



The Standard in Information and Diagnostic Systems

Guide to Air Conditioning

The art of keeping cool
on the move



flexibility, adaptability, profitability



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Introduction

It is only a few years ago that Air Conditioning was fitted as standard to luxury cars. More recently, Air Conditioning is now available as standard on virtually every family car available. In their quest to offer even higher levels of specification and equipment, it seemed inevitable that manufacturers would offer Air Conditioning. Statistically, at the time of writing, about 85% of new cars are fitted with Air Conditioning.

The main benefits of Air Conditioning are:

- Driver comfort and hence safety
- Cools the vehicle interior on hot days. (actually it removes heat!)
- Removes moisture and therefore speeds up de-misting on cold, damp days.
- Helps to remove dirt and dust from the air in the vehicle interior. Ideal for allergy sufferers.

Refrigerants

In its basic form, a refrigerant is simply a 'heat carrier'. It carries heat from the interior of the vehicle and disperses it to the atmosphere outside. Although there are many types of refrigerant in use, generally, the main type used in automotive applications is R-134a. Due to its negative impact on the environment R-12 was phased out at the end of 1994. R134a refrigerant has been in use since approx 1993.

Refrigerant Legislation

You may have heard of the concern over the ozone layer above the earth. The ozone layer is a fragile layer surrounding the earth, which acts as a shield against the Sun's harmful radiation. Scientists have discovered a 'hole' in this layer above Antarctica and believe it has been caused by the release of chlorofluorocarbons (CFC's).

The destruction of the ozone layer would result in more radiation striking the earth, which in turn could result in an increase of skin cancer, damage to the human immune system, global warming and drought. CFC's are chiefly used as refrigerants in automotive and building air conditioning units, refrigerators, food display cabinets and cooling installations.

They are also used in cleaning solvents, sterilant, aerosol propellants and blowing agents in plastic foam products. In 1987 most developed countries signed the Montreal Protocol calling for a phased reduction in CFC production to 50% of the 1986 level by the year 2000. It was subsequently reviewed and required a total CFC production phase-out by the 1st January 1996.

The European Union agreed a more rapid phase-out. Regulation enforced an 85% cut in CFC production by the end of 1994. As the production of CFC is reduced and finally stopped, the cost of CFC will steadily increase. It is estimated the typical dealership can recover and re-use approximately 30% of the refrigerant currently used. The automobile industry has been identified as the single largest venter of CFC R-12 releasing approximately 9% of all CFC's. This fact clearly emphasises the industry's major objective: Design, Manufacture and Acceptance of CFC Recovery and Recycling Equipment for use in the automotive industry to slow the release of CFC's to the atmosphere. Although the newer R134a refrigerant does not deplete the ozone layer, it has a global warming potential. Therefore in view of this and for reasons of economy, we always recycle the refrigerant wherever possible.

On the 1st October 2000 a trading ban applied to R12 refrigerant, with a total 'use ban' on the 1st January 2001. Looking to the future, it is very likely that we will see new refrigerants in use, such as CO₂ (Carbon Dioxide). However, the widespread use of R134a refrigerant will ensure that these vehicles will require service for many years to come.

Operation of an Air Conditioning System

To understand how an air conditioning system works, we first have to know something about heat. Heat is the energy available in an object. All substances contain a certain amount of heat. Something 'feels' hot when it is substantially warmer than our own body temperature. When something contains much less heat than our own body temperature we say it is cold. Cold is merely the removal of some heat. When the temperature is in the zone of about 21 to 26 degrees Celsius all objects are comfortable to touch. As the temperature of anything goes above or below this range, we think of it as hot or cold.

Heat always moves from hot to cold. Whenever there is a temperature difference between two objects the heat energy will be transferred from the warmer object to the cooler one until both objects have stabilised at the same temperature. The greatest quantity of heat movement occurs during a change of state. When enough heat is added to a liquid substance it changes into a vapour. Heat is given off during the transformation from vapour to liquid. The quantity of heat used for these changes of state is called 'Latent heat' and cannot be read on a thermometer. The air conditioning system does not add cold to the interior of the vehicle, it removes heat.

Heat Movements

There are three types of heat movement that we need to discuss to understand the working principle of an air conditioning system. Each of these affects how well an automotive air conditioning system works. The three types of heat movements are, radiation, convection and conduction.

