling system warms up, pressure builds in the sealed system.

This pressure increases the boiling point of the water well above 212°F. As long as the system remains sealed and pressure is maintained, the water can be heated above its normal boiling point without boiling.

However, if the radiator cap is removed, the pressure in the cooling system is released. The pressure acting on the water is now ambient air pressure.

The water, heated under pressure to more than 212°F, will boil as soon as the pressure is released.

This example is quite useful because pressure affects all liquids the same way it affected the water.
Effect of Pressure on Gases and Vapors

Pressure also affects the temperature of gases and vapors. Compressing a gas or vapor increases its temperature because the same amount of heat is concentrated into a smaller area.

Thus, the temperature of the gas or vapor can be increased without adding extra heat.

This is what happens inside an air conditioning system's compressor. The compressor uses pressure to concentrate the heat of a vapor.

A heat transfer occurs when the vapor contacts a cooler surface. Transferring heat away from the hot, high-pressure vapor condenses it into a liquid.

Lowering the pressure of this liquid causes it to boil and absorb heat as it changes state.
A/C System Temperature-Pressure Relationship

Pressure in an air conditioning system raises the boiling point of the refrigerant. Thus, automotive air conditioning systems are designed to operate at pressures that keep the boiling point of refrigerant at just the right temperature for taking heat out of the passenger compartment.

A definite temperature and pressure relationship exists between liquid refrigerants and their vapors.

The heating of refrigerant causes it to expand. When confined in a closed space, an increase in temperature is always accompanied by an increase in pressure, even though no compressor is present.

For every temperature increase, a corresponding pressure will exist in a container of R-12 or R-134a.

The chart displays this temperature-pressure relationship for both refrigerants.

Pressures are expressed either as positive gauge pressure or negative gauge pressure.

Referring to the chart, a pressure gauge attached to a container of R-12 at 70°F reveals a pressure of about 70 pounds per square inch.

If the temperature is increased to 100°F, the gauge will register about 117 pounds per square inch.

The pressure characteristics of R-134a differ from those of R-12.

The boiling point of R-134a is minus 16°F at sea level. R-12 boils at minus 22°F, which is a difference of 6°F.

Because of this difference, R-134a system gauge readings will differ slightly from previous R-12 systems.

Also if the refrigerant within a refrigeration system or container is not pure, the pressure-temperature relationship will not match the figures in the chart.
Basic Refrigeration Cycle

A/C system move heat from one place to another by compressing, condensing, evaporating refrigerant. The A/C system creates these special conditions by using pressure and heat transfer to control the changing states of liquid and vapor. An A/C refrigerant system consists of several components connected together with tubes and hoses to form a closed loop for the refrigerant cycle. The refrigerant flows through the closed loop, absorbing heat in the evaporator and releasing it in the condenser. All automotive A/C systems contain these components:

- Compressor - uses pressure to concentrate the refrigerant's vapor heat.
- Condenser - transfers heat from the vapor coming out of the compressor, condensing the refrigerant into a liquid.
- Evaporator - transfers heat from the passenger’s compartment air to the refrigerant, vaporizing the refrigerant.
- Refrigerant - absorbs and releases heat as it changes states.
- Lubricant - extends compressor life.

Controlling Refrigerant in the A/C System

Pressure and Flow

In addition to the compressor, condenser, any evaporator, AC systems require some method of controlling refrigerant pressure and flow. The compressor can pump refrigerant vapor through the system. But unless it has something to push against, it cannot build up system pressure and maintain the necessary conditions to achieve the refrigeration effect.
Refrigerant system pressure is necessary. Low side system pressure keeps the boiling point of the refrigerant at the proper level. High evaporator pressure would slow the evaporation of refrigerant to reduce the refrigerant affect. High-side pressure allows the refrigerant to condense at normal ambient temperatures.

A metering device is used to help from the compressor build pressure and maintain the refrigerant cycle. GM uses two types of metering devices: orifice tubes and thermostatic expansion valves. Orifice tubes have openings of fixed diameters for metering refrigerant flow. Thermostatic expansion valves vary refrigerant flow based on evaporator outlet temperatures.

**High and Low-pressure Areas**

The refrigerant system is divided into two portions: a high-pressure area high side and a low-pressure area low side. These two areas are separated by metering device orifice tube or TVX and compressor. Because the compressor can move more refrigerant than is able to pass through the metering device any given time, pressure builds between the compressor outlets in the metering device. Therefore, the high side of the refrigerant system extends from the compressor outlet, through the condenser, to the metering device inlet. During operation, high-pressure side is also the high temperature side of the system.

