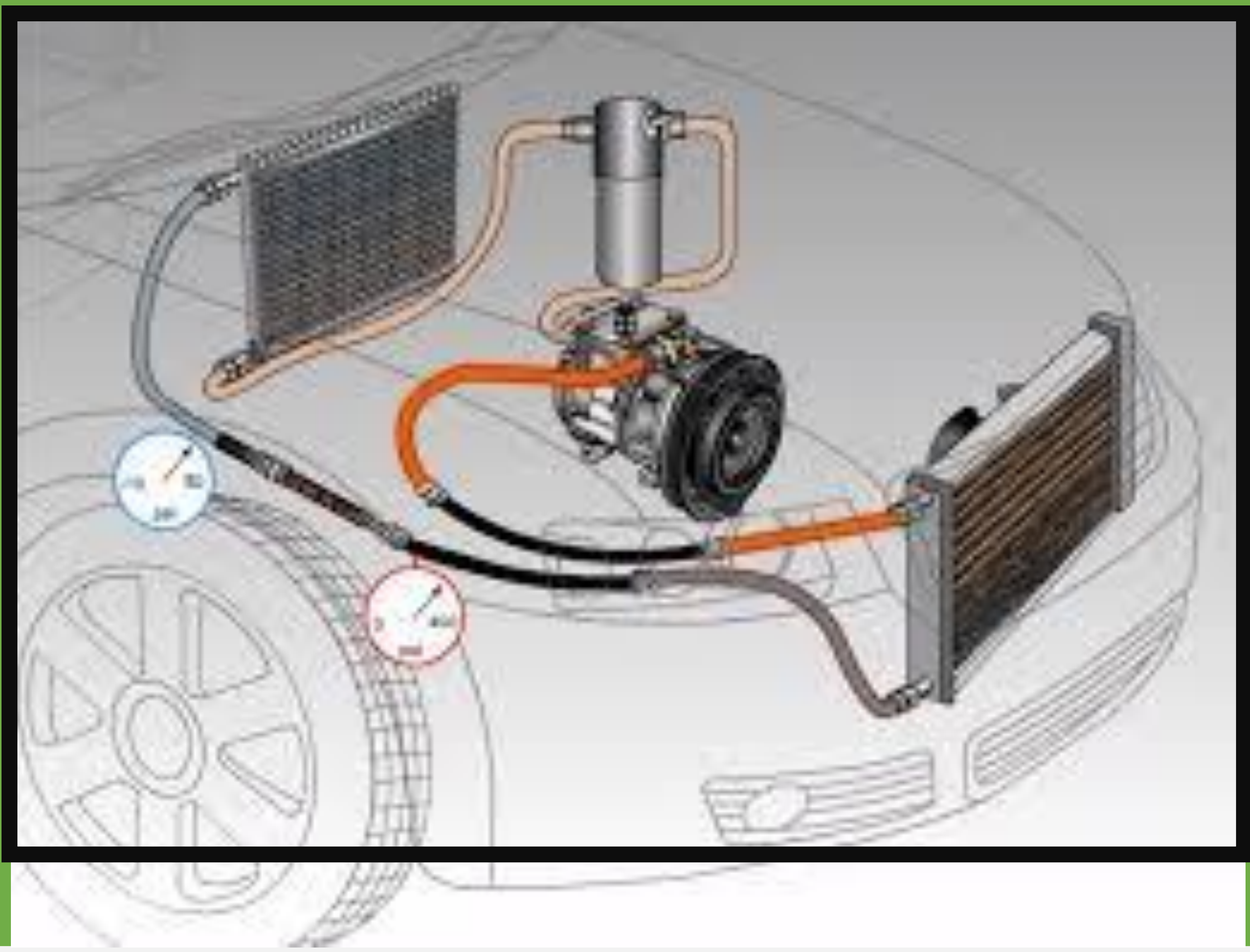
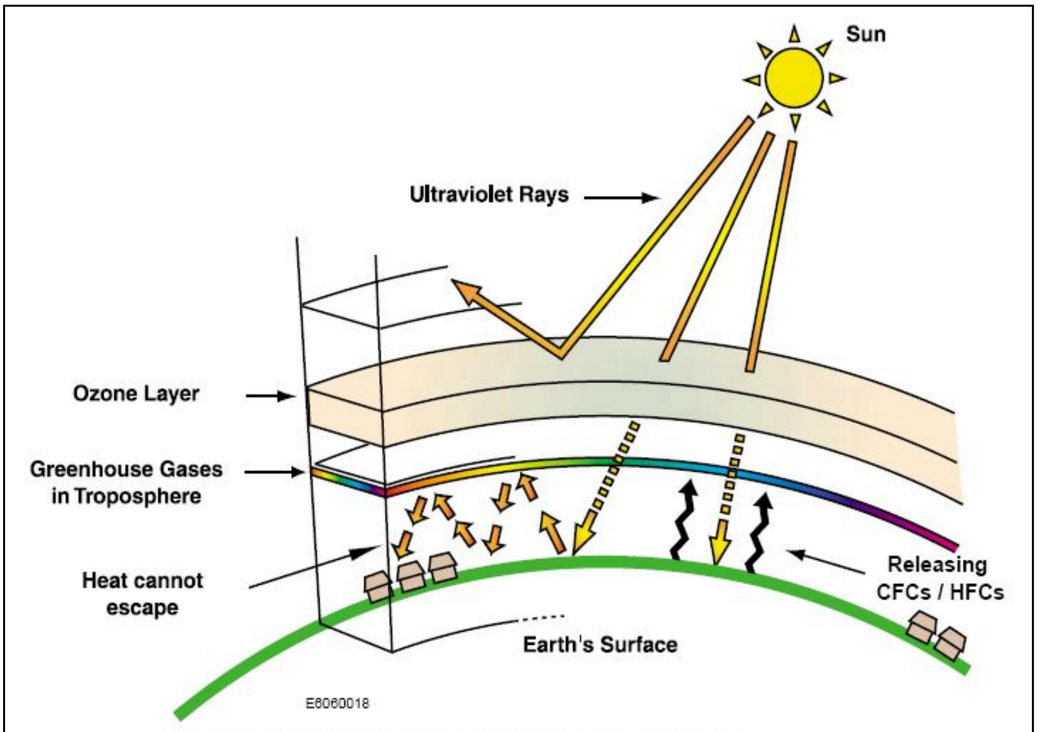
AIR CONDITIONING SYSTEM, COMPONENTS & OPERATION