Radiation

Heat radiates from hot substances, and increases the temperature of surrounding cooler ones. The Sun is the major source of heat for the Earth. Its energy, transmitted through space, heats the Earth. Direct sunlight is a prime example of heat by 'Radiation'.

Conduction

Heat is absorbed into cooler substances by 'conduction'. We have all experienced this by lifting a hot pan from the stove. The handles are hot even though they are not in direct contact with the burner. The heat is conducted through the metal of the pan to the cooler handles. Similarly, a metal bar heated at one end will become hot at the other end.

Convection

The radiator in your house will heat the air by means of convection. The warmer air will move up and is displaced by cooler air. This movement will accelerate the flow of heat.

Summary

The warm air inside the vehicle is blown across the evaporator unit in the vehicle (convection). The heat is absorbed into the cooler refrigerant inside the evaporator (conduction). The refrigerant circulates the heat to the condenser unit outside of the vehicle (convection). The heat is absorbed into the cooler condenser fins (conduction). Next it is given off to the cooler atmosphere (radiation). Airflow then carries heat away (convection).

Air Movement

Air temperature is only one factor affecting our body comfort. Others include air movements and humidity. Movement of air provides for body comfort due to removal of the following: (1) nearby moisture, lost by the body during the evaporation process; (2) heat surrounding the body, lost by the convection process; and (3) heat of surrounding items, generated by the radiation process. That's why an electric fan, or even a hand fan, provides comfort on a warm day. Humidity is moisture in the air; Relative humidity is the percentage of moisture in the air in relation to what the air is capable of holding at a given temperature. Low humidity means the air is relatively dry and capable of absorbing moisture. When humidity is relatively high evaporation processes are slowed. Removal of heat by evaporation decreases. Just as our temperature comfort range is 21 – 26 degrees Celsius, likewise, our humidity comfort range is 45 – 50% relative humidity. Therefore, to be effective on hot, humid days, an air conditioner must remove both heat and moisture from the vehicle.

Refrigerant

The movement of heat and change of state of a substance leads us now to refrigerants. This is the chemical substance used as the 'heat carrier' within the automotive air conditioning system. R134a denotes refrigerant; 134a is the type of refrigerant. R134a is used because it changes state as required by the air conditioning and can do this within the temperature range of an automotive air conditioning system. R134a is used in most automotive air conditioners because of its low boiling point (the point at which evaporation occurs). At any temperature above approx. -26 degrees Celsius the refrigerant will change state, become vapourised and thereby absorb greater quantities of heat inside the vehicle. This creates the 'cooling effect' of the air conditioning.

Pressure–Temperature Relationship

The pressure-temperature relationship of the refrigerant is essential. If the pressure of the refrigerant is low, the temperature will also be low. If the pressure of the refrigerant is high, the temperature will be high also. Utilising this quality, an increase or decrease in the refrigerant temperature can be obtained by varying the refrigerant pressure. To operate at peak efficiency, the refrigerant must be at its coolest state without icing (low pressure) in the evaporator and its warmest (high pressure) in the condenser. It is mentioned that the refrigerant vapourises at a low temperature and absorbs great quantities of heat. In the evaporator, the refrigerant is under very low pressure. Thus, a low temperature is also obtained. This temperature is much lower than the temperature inside the vehicle. For this reason, the vehicles heat will travel to the colder refrigerant. As the heat is absorbed, the refrigerant vapourises and carries the heat from the evaporator to the compressor. The compressor increases the pressure, and the temperature of the refrigerant vapours. The vapours are then pumped to the condenser where the heat is transferred to the outside air, which has a much lower temperature than the vapourised refrigerant, and condensation takes place. The refrigerant while giving off its heat then returns to a liquid state.

System Operation

An air conditioning system works because of its basic principle:

- Heat travels from warmer to cooler.
- Liquid to vapour.

Evaporator refrigerant absorbs heat in the vehicle passenger compartment during evaporation.

- Vapour to liquid.