The low side starts at the metering device outlet, includes the evaporator in the accumulator and continues to the compressor inlet. During operation the low-pressure side is also the low temperature side of the refrigerant system. The high and low pressure sides can be distinguished in several ways:

- **Tube diameter** - high side to being is often smaller than low side to be.
- **Feel** - high side to being is hotter than low side to being.
- **Sight** - low side to being is often cool enough to collect frost or water droplets 1 high humidity days.
- **Pressure** - a gauge said can be used to measure the pressures and EC system.
- **Refrigerant temperature** - various methods can be used to determine refrigerant temperature
Inside an operating A/C system, the following process continuously occurs:

- Low-pressure refrigerant vapor is drawn into the compressor. During compression this vapor becomes a hot high-pressure vapor.
- The hot high-pressure vapor then passes into the condenser. Here, the vapor transfers its heat to the condenser surfaces.
- As the refrigerant vapor gives its heat, it condenses and cools into a high-pressure liquid.
- A high-pressure liquid passes through a restriction (orifice tube or TXV) into the evaporator. The restriction controls the volume of refrigerant entering the low-pressure side of the system. Inside the evaporator, the low-pressure refrigerant begins to vaporize as it soaks up heat from the evaporator surfaces. This refrigerant vapor collects in the accumulator, which acts as a storage tank.
- As the refrigerant vaporizes, it expands and increases the low side pressure. This refrigerant vapor is drawn into the compressor, in the cycle repeats.
Controlling Refrigerant Flow

Depending on the design, automotive A/C systems use several methods to control the flow of refrigerant. Central to each design, however, is the continuous interaction of the compressor with a flow control device, such as an orifice tube. The volume of flow is adjusted based upon the pressure-temperature load, which is monitored at a key location in the system.

Factors Affecting Heat Transfer Efficiency

The heat transfer efficiency of automotive AC systems is greatly affected by heat load the amount heat that must be absorbed by the refrigerant. Factors affecting heat load are airflow at the condenser and evaporator, humidity, ambient temperatures, and sun load.

Cooling Fan

Engine cooling fans are an important part of the A/C system. In addition to causing engine overheating and nonfunctional cooling fan hinders the heat transfer process taking place at the condenser and radiator. Insufficient heat transfer at the condenser causes the compressor to work hard at compressing the refrigerant vapor. This in turn causes the compressor head pressure or high side pressure to rise to unacceptable levels.

Condenser. Any obstruction which reduces or blocks the airflow through the condenser will affect the efficiency of the condenser and the overall A/C refrigerant system performance. If air is diverted around the condenser, the A/C refrigeration system performance will also be affected.

Blower motor. The blower motor affects the evaporator heat transfer in the same way that the cooling fan affects the condenser heat transfer. Blower motor speed controls airflow speed which determines the volume air over the evaporator. This, in turn, determines the amount of heat that can be absorbed by the refrigerant any given time. Therefore, the blower speed directly affects the heat exchange rate at the evaporator.

Humidity. Humidity is a measure of water vapor present in the air. When this water vapor condenses on the evaporator, the heat of vaporization of the water is absorbed in by the cooler evaporator surface. This heat is then absorbed by the refrigerant and in the evaporator. This reduces the amount heat that can be removed from the air. Therefore, on a humid day, the air is not cooled as efficiently as it is on a dry day.
**Sun load.** Sun load is the intensity of long wave heat rays from the sun. Ambient temperatures together with the type and color of interior and exterior materials, affect heat load and, thus, the efficiency of the A/C system.

**Compressors**

The compressor performs one main function. It compresses low-pressure refrigerant vapor from the evaporator into a high-pressure, high temperature vapor.

General Motors currently uses compressors made by Harrison, Sanden, Nippondenso, and Zexel.

There are two main types of compressors; Cycling Clutch and Variable Displacement. These compressors differ in design and displacement.

The cycling clutch compressors used by General Motors are fixed displacement compressors. Cycling clutch compressors are controlled by cycling them ON and OFF according to the pressure in the low-pressure side of the refrigeration system.

When the compressor is cycled ON, electric current energizes the electromagnetic clutch and the engine drives the compressor. When the compressor is cycled OFF, the electromagnetic clutch is de-energized and the pulley on the front of the compressor is allowed to freewheel.

Control of the compressor clutch can either be directly controlled by a pressure cycling switch, or by the Powertrain Control Module or Electronic Control Module. If the Powertrain Control Module or Electronic Control Module, also referred to as the PCM or ECM, respectively, controls the compressor clutch then the pressure cycling switch would be used as an input.

Some cycling clutch refrigeration systems may use a thermostatic switch or sensor instead of a pressure cycling switch.

High and low-pressure cutoff switches may also be used to protect the compressor in cases where the refrigerant pressure is outside of proper operating parameters.

The second type of compressor is the Variable Displacement Compressor. Currently, General Motors uses only one type of variable displacement compressor, the Harrison V-5.