Servicing Air conditioning and the Law

This article continues the series on air conditioning and focuses on the changes in the law and the new qualifications needed to safely handle refrigerant gas. In this booklet we shall look into some of the guidelines, policies and changes to the law.



Effects of CFCs / HFCs released into Earth's Atmosphere

If we refresh our environment impact knowledge we have established that *chlorine* released from R12 damages the ozone layer allowing harmful ultraviolet rays to travel to the earth's surface causing all sorts of health issues; two examples being eye damage and skin cancer. We have also established that both R12 and R134a refrigerant gasses contribute to the greenhouse effect, trapping heat between the earth's surface and the troposphere therefore raising the temperature of our natural climate. This is why from 1991 it has been illegal to deliberately release R12 or R134a into the atmosphere. (Refer to section 33/34 of the Environmental Protection Act 1990 EPA)

Environmental damage potentials of refrigerants

Global warming potential (GWP) is a number attached to a gas which allows us to understand the potential a gas has to contribute towards global warming. Global warming potential is measured in relation to CO_2. If a gas has a global warming potential of 1, it has the same potential to contribute to global warming as CO_2. If a gas has a global warming potential of 2 that means its potential is twice that as CO_2. HFC R134a has a global warming potential of 1300. That's one thousand three hundred times worst than $C0_2$!

CFC R12 – GWP 8500
HFC R134a – GWP 1300

Likewise, Ozone depleting potential (ODP) is again a value compared to another gas. ODP relates to the potential a gas has to deplete the ozone layer in relation to R11. R11 has an ODP of 1.0. If a gas has an ODP of 0 it is not harmful to the ozone layer, if it has an ODP of 1 it is just as damaging to the ozone layer as R11 and if it has an ODP of 2 it is twice as damaging to the ozone layer as R11.

CFC R12 – ODP 1.0
HFC R134a – ODP 0

The MAC Directive (EC Directive 2006/40/EC)

- The MAC Directive (EC Directive 2006/40/EC) refers to the phasing out of HFC 134a in new vehicles from 2011 and a replacement gas with a maximum (GWP) 150 will be introduced.
- This directive states that maximum limits on leakage from MAC systems in new vehicles will be set. Vehicle type approval will not be granted to vehicles fitted with an air conditioning system designed to contain R134a unless the leakage rate is 40g for a single evaporator and 60g for a double evaporator over a 12 month period.
- Abnormal leaks must be repaired before systems are refilled.

Montreal Agreement

A treaty was opened for signature in 1987 to protect the ozone layer called the Montreal Agreement. This treaty planned a structure for phasing out all substances containing chlorine or bromine minimising any further damage to the ozone layer. There have been several revisions to this agreement since its inception.