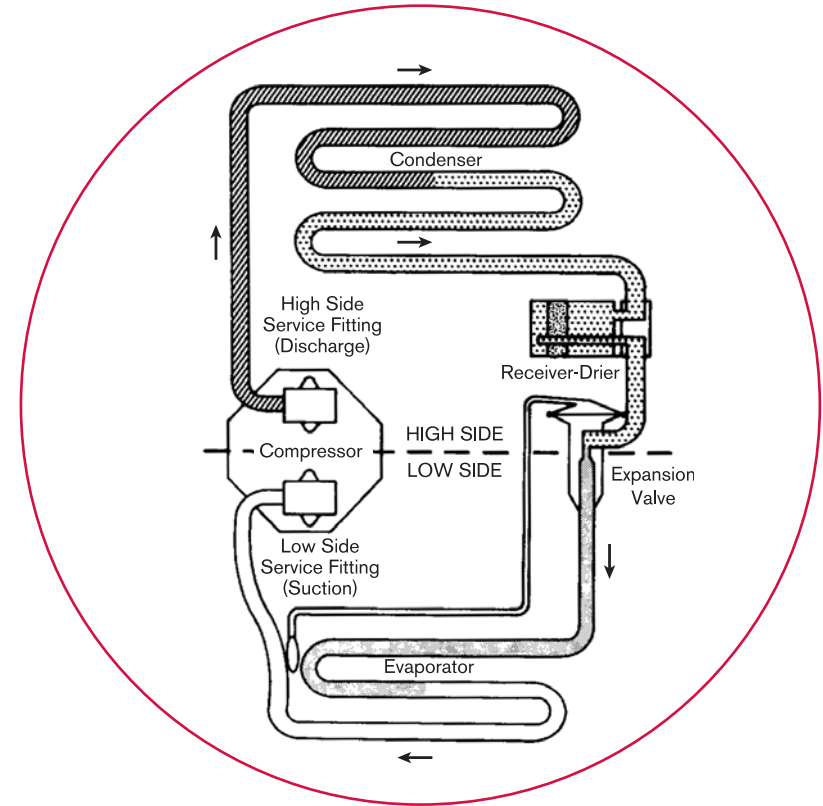
Condenser refrigerant releases heat to the atmosphere during condensation.

All automotive air conditioning systems contain the following 5 basic components:

- Compressor
- Receiver-drier or accumulator
- Evaporator
- Condenser
- Expansion valve or orifice tube

Each of these components is necessary for system operation, and all are dependent upon the function of one another. Additional components are used for controlling the system operating temperature, and these vary according to application.

Refrigerant Circuit - Receiver-Drier Type



Description

An air conditioning system is divided into two parts, a High Side and a Low Side. This is true of all air conditioning systems, and the division of these two 'sides' always occurs at the same point.

High Side

High side simply refers to the side of the system in which high pressure exists. As shown in the illustration on page 9 the high side is (following the flow arrows) from the outlet (discharge) side of the compressor, through the condenser, through the receiver – drier (if equipped) and up to the expansion valve (or the orifice tube).

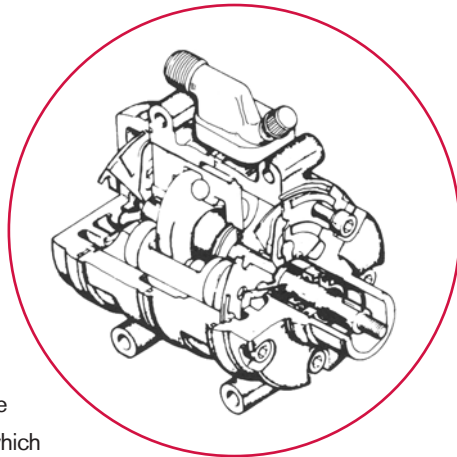
It is the compressor's job to create the high pressure and high temperature so that the refrigerant will be able to condense and release heat at the condenser. A pressure differential is created at the expansion valve or orifice tube, the dividing point in the system. High side pressures can be typically from 7 to 15 bar, depending on the system used.

Low Side

Low side is the term used for the side of the air conditioning system in which the low pressure and temperature exist. From the expansion valve or orifice tube through the evaporator and accumulator (if equipped) to the inlet of the compressor, the refrigerant is in a low pressure state. This allows heat to be transferred from inside the vehicle to the 'colder' refrigerant, which carries it away. Low side pressures are nearly always in the 1 to 2 bar range.

Compressor

There are 2 basic types of air conditioning compressors – the piston type and the rotary vane type. Piston-type compressors may have their pistons arranged in an in-line, axial, radial, or V design. Rotary vane compressors have no pistons. The most common compressor used by car manufacturers is the Piston-type. After market systems are usually Vane-type compressors. Automotive air conditioning compressors are belt-driven from the engine crankshaft. They have an electromagnetic clutch, which enables the compressor to 'shut down' when compressor operation is not required.