This type of compressor varies its displacement in relation to the difference in pressure between the high-pressure side and the low-pressure side. If the low-pressure side becomes too low, the compressor
will use a short piston stroke. The piston stroke is dependent on the wobble plate inside the compressor. The wobble plate position is dependent on the crankcase pressure which is controlled by the control valve assembly.

By varying the displacement and not the ON time, the compressor can keep a more equal load on the engine. This action prevents the surges in engine performance that can be felt with cycling clutch compressors. When air conditioning is requested in a variable displacement compressor system, the electro-magnetic clutch will remain ON until the driver command turns the air conditioner off or if the cut-off switches or the PCM or ECM detects refrigerant pressures outside of parameters.

**Cycling Clutch Compressors**
- HR-100/HR110 (R-4)
- HR-6
- SD-5
- Nippondenso
- Zexel KC-50

**Variable Displacement Compressors**
- V-5
- Swash plate design
- 5 cylinders
- Variable displacement
Oil Charge

- How much do you add?
- How do you add?
- What kind of oil do you add?
- When do you add oil?
  - Broken refrigerant hose
  - Leaking hose or fitting
  - Bad compressor seal leak
  - Collision damage

Refrigerant carries a charge of lubricating oil throughout the system to lubricate moving parts. Most compressors used today rely totally upon the oil-saturated refrigerant to lubricate their internal moving parts.

Therefore, it is imperative that the proper level, viscosity, and purity of the oil be maintained for proper operation.

As refrigerant enters the compressor, some oil droplets separate from the refrigerant and fall into the crankcase, lubricating the moving parts. The oil is then picked up by the exiting refrigerant and continues through the system.

General Motors uses only two types of lubricating oil:

- 525-viscosity mineral-based oil is used with R-12 systems, and
- Polyalkaline Glycol oil, also referred to as PAG oil, is used with R-134a systems.

Both lubricating oils will absorb water vapor and therefore should not be exposed to air for prolonged periods.

Ensure the two oils do not mix. If PAG oil is added to an R-12 system the oils separate, but the refrigerant reacts with the PAG oil and produces a sticky sludge. Adding mineral oil to an R-134a system causes the oil to separate and become inert.

During air conditioner operations, there is a small amount of oil located in all system components. The average total oil charge is 8 ounces. However, this may vary from 6 to 9 ounces; make sure you check the appropriate service manual for specific applications.

It is not recommended that compressor oil level be checked as a matter of course. Generally, it should be checked only when there is evidence of a major loss of system oil. This could be caused by:

- a broken refrigerant hose,
- a hose fitting leak,
- a bad compressor seal leak,
- Or collision damage to system components.
Refrigerant System Capacities Guidelines

<table>
<thead>
<tr>
<th>Application</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAG Oil GM P/N 12378526 for United States</td>
<td></td>
</tr>
<tr>
<td>PAG Oil GM P/N 88900060 for Canada</td>
<td></td>
</tr>
<tr>
<td>Accumulator Replacement</td>
<td>ml*</td>
</tr>
<tr>
<td>*Add 60 ml (2 oz.) of PAG oil, plus the equal amount of oil drained from the accumulator</td>
<td>o*</td>
</tr>
<tr>
<td>Compressor Replacement</td>
<td>60 ml</td>
</tr>
<tr>
<td>Condenser Replacement</td>
<td>30 ml</td>
</tr>
<tr>
<td>Evaporator Replacement</td>
<td>90 ml</td>
</tr>
<tr>
<td>Evaporator, Rear Replacement</td>
<td>90 ml</td>
</tr>
<tr>
<td>Condenser Replacement</td>
<td>30 ml</td>
</tr>
<tr>
<td>If more than the specified amount of PAG oil was drained from a component, add the equal amount of oil drained.</td>
<td></td>
</tr>
<tr>
<td>Total System PAG Oil Capacity</td>
<td>240 ml</td>
</tr>
<tr>
<td>Total System PAG Oil Capacity with Rear A/C</td>
<td>330 ml</td>
</tr>
<tr>
<td>R-134a</td>
<td></td>
</tr>
<tr>
<td>Refrigerant Charge</td>
<td>0.8 kg</td>
</tr>
<tr>
<td>Refrigerant Charge Utility with Front and Rear A/C</td>
<td>1.2 kg</td>
</tr>
<tr>
<td>Refrigerant Charge Suburban with Front and Rear A/C</td>
<td>1.4 kg</td>
</tr>
</tbody>
</table>

For specific information regarding oil replacement, ensure the service manual is checked.

If necessary, the accumulator can be used to help determine the oil level in the refrigerant. Because the accumulator can easily be removed, the amount of oil it contains can be measured and this can indicate the relative oil balance of the system.