Kyoto Protocol

A treaty was also created in 1997 as a response to greenhouse effect called the Kyoto protocol. Its aim is the stabilisation of greenhouse gas concentrations that would prevent dangerous interference to the world’s climate. A total of 169 countries signed up to the protocol representing 61.6% of the earth’s manmade emissions. This protocol has been revised several times in the last 15 years.

R12

The use of R12 is banned in the UK. From 1st October 2000 it became illegal to trade R12. From 1st October 2001 it became illegal to service any vehicle system containing R12. Severe penalties exist if these laws are broken. An R12 vehicle will usually be fitted with screw type service unions as opposed to the quick release unions found on R134a systems. Vehicles containing R12 must have their gas recovered by approved companies and the system changed / retrofitted to accommodate usually, R134a.

R1234yf

R1234yf – A new, safe and environmentally friendly refrigerant for mobile air conditioning

Cars using R1234yf are as safe as those using R134a.

Significant differences between R1234yf and other fluids used in a car:

• High ignition energy (more than10,000 times higher than gasoline).
• Flammable only at high concentration.
• Low heat of combustion.
• Low “Blow off” velocity.
• Large “Quenching” distance.

Ignites only at presence of an open flame or high energy spark.

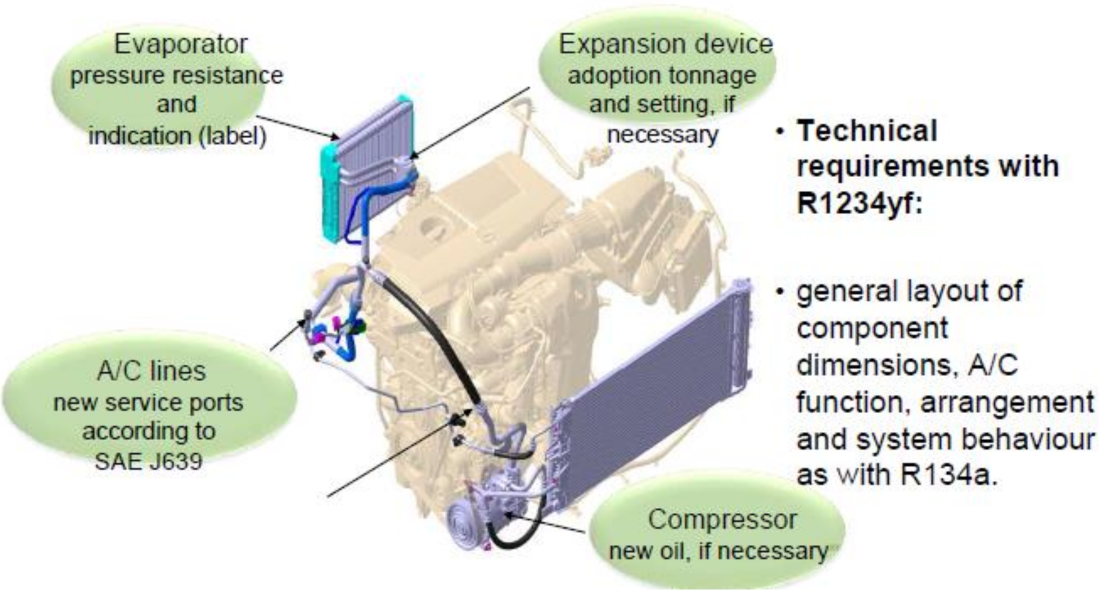
In flammability observed only when sprayed on hot surfaces above 900°C (pure R1234yf) resp. 700°C (with 3% PAG lubricant).

Ignition of R1234yf is nearly impossible in the engine compartment considering operating conditions of the vehicle.

Ignition of R1234yf is impossible inside the vehicle cabin in reality.

Car manufacturers refrigerant of choice is R1234yf with a GWP of 4: Improvement by more than 99% compared to R134a and 97% below the legal requirement.

Handle in the same way as other aircon gasses but separate aircon machines must be used as it can’t be mixed.



Disposable cylinders

Disposable R134a containers have been banned as of 4th July 2007. When the distributors stocks have been exhausted you will only be able to use a refillable vessel much like the gas available from petrol station

forecourts.

If refilling a refrigerant vessel, only fill to around 75% capacity to ensure enough space is left to compensate for material build up in the cylinder and pressure variations due to temperature.

Gross weight – tare weight = net weight.
Net weight x 0.75 = recommended amount to fill a pressurised cylinder.