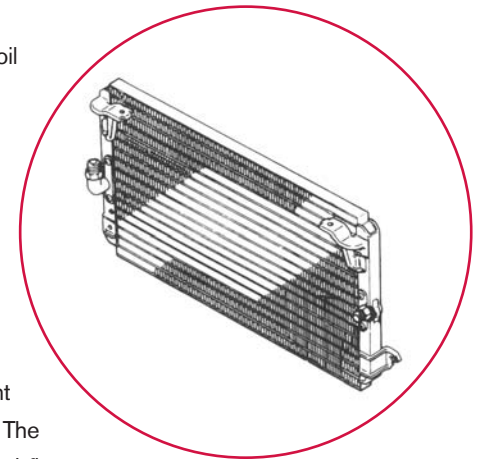


The compressor acts as a system pump to keep the refrigerant circulating. The suction side of the compressor draws in the refrigerant vapour. From there, the refrigerant passes to the outlet or discharge side of the compressor, where it is compressed (and thus the temperature is raised). In recent years the scroll type of compressor has become more common place. It offers efficient operation with compact dimensions, although its function remains the same.

It is very likely that we will see electrically driven compressors in the future, especially with the move to 36 Volt electrical systems. The high-pressure, higher temperature, vapourous refrigerant is then forced out of the compressor and onto the condenser. This high temperature refrigerant vapour will have a higher temperature than the out-side air temperature, so it will condense easily. Some models may have a muffler on both the discharge and suction sides to help reduce system noise. Therefore, the two main functions of the compressor are (1) to circulate the refrigerant through the systems, and (2) to raise the pressure and temperature of the refrigerant so it will condense and release its heat.

Condenser

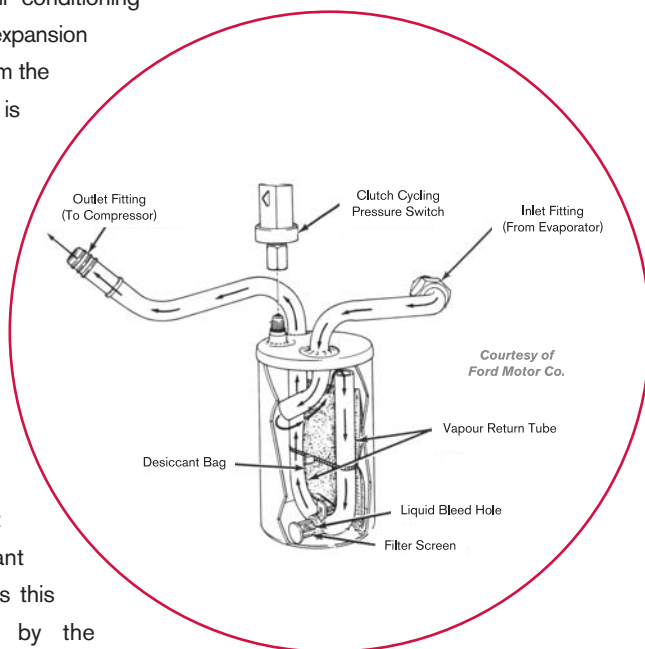
The condenser consists of a refrigerant coil mounted in a series of thin cooling fins. This arrangement provides maximum surface area for heat transfer with a minimum amount of engine compartment space. The condenser is mounted directly in front of the radiator where it can receive the full air flow created by the vehicle's forward motion and by the engine cooling fan. The condenser receives heat-laden, high pressure refrigerant vapour from the compressor's discharge pipe. The vapour enters at the top of the condenser and flows through its coils. Heat follows its natural tendency, and radiates from the hot refrigerant to the 'cooler' atmosphere. As the vapours are cooled and flow down through the condenser a point is reached where condensation occurs.



The vaporous refrigerant becomes a liquid. A large amount of heat is given off by the refrigerant at the point of condensation. The refrigerant in the lower portion of the condenser is a warm high-pressure liquid. In an air conditioning system, which is operating under average heat load, the condenser will have a combination of hot refrigerant vapour in the upper two-thirds of its coils, with the lower third of the coils containing the warm liquid refrigerant, which has condensed. This high pressure, liquid refrigerant flows from the condenser and towards the evaporator.