If the accumulator doesn't have enough oil according to the oil distribution specifications located in the service manual, additional oil may need to be added.
Cycling Clutch Controls

Pressure Cycling Switch
- Evaporator pressure sensor
- Pressure Switch
- Controls cycling clutch

Thermostatic Switch
- Senses evaporator temperature
- Controls cycling clutch

Evaporator Thermistor
- Senses evaporator temperature
- Controls cycling clutch

Pressure and Temperature Sensors and Switches
- Pressure and Temperature Sensors
  - Sense high and low side pressure
- Cutoff Switches
  - Sense high and low side pressure
- Pressure Relief Valve

Figure 1-25,

Figure 1-26,
A/C System Components

Condenser
The condenser is used to release heat from the high pressure vapor which will change it to a high pressure liquid.

Figure 1-27, Condenser

Evaporator
The evaporator is used to absorb heat from the passenger compartment to change the low pressure liquid to a low pressure vapor.

Figure 1-28, Evaporator

Receiver/Dryer
- A storage tank for liquid refrigerant
- A dryer for the refrigerant (desiccant)

Figure 1-29, Receiver/Dryer
**Accumulator-Dryer**
- Vapor liquid separator
- A storage tank
- A dryer (desiccant)
- GM uses XH-7 a molecular sieve as desiccant

**Orifice Tube**
- Dividing point between high pressure and low pressure
- Reduces pressure and controls flow

**Dual Stage Orifice**
- Dividing point between high pressure and low pressure
- Reduces pressure and controls flow
- Orifice size can vary from 1.57 mm (0.062 in) to 2.03 mm (0.080 in)

**Thermostatic Expansion Valve (TXV)**
- Dividing point between high pressure and low pressure
- Reduces pressure and controls flow

**CFC and Ozone**
- 30% of CFC come from mobile A/C
- CFC's Destroy Ozone
- Ozone Has 3 O2 atoms
- Act as sunscreen to protect life from harmful ultraviolet rays
Leak Detection

Automotive systems naturally leak small amounts of refrigerant. This slow leakage comes from the soft, flexible hoses in the system and the shaft seal on the compressor.

Other major sources of leaks are at the threaded connections for the hoses, and where the soft, flexible hoses are crimped and join to harder metal tubing.

A service technician's major responsibility is to minimize the amount of refrigerant escaping into the atmosphere. One of the worst things a service technician can do is service an automotive air conditioning system and then find out that the system has large leaks.

Because some leaks are not visible to the technician, leak detection devices must be used.

Various refrigerant leak detection methods have been used in the past, ranging from soapy liquid solutions and compressed air through electronic devices to fluorescent tracer dyes.

Due to differences between the newer refrigerant R-134a, and R-12, the recommended leak detection methods for today's refrigeration systems have changed substantially from the past.

R-134a molecules are smaller than those of R-12, and R-134a does not contain chlorine which many older types of electronic leak detectors easily detected.

Additionally, older leak-detection methods are no longer viable for today's air conditioning system diagnosis and service needs because of the danger unapproved flammable refrigerants may be in the system, or refrigerant release during testing is now strictly prohibited.

As such, methods involving soap solutions, compressed air, propane gas flame, and others are not recommended.

Electronic and Halogen Leak Detection

"What are SAE specifications for leak detectors?"

- Must be capable of detecting a leak of 0.5 ounce per year leak of R-134a.
- Must detect the leak when held 0.25 inches away from the leak.
- Must detect the leak when moving at 2 inches per second.
• Must clearly indicate the leak in 9 out of 10 passes.
• Must clearly alert the operator of the detection.

Electronic and halogen leak detectors can accurately detect refrigerant leaks on both R-12 and R-134a refrigeration systems.

General Motors recommends two types, the J 39400 unit and the J 41995.

The J 41995 is a hand-held device, powered by rechargeable batteries.

The J 39400 leak detector works off the vehicle's battery power.

Both types of halogen leak detectors are certified to meet stringent industry specifications for detecting leaks of as little as half an ounce per year.

Each uses a heated diode sensor probe, and both have audible and visible leak detection alarms.

Key features of the J 39400 halogen leak detector include:
• a detector probe with a 6-foot flexible hose
• a cigarette lighter plug with a power cord and battery clamp adapter
• a probe balance control, which is used to adjust the detector's sensitivity
• a calibration reference bottle
• a 3-position switch

The switch setting options are
• R-134a
• R-12
• gross leak

The J 39400 will find either refrigerant in any of the switch positions.

The switch sets the sensitivity of the leak detector.

Think of the options as three separate sensitivity settings for a SMALL, MEDIUM, or LARGE leak.

Both R-12 and R-134a can be detected with any of these settings.