If needing to dispose of refrigerant / contaminated refrigerant, the use a certified gas handling/disposal company is essential. A waste transfer notice will need to be completed during the transaction. Liability is not transferrable when it comes to the disposal of hazardous waste and so even if a disposal company provides you with a waste transfer note, as part of your environmental audit the disposal process of the disposal company should be monitored by your organisation.

Safety

Fluoroelastomer gloves are recommended gloves that protect you from R134a refrigerant and its –26.3c boiling point.
Always wear gloves, full face goggles and some form of overalls when working on air conditioning systems as this will minimise the risk of frostbite.

Always work on air conditioning systems in a well-ventilated area as R134a refrigerant gas is heavier than air and if inhaled will replace the oxygen in your lungs, potentially leading to suffocation.

Always Refer to Material Data Sheets in companies COSHH (Control of Substances Hazardous to Health) file – all employees of a company employing more than 5 people should have seen these sheets and signed to say they have read them. Material safety data sheets are very important documents in the even of an accident. They contain potentially very usefull infomation to first aiders and the emergency services in the event of an accident.

Refrigerant must never be used to investigate potential leaks in air conditioning systems. Leak detection processes involving pressure testing the systems is only allowed if Oxygen Free Nitrogen testing kits (or equivalent) are used.
Remember, it is illegal to pressure test an A/C system with refrigerant if a leak is suspected.

From 4th July 2010, all Mobile Air Conditioning (MAC) technicians working with cars and car derived vans must have achieved as a minimum requirement, a refrigerant handling qualification which fulfils the European Union F Gas Regulation (EC842/2006 and Annex to Regulation EC307/2008).

This article has been compiled using a selection of documentation provided by DEFRA and the HSE. If you require further guidance, and how the regulation changes will affect you or your work place we recommend the DEFRA website www.defra.gov.uk/fgas and http://www.hse.gov.uk/.

Legal guidance should always be sought on the F Gas regulations, servicing A/C systems and other associated areas if you are unsure. This document is not meant as a substitute to legal advice.

The Science of Air Conditioning

Before it is possible to go into the nuts and bolts of the system there are a few key pieces of physics that need to be clearly understood.

The flow of heat

Simply put, "*hot travels to cold*". If two items of differing temperatures are placed next to each other the energy stored in the hotter item will travel in the direction of the colder item. Think about holding an ice cube in your hand, the energy from your hand is transmitted into the ice cube. We can view this, as the ice cube melts, and we can feel this, as our hand gets colder through it losing some of its energy to the ice cube.

The 3 states of matter

No prizes for guessing what they are! Matter can exist in three main states - solids, liquids and gasses. I'm sure you've heard these listed many times before. In this instance the 'matter' that we are going to discuss further is water.

Let us imagine what processes need to occur for water to evolve into the above three states.

It's minus 10°C, water is in its solid state - ice. If we apply some energy to the ice (heat energy) its temperature will increase. This increase in temperature is measurable as the ice warms up progressively up to 0°C. If we apply just enough energy to the ice so that its temperature increases up to smack on 0°C, the water will still be in a solid state. If we now decide to apply more heat to the ice we will find that the ice melts into its liquid form, but for the vast majority of this process the temperature of the ice will still stay at 0°C. This means that even though we have applied heat to the ice, its temperature didn't change. This heat that has been applied to the ice is known as latent heat. The water is now in a liquid state and its temperature is still 0. If we now apply heat to the water we can measure the temperature increase. This process will continue all the way up to 100°C. Once we are at 100°C we will find that the water is still in a liquid state. If we continue to apply energy to the water we will find that the temperature of the water does not increase but the heat is still performing an action. The heat is now being used to convert the liquid into a gas or vapour. Again, this large amount of energy being applied to the water but having no notable effect on temperature is latent heat.

The key statement is as follow: "*It takes a great deal of energy to promote a state change"*. Cling onto this statement, as this piece of info is key to the clear understanding of air conditioning systems.