Receiver-Drier / Accumulator

A receiver-drier is used on air conditioning systems which incorporate an expansion valve. It receives refrigerant from the condenser. The receiver-drier is mounted either adjacent to the condenser or somewhere downstream before the expansion valve. It consists of a small tank, a filter, a drying agent (desiccant), a pick up tube and (on some applications) a sight glass. It has several functions. First the receiver-drier acts as a storage tank. It receives the liquid refrigerant from the condenser and holds this liquid until it is required by the evaporator. Requirements vary according to operating conditions.



Second, the receiver-drier also acts as a protection agent for the system. The portion of the receiver-drier that contains the drying agent absorbs any moisture in the refrigerant. The drying agent called desiccant is usually in the form of silica gel. It is important that moisture be removed from the system, as it can be extremely harmful to the air conditioning system, components and to system operation, causing corrosion and freezing of the system. Where receiver-driers are equipped with a sight glass, this component allows the service technician to 'view' the internal system operation. Generally, a system using R12 only has a receiver-drier sight glass.

Sometimes the receiver-drier function is taken over by the accumulator. Where there is nothing mounted in the high side part of the air conditioning system, there has to be an accumulator in the low side part. It is mounted in the low side of the system, after the outlet of the evaporator.

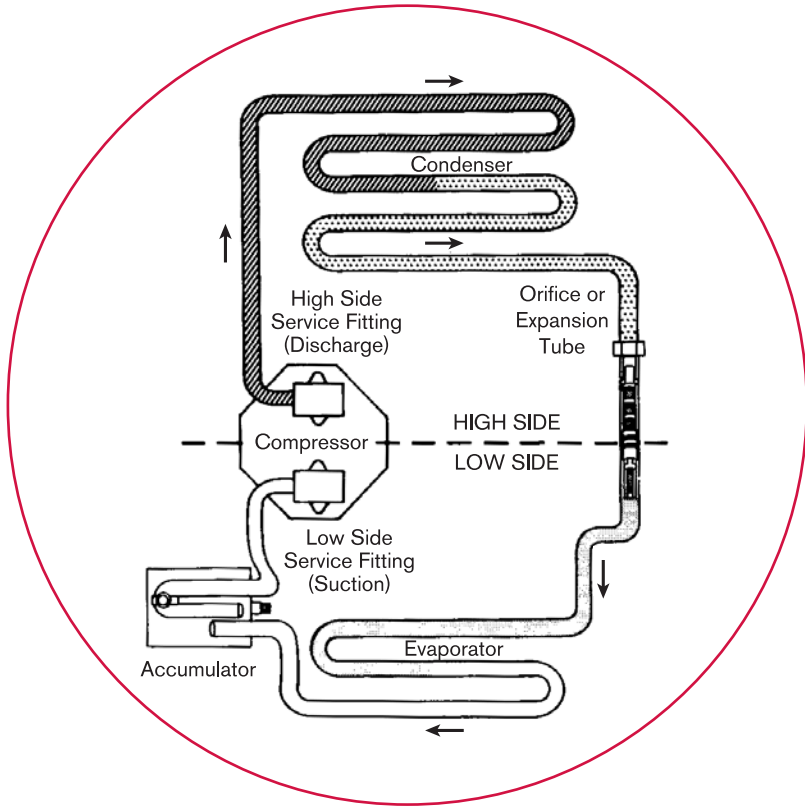
The function however, is basically the same as that of the receiver-drier, to accumulate or store excess refrigerant and filter and dry the refrigerant. The accumulator also contains a drying agent. If any liquid refrigerant passes out of the evaporator, it will be stored in the accumulator. Liquid refrigerant is harmful to the compressor. An accumulator is used on air conditioning systems which incorporate an orifice tube. If any contamination is suspected due to malfunctioning components or hose leakage resulting in air ingress, the receiver-drier or accumulator should be replaced.

The receiver-drier or accumulator have the same function in the air conditioning system.

- Acts as a storage tank, receiver-drier for liquid, and accumulator for liquid-vapour refrigerant.
- Acts as a filter.
- Acts as a moisture remover.
- Acts as a vapour-liquid separator.

Some manufacturers recommend that the Receiver-Drier or Accumulator is replaced on a routine basis.