While checking for leaks, keep in mind that refrigeration gas is heavier than air, so always check for leaks on the underside of lines, fittings and components.
If possible, slowly circle the areas being checked, as shown in the examples.

Never touch the probe tip to the part being checked, and avoid using the unit in areas where its sensor heat might ignite combustibles.

To calibrate and operate any type of halogen leak detector, always follow the manufacturer’s specific calibration and operation instructions.

Halogen leak detectors require at least two minutes to warm up. Proper warm-up and calibration are critical for accurate readings.

To calibrate the J 39400 halogen leak detector:

1. Slide the CONTROL switch to ON and make sure the airflow ball floats in the probe tip.
2. Set the 3-POSITION SWITCH to the R-134a position.
3. Adjust the BALANCE control until the unit ticks slowly.
4. Place the probe tip over the CALIBRATION REFERENCE BOTTLE.

The unit is ready for system leak detection when a faster audio signal is heard and the flashing lamp illuminates.

Caution:

Halogen Leak Detectors should not be used where fuel vapors or other combustibles are present.

The sensor heats to about 1000°F. Vapors drawn into the probe and over the sensor could cause an explosion.
Dye

- Fluorescent
- Use Black light to see

The second leak detection method recommended by General Motors uses fluorescent dyes and ultraviolet light.

For leak testing R-12 refrigerant systems, fluorescent tracer dyes have been available but not commonly used.

These dyes were thought to detect only large leaks and have several other negative effects. These included the possibility of precipitating out and restricting system valves, causing an oil over-charge condition, and breaking down when exposed to refrigerant, oil, and system contaminants.

Today, with new standards for refrigerant leak detection and legal restrictions on releasing any R-12 into the atmosphere, fluorescent tracer dyes may be used more frequently on R-12 systems.

R-134a and R-12 use their own, specific fluorescent tracer dyes.

If a technician cannot find a leak with a halogen leak detector, and the system is known to have lost adequate refrigerant charge, new dyes are available that mix well with PAG oil and may be the ONLY method capable of detecting the very tiny leaks that may occur with R-134a refrigerant.

These dyes are placed into the system with a special injector tool or can be added directly into a newly replaced system component.

Very small leaks can be detected using an ultraviolet, or black, light. If there is a leak in the system, the leaking refrigerant will glow yellow-green fluorescent under the ultraviolet light as shown in the example.

Not all of the R-134a fluorescent tracer dyes available are compatible with General Motors' specific type of PAG oil.

General Motors recommends only J 41447 tracer dye for use in its air conditioning refrigeration systems.
Other R-134a fluorescent tracer dyes may decrease the PAG oil viscosity or chemically react to affect system reliability and possibly cause premature compressor failure.

Of course, R-134a TRACER DYE SHOULD NOT BE USED IN R-12 SYSTEMS.

Tracer dyes specifically designed for General Motor systems using R-12 refrigerant are available.

The components used with General Motors J 41447 fluorescent tracer dye for leak testing R-134a refrigerant systems include an injector tool, black ultraviolet light, and a quarter-ounce bottle of dye.

Additionally, refrigerant leak detection notice labels are supplied. These labels are used and posted when the tracer dye is used.

These items are shown in the illustration. The R-12 dye injector is also shown.

Some guidelines to keep in mind when using fluorescent tracer dyes on General Motors systems are:

- Use only a quarter ounce of dye. This is the amount needed to detect leaks. Increasing the amount will not shorten the time for leak detection, it would most likely cause system reliability concerns.
- Complete the refrigerant leak detection notice label supplied if you use the dye. This label notifies other service technicians that a tracer dye may still be in the system.
- Use of the R-134a tracer dye requires time. Depending on the leak rate, it may take as little as 15 minutes or even up to 7 days for the leak to become visible under the black light.
- Tracer dye, mixed with PAG oil, is retained in the system and may be detected for more than two years.
- PAG oil is water soluble and traces of PAG oil found at leaking joints can be "washed out."
- Condensation on refrigerant lines or the evaporator core may wash PAG oil and tracer dye off the line or off the core and out the condensate drain. This can make some leaks harder to find using a dye detector.
- Fluorescence at the drain opening would indicate a core leak.
- After using the dye, wipe all repaired leaks or component access ports with General Motors solvent number 1050436 to prevent a possible false diagnosis at a later time.
Refrigerant Safety

- R-12 -22° F
- R134A -16° F
- Frost Bite Potential
- Keep under 125°F
- Always work in a well-ventilated area
- Always wear goggles for eye protection
- Do not expose refrigerant to an open flame

Refrigerant Handling

Refrigerant R-12 and R-134a are colorless in both the liquid and gaseous states. Both are vapors at normal room temperatures.