State changes though altering pressures and temperatures

Temperature

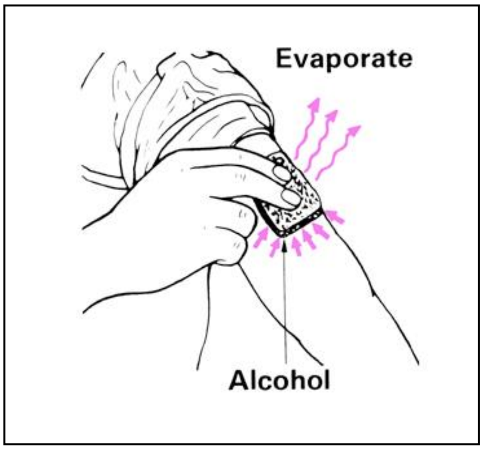
As stated above, if we increase the temperature of a liquid it will eventually become a gas. Equally, if we reduce the temperature of a gas, it will eventually become a liquid. Heat up water and it boils becoming a gas, cool down a gas and it will condense – becoming a liquid. This could be demonstrated by boiling a kettle. Eventually the kettle will boil and during this process, vapour or gas will exit the spout. If we were to hang a mirror just above the spout of the kettle and allow the steam to hit it, "*hot would travel to cold*", the steam would lose some energy to the cold mirror, and the vapour or gas would condense and become a liquid again in the form of condensed water.

Pressure

If we increase the pressure of a gas, the molecules will become closer together. The higher the pressure, the closer they will be. If we increase the pressure sufficiently the molecules will be so close together that they will merge. The more molecules to merge the bigger the groups will become. Eventually the groups of molecules will be so large that they will be visible in the form of droplets. Once the droplets all join together we could easily describe them as a liquid.

Inversely if we reduce the pressure applied to the liquid, the reverse will occur. The molecules will spread further and further apart until there is nothing holding them together and they are totally free to roam around. Once the molecules are able to roam around totally independent of one another, they have become a gas.

Evaporation and condensation



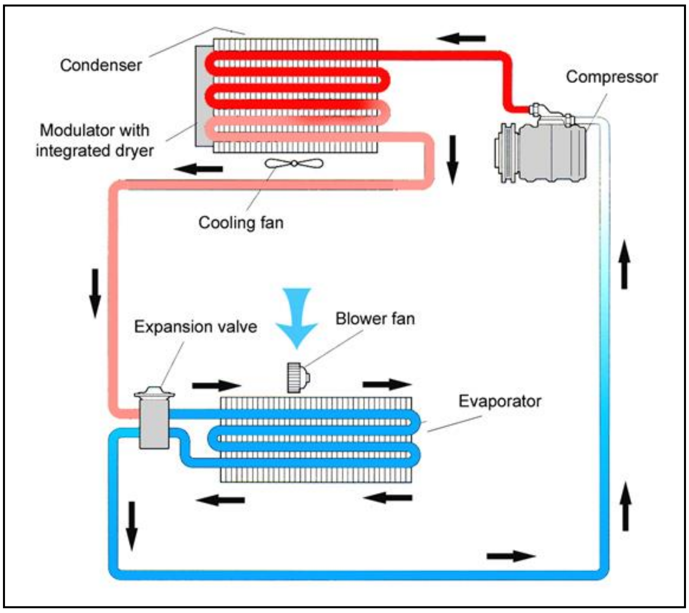
When evaporation occurs, energy will be absorbed from the surrounding area. Equally when condensation occurs, heat will be output to the surrounding area. Appreciating what is happening when we sweat can assist in remembering this final key principle. So, why do we sweat? Simply put, we sweat to place a liquid on the surface of our skin. As the liquid absorbs energy it turns into a gas

– it evaporates. During the process of evaporation, energy is absorbed from somewhere, and that somewhere is your body's core. The more energy removed from your body's core, the cooler you will feel. Appreciating this process with sweat is not always so easy, but think about what happens when you get a solution on your skin such as neat alcohol or brake cleaner. That solution as it lands on your skin feels very cold. The actual temperature of that solution may be at room temperature but to you it feels especially cold – why? It is not that the temperature of the solution makes it feel cold; it is the fact that it is a solution that readily evaporates – you can see this with the naked eye whenever you spill any. And it is the process of evaporation absorbing energy from your body's core that makes you feel cold in the area where it is on your skin. The faster the liquid evaporates, the quicker the energy is removed from your body, and the colder the sensation you will feel.