Refrigerant Circuit – Accumulator Type



Thermostatic Expansion Valve

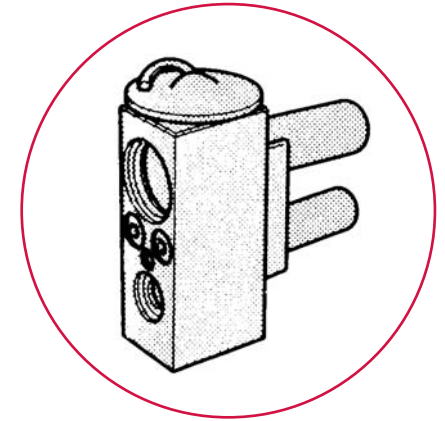
The refrigerant flow to the evaporator must be controlled to obtain maximum cooling, whilst ensuring complete evaporation of the liquid refrigerant within the evaporator. This is accomplished by a thermostatic expansion valve or a fixed orifice tube.

The thermostatic expansion valve performs three functions:

- Metering action
- Modulating action
- Controlling action

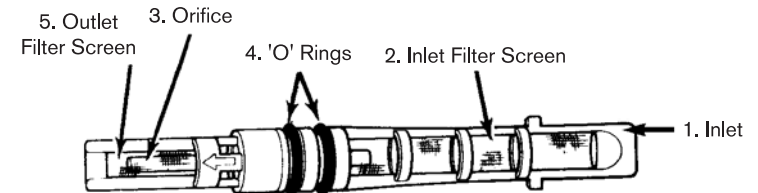
Metering Action

Refrigerant from the receiver-drier enters the expansion valve as a liquid under high pressure. As it passes through the Metering orifice in the valve, the refrigerant is forced through the small orifice and 'sprayed' out the other side. This creates a pressure differential, the pressure and temperature are thus lowered and the atomised refrigerant can flow through the evaporator and easily vapourise, thus absorbing heat.



Modulating Action

The thermostatically-controlled valve located within the expansion valve body, fluctuates towards open or closed position as required to control the liquid refrigerant passing through the orifice. This ensures that the evaporator receives the proper amount of refrigerant, depending on the cooling required.

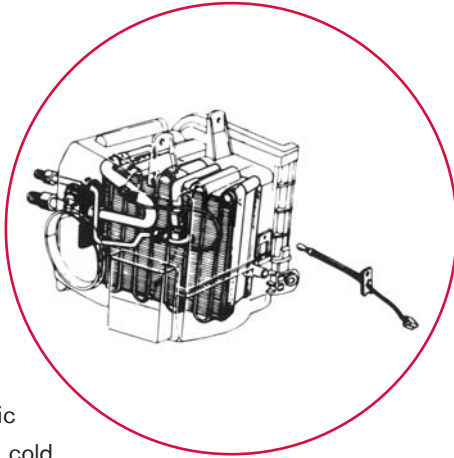


Orifice Tube

The orifice tube serves the same basic function as the expansion valve, but has a different configuration. The orifice tube is a straight tube of sintered metal or plastic. Some of these tubes have a filter screen to remove contaminants and a calibrated orifice tube to meter refrigerant flow. The orifice opening is fixed, the orifice tube does not affect the compressor operation as does the thermostatic expansion valve which 'cycles' the compressor clutch off and on. The orifice tube has a constant flow through the fixed orifice, which gives a constant pressure drop.

Evaporator

The evaporator, like the condenser, consists of a refrigerant coil mounted in a series of thin cooling fins. It provides a maximum amount of heat transfer in a minimum amount of space. The evaporator is usually mounted in a housing under the dash panel or cowl. In MAX / AC position warm air from the passenger compartment is blown across the evaporator coils and fins. The evaporator receives refrigerant from the thermostatic expansion valve or orifice tube as a low pressure, cold atomised liquid. As this cold refrigerant passes through the evaporator coils, heat moves from the warm air inside the vehicle into the cooler refrigerant. When the liquid refrigerant receives enough heat a change of state takes place. This causes the refrigerant to change from a low pressure liquid, into a low pressure vapour. The thermostatic expansion valve or orifice tube continually meters the exact amount of refrigerant required to maintain proper heat transfer efficiently. This action also ensures that all liquid refrigerant will have changed into vapour by the time it reaches the evaporator outlet. The vapourous refrigerant then continues onto the inlet (suction) side of the compressor.