Vaporized refrigerant is heavier than air, nonflammable, nonexplosive, and nonpoisonous.

These refrigerants are noncorrosive, except when in contact with water. Observe the following safety precautions when handling these refrigerants:

Caution:

- Always wear goggles for eye protection when working with refrigerant containers or refrigerant system connections.
- Do not expose the eyes to refrigerant liquid or vapor.
- Wrap a clean cloth around fittings, valves, and connections when performing work that involves opening the refrigerant system.
- Always work in a well-ventilated area.
- Do not weld or steam clean near any vehicle-installed air conditioning lines or components. Heat associated with these processes can cause excessive refrigerant pressure.
- If it is necessary to transport refrigerant, do not carry containers in the passenger compartment of a vehicle.
- Do not expose refrigerant containers to high temperatures above 125°F, or to direct sunlight.
- And finally, do not expose refrigerant to an open flame.
Caution:
If refrigerant contacts the eyes or skin, flush the exposed area with cold water to raise the temperature above freezing and avoid severe frostbite.
Immediately seek medical help.
If available, apply an antiseptic to the eyeballs to provide a protective film and reduce the potential of infection.
Discharge air conditioning systems into an approved recovery system only.
Do not vent to the atmosphere.
Avoid breathing mists.
In the event of a sudden refrigeration system discharge, clear the area and ventilate until the mist is no longer visible.

Chemical Stability
- Keep air, dirt and moisture out of the system.
- Wipe connections before disconnecting.
- Keep all tools and equipment clean.
- Do not leave the system open for long periods of time

Now let's look at several ways you can identify an R-134a refrigerant system.

The service valves are a quick-connect primary seal type and require special fittings to access the system. Refrigerant charge labels and warning labels are located on the top of the blower housing, or on the front fan shroud. The refrigerant container is LIGHT BLUE and bears the halogenated hydrocarbon, or R-134a labeling.

A dedicated manifold gauge set must be used for R-134a and should be clearly marked.

The ends of the service hoses have R-134a specific, quick-connect primary seal connections attached and have a smooth texture. All connections on R-134a systems are metric. Also, grooved fittings can be used to identify an R-134a system.
Here are some of the ways you can identify a system as R-12. Service valves are of Schrader type. High and low-pressure fittings have different sizes to reduce the possibility of improper connection. The refrigerant charge labels are located on either the top of the blower housing, the front fan shroud, or on top of the accumulator.

The refrigerant container is WHITE with an R-12 label. A dedicated manifold gauge set must be used for R-12 and should be clearly marked. The ends of the service hoses have R-12 specific thread-on fittings with a Schrader valve depressing point inside.

Recovery units are clearly labeled for R-12 or R-134a.

Use ONLY on the system indicated.

Charging stations are clearly labeled for R-12 and R-134a and should NOT be mixed.

The refillable storage tank on the R-12 charging system is WHITE.

And finally, R-12 systems use English threads on both the fittings and containers.
Tools and Identification

One of the key tools used in performing air conditioning system service is the refrigerant handling station.

Various types of refrigerant handling stations are available. Some may be used only for recovering and recycling refrigerant, while others may also offer the additional capabilities of system evacuation and recharging.

However, General Motors recommends the ACR3 for R-12 systems and the ACR4 and ACR 2000 for R-134a. The ACR3 does not have the recharging feature.

Proper air conditioning system diagnosis and service requires the use of a manifold gauge set. Traditionally, this service tool, together with its service hoses, was a stand-alone piece of equipment. Today, most gauge sets are part of a complete refrigerant handling station. The manifold gauge set is used for measuring both high- and low-side refrigerant pressures during operation of an air conditioning system. When diagnosing causes of system problems, technicians can compare these pressures with system design pressures at various ambient air temperatures and relative humidity levels.

This process of measuring and comparing pressures, temperatures and humidity levels is called an air conditioning performance test. We will look at this test again, later in the course.

When servicing an air conditioning system, technicians can use a gauge set, its service hoses and other equipment to charge the system. As part of a refrigerant handling station, the gauge set can also be used for refrigerant recovery, recycling, system evacuation and recharging. We will discuss the terms recovery, recycling, system evacuation and recharging shortly.

Caution:

When connecting a manifold gauge set to an air conditioning system, always wear safety goggles to prevent refrigerant from contacting your eyes. Immediate freezing and eye injury can occur.
Refrigerant Recovery Tanks are 30 or 50-pound refillable tanks used during refrigerant recovery and shipment for recycling, or during refrigerant recharging procedures.

To avoid system contamination, two separate tanks must be available: white for R-12 and light blue for R-134a.

Additionally, the fittings on General Motors R-12 and R-134a recovery tanks are different to prevent accidental cross-contamination.