The refrigerant cycle

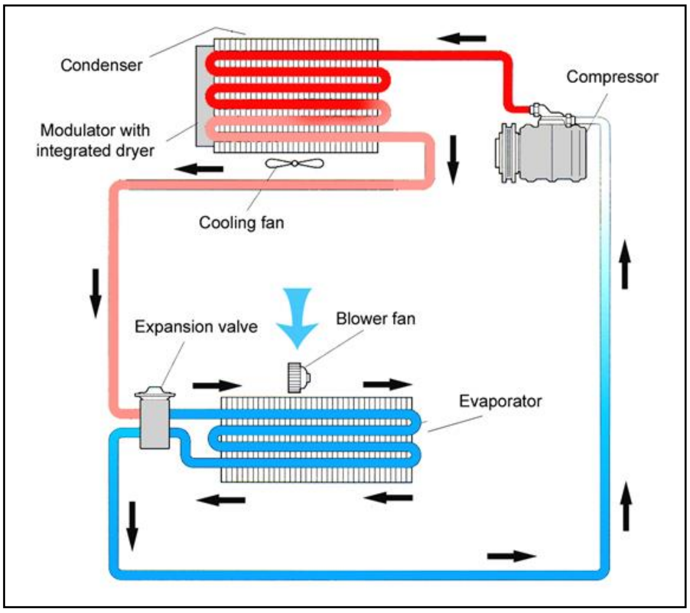
Two key points that are critical to the understanding of the A/C system are the route through which the refrigerant flows and the differing states the refrigerant is in as it travels around the circuit. A great starting point for the understanding of this is at the compressor.

Commonly, A/C compressors contain reciprocating pistons. As the piston travels in one direction, through a one way valve, it draws-in the refrigerant gas from the low pressure side of the circuit. The piston then travels back in the other direction and compresses the refrigerant gas causing a large increase in pressure. Once the pressure reaches a specific threshold it will overcome a second one way valve and allow the now high pressure refrigerant gas to exit the compressor and into the high pressure side of the refrigerant circuit. There is a relationship between pressure and temperature. When the pressure of a substance is increased its temperature will also increase. The pressure increases substantially as the refrigerant travels through the compressor. The low pressure side of the circuit would typically be under the pressure of 2 bar, the high pressure would typically be under the pressure of 15 bar. A rise of 13 bar! This large increase in pressure also results in a large increase in temperature. The temperature of the refrigerant entering the compressor would be 10-20°C and the temperature of the refrigerant exiting the compressor would be in the region of 90°C!



This high pressure high temperature gas then travels onwards to the condenser. The condenser is a large heat exchanger usually located in front of the engine radiator. If two substances of differing temperatures are placed together, heat will travel from the hotter substance to the cooler substance until both substances reach an equal temperature. As the term heat exchanger suggests, heat is exchanged from the hotter body to the cooler body. In this case the hotter body is the refrigerant gas and the cooler body is the fins of the condenser. As the heat is transferred to the fins of the condenser, cooling air flows over them. Again a heat exchange process occurs allowing the heat from the fins to transfer into the cooler air travelling past them into usually, the engine compartment. As the heat is removed from the refrigerant it starts to condense. As the refrigerant continues its journey through the condenser it continues to condense and ideally, the refrigerant will turn fully into a liquid by the time it exits the condenser. From the condenser, the liquid refrigerant travels onto the modulator. This looks like an extra tube welded onto the side of the condenser. The modulator performs three main actions. One, it acts as a filter, filtering out particles as they travel around the AC system. Two, it acts as a dryer. The dryer in the modulator contains desiccant (Like the silica gel you find in a new box of shoes). This desiccant absorbs water. As water gets into the system the dryer tries to remove it. The third function of the modulator is as a reservoir. Bearing in mind the pressure and temperature of the refrigerant inside the AC system regularly changes, so does the refrigerants volume. This varying volume is accommodated by the receiver dryer.

Onwards from the modulator the refrigerant flows on towards the thermal expansion valve or TXV. This is a self regulating valve which controls the amount of refrigerant able to pass into another heat exchanger located by the heater matrix called the evaporator. As liquid refrigerant passes through the expansion valve, into the low pressure side of the circuit, a pressure reduction occurs. This pressure reduction causes the liquid refrigerant to be on the verge of becoming a gas but it is still a liquid at this specific point. If you increase the pressure applied to a gas you eventually will end up with a liquid, inversely, if you reduce the pressure applied to a liquid you will eventually end up with a gas. It is only when the liquid travels into the evaporator will the liquid evaporate and actually become a gas. This process occurs due to the refrigerant absorbing heat from the air being blown through the evaporator. The process of evaporation causes a cooling effect. The larger the quantity of liquid travelling into the