The warm air blown across the evaporator will usually contain some moisture (humidity). The moisture in the air will normally condense on the cold evaporator coil and be drained off as water. A drain tube in the bottom of the evaporator housing leads the water outside the vehicle. This dehumidification of the air is an added feature of the air conditioning system that adds to passenger comfort. It can also be used as a means of controlling fogging of the vehicle windows. An important component in the cooling action of the evaporator is the blower motor/fan, also located in the evaporator housing. The blower draws warm air from the passenger compartment, over the evaporator, and blows the 'cooled' air into the passenger area.

Air Conditioning Control

Although we have covered the main components and operation of an air conditioning system, there are a number of other control devices to protect system components, improve cooling and give good driveability. Some of these control devices which may be fitted are:

- Sunlight sensor
- Ambient temperature sensor
- Low pressure cut-out switch
- High pressure cut-out switch
- High pressure relief valve
- Thermal cut-out switch
- Evaporator temperature sensor
- Wide open throttle (WOT) switch
- High pressure fan switch

Electrical Operating System

The air conditioning electrical operating system can be very complicated. Briefly, the compressor magnetic clutch is operated by a relay which gets its power from the vehicle battery via fuses. The compressor relay is usually grounded by the vehicle engine management control unit, upon receiving the following:

- Air conditioning switched on
- Blower switched on
- Pressure switch signal
- Evaporator temperature signal

With an automatic climate control, the air conditioning system usually has its own Electronic Control Unit (ECU), which controls the compressor, selected temperature and various air outlets. These systems usually have built in diagnostics, or can be diagnosed by code readers or scanners.

Recycling Equipment Operation

The Sun Mobile Recycling Centres use a single pass filtration system. This means that the refrigerant is recovered and recycled in a single pass through a master filter with a drying medium into a CE approved storage container. Moisture, contaminants and particulates are trapped in the master filter. Clean, recycled refrigerant is stored in the container ready for re-use at any time. Any oil, which may be drawn from the vehicle, is collected in a separator unit which allows the quantity to be measured.

Non-Condensable Gases (i.e. Air)

Some of the Sun Mobile Recycling Centres monitor refrigerant pressure and temperature. At pre determined purge pressures, a purge solenoid automatically opens to purge any non-condensables from the machine.

Safety

The Sun range of air conditioning equipment is CE approved. Refrigerant storage tanks are protected from overfilling. A high pressure cut-out switch protects the equipment and the operator, should the pressures in the equipment exceed a certain value.

Recharging

The Sun range of air conditioning equipment uses an electronic scale to accurately monitor refrigerant contents, reclaimed refrigerant and the re-charge amount.

Vacuum

A high vacuum, or very low pressure, is applied to an air conditioning system to ensure that the system is completely empty of refrigerant, non condensables and any moisture. The Sun Mobile Recycling Centres feature a built-in high vacuum pump.

System Lubrication

The compressor in an air conditioning system relies on a lubricating oil to lubricate and seal its moving parts. Part of this lubricating oil also mixes and circulates with the refrigerant to lubricate and seal compressor pistons or vanes. It is very important that any oil recovered from a vehicle air conditioning system is replaced prior to re-charging the vehicle air conditioning system. In general R12 systems use a mineral oil and R134a systems use a PAG (Poly-Alkyl-Glykol) oil. Viscosities vary according to compressor manufacture.

Operator Safety

It is extremely important that the necessary safety precautions are followed when handling refrigerants, and working on air conditioning systems. The main danger is frostbite. Remember that R134a evaporates or 'boils' at -26.5 degrees Celsius.

Therefore:

- Always wear the correct protective gloves.
- Wear suitable eye protection, such as goggles.
- Always work in a well ventilated area.
- Ensure that you have the correct training before handling refrigerants or working on an air conditioning system.
- Refrain from smoking and ensure that no naked flames are in the vicinity of the refrigerants.
- Observe regulations and local storage requirements for refrigerant containers. Keep valve connections and pipes clean.
- Close all container valves when the equipment is not in use.

Proposals are under way to ensure that only properly qualified and competent staff will be able to purchase and hence work with refrigerants. These proposals will take the form of an individual operator licence. Attendance on approved training courses, or verification of competence will be required for licensing. It is envisaged that licensing will become mandatory in the near future.