The Precision Thermometer is a hand-held, probe-type thermometer which can be inserted through an appropriate instrument panel outlet to measure the exact temperature of the discharge air during system performance tests.

Contaminated Refrigerant Detectors are used to identify contaminated refrigerant and prevent recovery of contaminated refrigerant.

• Pureguard 1 is the contaminated refrigerant detector used with the ACR3, and Pureguard 2 is used with the ACR4.

• Pureguard 2 has the added feature of a service port for sampling additional recovery tanks. It can identify pure R-12, pure R-134a and contaminated refrigerants.

• ACR 2000 is capable of testing and printing the purity results of any source tank. It can identify pure R-12, pure R-134a and contaminated refrigerants.

Other service tools include:

• Evaporator Cleaning Gun for cleaning and disinfecting an evaporator core to eliminate odors caused by microbial growth,

• Expansion Tube Remover for removing the orifice tube from the condenser-to-evaporator line for cleaning and repairing,

• Octagon Socket for removing and installing the high-side service valve in the compressor and condenser line,

• Valve Core Remover and Installer for system access through a low-side Shrader service valve.

• Additionally, various equipment maintenance kits are available for refrigerant handling stations, vacuum pumps and electronic leak detectors.
Cooling System Components

- Air Intake
- Radiator
- Cooling Fans
- Seals and Shrouds

The cooling sub-system directs cool air into the engine compartment to absorb heat radiated from the condenser and the radiator.

Malfunctions in any of the components could result in inefficient operation of the cooling system.

Air Distribution System

- Air Ductwork
- Water Control Valve
- Air doors/valves
- Air door/valve control unit
- Evaporator
- Heater
- Blower
- Blower Control

The air distribution system is designed to control the climate inside the passenger compartment. To achieve this, the air distribution system is required to regulate the air flow path, the air temperature, and the force of the air entering the passenger compartment.

To control these three functions, the air distribution system uses certain components.
Manual HVAC Systems

Performance Testing

- Connect the ACR 2000 to the vehicle
- Static Pressures
- Ambient Temperature
- Humidity

Check with Vehicle running

- High side pressure
- Low side pressure
- Duct temperature
- Accumulator or Receiver hot or cold to touch
- Compressor outlet cold or hot to the touch
- evaporator inlet line cold or hot to the touch
Refrigerant Recovery and Recharging

Caution:
Avoid breathing the A/C Refrigerant 134a (R-134a) and the lubricant vapor or the mist. Exposure may irritate the eyes, nose, and throat.

Work in well ventilated area.

In order to remove R-134a from the A/C system, use service equipment that is certified to meet the requirements of SAE J 2210 (R-134a recycling equipment).

If an accidental system discharge occurs, ventilate the work area before continuing service.

Additional health and safety information may be obtained from the refrigerant and lubricant manufacturers.

Caution:
For personal protection, goggles and gloves should be worn and a clean cloth wrapped around fittings, valves and connections when doing work that includes opening the refrigerant system.

If R-134a comes in contact with any part of the body severe frostbite and personal injury can result. The exposed area should be flushed immediately with cold water and prompt medical help should be obtained.

Note:
R-134a is the only approved refrigerant for use in this vehicle. The use of any other refrigerant may result in poor system performance or component failure.

Note:
To avoid system damage use only R-134a dedicated tools when servicing the A/C system.
Note:
Use only polyalkylene glycol synthetic refrigerant oil (PAG) for internal circulation through the R-134a A/C system and only 525 viscosity mineral oil on fitting threads and O-rings. If lubricants other than those specified are used, compressor failure and/or fitting seizure may result.

Note:
R-12 refrigerant and R-134a refrigerant must never be mixed, even in the smallest of amounts, as they are incompatible with each other. If the refrigerants are mixed, compressor failure is likely to occur. Refer to the manufacturer instructions included with the service equipment before servicing.

1. The ACR 2000 (J 43600) is a complete air conditioning service center for R-134a. The ACR 2000 recovers, recycles, evacuates and recharges A/C refrigerant quickly, accurately and automatically. The unit has a display screen that contains the function controls and displays prompts that will lead the technician through the recover, recycle, evacuate and recharge operations. R-134a is recovered into and charged out of an internal storage vessel. The ACR 2000 automatically replenishes this vessel from an external source tank in order to maintain a constant 5.45-6.82 kg (12-15 lbs) of A/C refrigerant.

2. The ACR 2000 has a built in A/C refrigerant identifier that will test for contamination, prior to recovery and will notify the technician if there are foreign gases present in the A/C system. If foreign gases are present, the ACR 2000 will not recover the refrigerant from the A/C system.