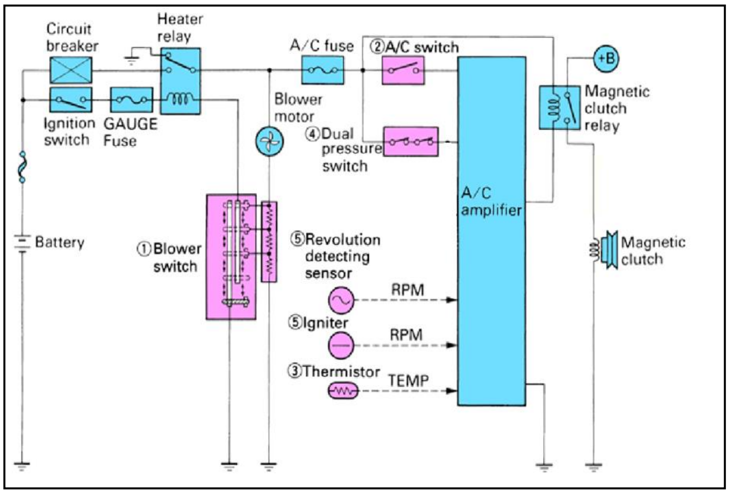
evaporator, the more evaporation that will occur, which in turn will lead to a higher quantity of heat energy being absorbed by the process. As air is blown through the fins of the evaporator and as stated previously hot travels to cold, the heat carried by the air transfers to the cold fins and in turn is absorbed by the refrigerant. As the air loses some of its heat, the air that comes back out of the fins of the evaporator is cool and that cooled air is then vented into the passenger compartment.

Now that the refrigerant has absorbed some of the heat from the passenger compartment, it has done its job in the evaporator and out it travels of the evaporator in a gaseous state. The refrigerant travels back to the compressor leaving the low pressure side of the circuit and the whole process starts again.

Manual Air conditioning – the electrics

In this second part of the series we will have an in depth look into the manual R134a air conditioning system to gain a greater understanding of the overall system operation. Let us begin with the electrical system.

The A/C electrical system consists of an ECU, (usually referred to as an amplifier), a selection of inputs – earths, lives and sensor values – with the primary output control function being the relay for the magnetic clutch. Providing all the sensor values are within the limits the amplifier will power up the magnetic clutch relay, the magnetic clutch will engage and refrigerant gas will be pumped around the circuit by the now operational compressor.



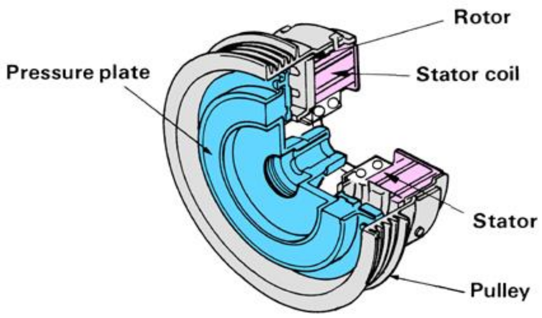
The circuit in detail

Blower switch

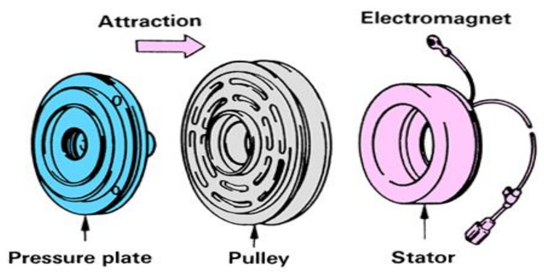
The blower switch performs 2 functions in 1 unit. Its first function is to provide a route to earth for the heater relay. When the switch is turned to any of its variable speed “on” settings, current can flow though the switch and down to earth to allow the relay to switch on. Once the relay is switched on, a feed is then provided to the A/C switch. Once the A/C switch is turned on, a feed is provided to the A/C amplifier to enable it to operate.

The second function of the blower switch is to perform the function of a variable resistor. Depending upon which position the switch is rotated to, its internal resistance will change accordingly. Position 1 – high resistance, 2 slightly less 3 slightly less still. This varying resistance controls how much current is able to pass through the blower motor; the higher the resistance, the lower the amount of current able to pass through the blower motor circuit. The less current that can pass through the motor, the slower it will rotate. This will in turn control the rate of air being passed though the evaporator and/or heater matrix depending upon the position of the vents in the heater box.