Leak Detection

All air conditioning systems lose refrigerant to some degree, typically 10% to 30% over a year. Greater loss of refrigerant is usually due to leaks. These can usually be detected by an electronic leak detector, which emits a visual and/or audible tone, increasing in pitch as a leak is discovered. These electronic leak detectors usually detect both R12 and R134a refrigerants. For more 'difficult' leaks, an ultra-violet dye can be injected into the vehicle air conditioning system, which 'glows' in the presence of an Ultra-Violet lamp.

Oxygen Free Nitrogen (OFN) Leak Detection

In order to comply with the Environmental Protection Act (EPA) 1990, it is very strongly recommended that OFN pressure testing is carried out in the first instance, in order to determine leaks on an air conditioning system. The use of an OFN kit is quick and easy and non-polluting since the Earth's atmosphere consists of about 79% Nitrogen.

Air Conditioning System Servicing

All vehicle air conditioning systems require at least an annual servicing. Also, it is very important that the vehicle air conditioning system is operated for at least a few minutes each week, throughout the year. This circulates the lubricating oil throughout the system and helps prevent the seals drying out.

Typical servicing would consist of:

- Clean condenser of dirt, leaves, flies etc.
- Check / adjust compressor drive belt.
- Check compressor security.
- Check all pipe work for condition, chafing, leaks and security.
- Check operating pressures and temperatures.
- Check / adjust refrigerant charge amount.
- Check operation of all air conditioning and heater controls and switches.
- Check / clean evaporator water drain tube.

Fault Tracing

The manifold gauge set or equipment pressure gauges are the key piece of test equipment for determining the correct operation of an air conditioning system.

They can help assist in the diagnosis of:

- No refrigerant charge / leaks.
- Undercharged system.
- Overcharged system.
- Blockages.
- Incorrect compressor, condenser or control valve operation.
- Pressure switch failures.
- Condenser cooling fan failures.
- Moisture in the system.
- Non-condensables i.e. air in the system.

Typical operating pressures would be

1.0 – 2.0 kg/cm²/(bar) low side and

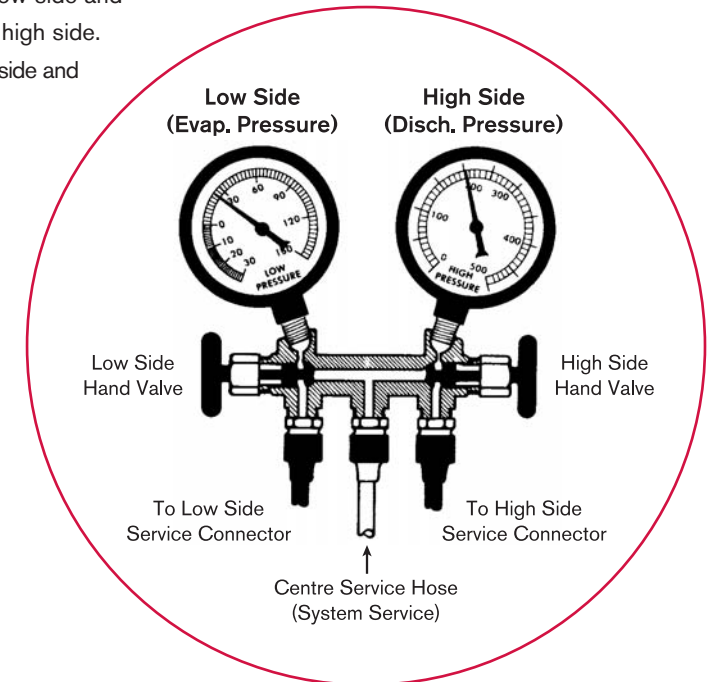
7.0 – 15.0 kg/cm² (bar) high side.

i.e. 14.5 psi – 29 psi low side and

102 psi – 218 psi

high side.

These pressures however, can vary greatly between different systems, especially the high side pressures.



Summary

We hope that the information given in this guide has proved to be informative and helpful to you. As you may now realise, there is a considerable amount to consider with air conditioning. We would strongly recommend that you take advantage of our training courses to gain the necessary in-depth theoretical and practical experience. This will assist you to competently service and repair vehicle air conditioning systems.

We can also supply the equipment, accessories, oils and refrigerant to assist you in this task, from low cost, semi automatic machines to fully automatic machines.





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