3. The ACR 2000 also features automatic air purge, single pass recycling and an automatic oil drain.

4. Refer to the J 43600 ACR 2000 manual for operation and setup instruction. Always recharge the A/C System with the proper amount of R-134a. Refer to Refrigerant System Capacities or A/C charge label on the vehicle for the correct amount.
Leak Detection Worksheet

Directions: Answer the following questions using the Service Information and leak detector operation manual. Some of the questions will require using a vehicle.

At this time power-up the leak detector.

1. What is the average warm-up time for the leak detector?

2. If the sensor has been replaced or the leak detector has not been used for an extended period of time, how much warm-up time is required before the leak detector will be operational?

3. How often should the filter in the tip of the sampling probe be replaced?

4. What position should the selector switch be placed in when calibrating the leak detector?

5. What is the required click rate to perform leak detection?

6. How should the leak detector respond when performing calibration?
At this time power-up the leak detector.

7. How do you activate a fresh bottle of the calibration liquid, and what is the liquid?

______________________________________________________

______________________________________________________

8. When performing leak detection, how fast should you move the probe tip?

______________________________________________________

______________________________________________________

9. If the leak detector no longer responds to the calibration procedures, how do you adjust the heater adjustment?

______________________________________________________

______________________________________________________

10. If the heater adjustment screw is fully seated and the leak detector still does not respond during the calibration procedures, what must you do to the leak detector?

______________________________________________________

______________________________________________________

11. Will the leak detector locate R-134a leaks when the selector switch is placed in the R-12 position?

______________________________________________________

______________________________________________________
The following questions are related to leak testing a vehicle refrigeration system. Some of these questions will require you to use the leak detector on a vehicle.

12. Should the service ports be tested with the valve caps on or off?
   _______________________________________________________
   _______________________________________________________

13. How should the compressor shaft seal area be prepared before leak testing?
   _______________________________________________________
   _______________________________________________________

14. How should the evaporator be prepared before performing leak detection?
   _______________________________________________________
   _______________________________________________________

15. What is the distance that should be maintained between the probe tip and the surfaces being leak checked?
   _______________________________________________________
   _______________________________________________________

16. List the number for the leak detector tune-up kit and list four of the items within the kit.
   _______________________________________________________
   _______________________________________________________

At this time, leak test the classroom vehicle.

17. Was a leak detected? If yes, where is the leak located?
   _______________________________________________________
   _______________________________________________________

18. What is the static pressure of the classroom vehicle?

______________________________________________________

______________________________________________________

19. Is the static pressure of the refrigeration system important for leak detection? Why or why not?

______________________________________________________

______________________________________________________

20. If using leak detection dye, how much should be injected into an R-134a system?

______________________________________________________

______________________________________________________

21. How do you place leak detection dye into a refrigeration system?

______________________________________________________

______________________________________________________

22. When using dye, what should you do to notify other technicians that the refrigeration system has dye inside of it?

______________________________________________________

______________________________________________________

23. How long does it take before the dye will emerge from a leak?

______________________________________________________

______________________________________________________

24. How long does the dye remain active within the refrigeration system?

______________________________________________________
Performance Test Worksheet

Directions: Answer the following questions using Service Information, classroom vehicle and the AC 2000 or ACR4.

Connect the AC 2000 OR ACR4 to the classroom vehicle.

1. Record the static pressures (non-running), ambient temperature and humidity:
   - High Side: ________________________ Low Side: __________
   - Ambient Temperature: _______________ Humidity: __________

Start the vehicle; follow the steps to perform the system Performance Test.

2. Record the following information:
   - High Side: ________________________ Low Side: __________
   - Duct Temperature: ___________________________
   - Accumulator or Receiver (cold or hot to the touch): __________
   - Compressor Discharge line (cold or hot to the touch): __________
   - Evaporator inlet line (cold or hot to the touch): ___________

Add an additional 0.75 lbs. to the system.

3. Record the following information:
   - High Side: ________________________ Low Side: __________
   - Duct Temperature: ___________________________
   - Accumulator or Receiver (cold or hot to the touch): __________
   - Compressor Discharge line (cold or hot to the touch): __________
   - Evaporator inlet line (cold or hot to the touch): ___________

Important
Always wear safety goggles when working with any equipment containing refrigerant.
Shut-off the engine, remove all but 0.75 lbs. of refrigerant from the system. Then restart the engine.

4. Record the following information:
   - High Side: ________________________
   - Low Side: __________
   - Duct Temperature: ______________________________
   - Accumulator or Receiver (cold or hot to the touch): ____________
   - Compressor Discharge line (cold or hot to the touch): __________
   - Evaporator inlet line (cold or hot to the touch): ________________

   • Shut-off the engine. Recover the remainder of the refrigerant charge.
   • Check the amount of oil that was removed.
   • Evacuate the system.
   • Charge with the correct amount of refrigerant.