A/C compressor clutch

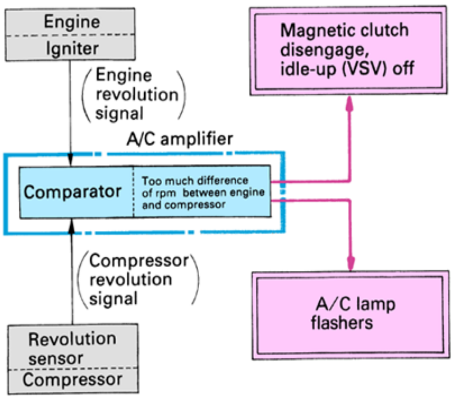


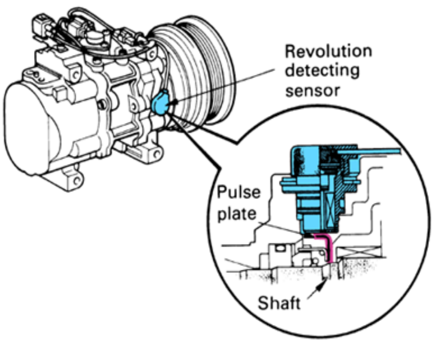
A fixed capacity compressor is usually fitted with an electromagnetic clutch giving the A/C system an ability to engage and disengage drive to the compressor. The clutch typically consists of 3 parts, a field coil or stator, a rotor assembly or pulley and a pressure plate. The pressure plate is connected to the central compressor shaft. If the pressure plate rotates, so will the compressor internals. The pulley is free to rotate at all times and is permanently driven by the auxiliary belt when the engine is running. When the stator is energised a magnetic field is generated. Current flows through the A/C clutch relay closed contact, through the stator winding and down to earth usually through the compressor casing and into the chassis of the vehicle. This magnetic field pulls the pressure plate along the splines of the compressor shaft where it comes into contact with the pulley. Once there is frictional contact between the pulley and the pressure plate the compressor shaft will start to rotate at pulley speed. When this frictional contact occurs the compressor is commonly described as being engaged. When the supply of current to the stator is removed by the A/C clutch relay opening, a spring, seated against the pressure plate, pushes the pressure plate out of contact with the pulley and the pulley is again disengaged from driving the compressor and rotates freely.



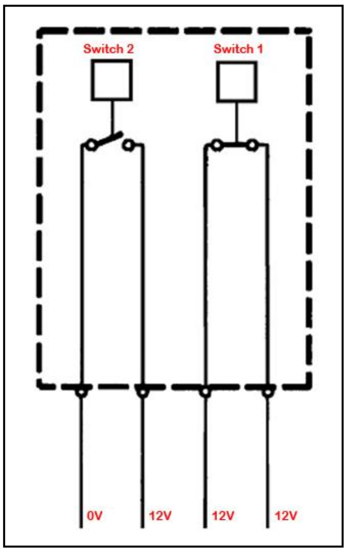
Compressor speed sensor

Some compressors are additionally fitted with a revolution speed sensor. This speed sensor value is monitored in relation to engine speed by the A/C amplifier (amplifier programming takes into account the pulley drive ratio). This comparison gives the A/C amplifier the ability to identify belt and / or magnetic clutch slippage, or even a locked up compressor. In this instance, to protect the system the magnetic clutch is disengaged and A/C operation will cease. The driver is notified about this fault through the light on the A/C on/off button flashing or by some other means dependent upon manufacturer.





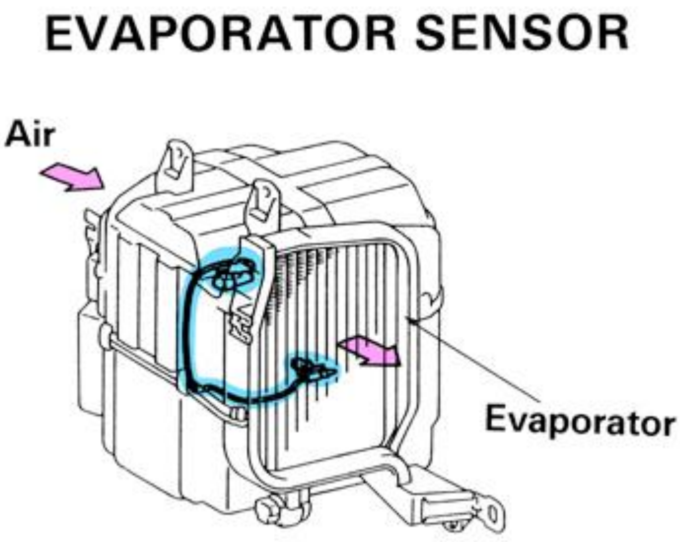
High pressure switch



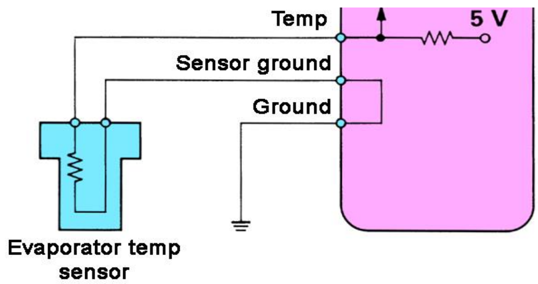
A pressure switch is fitted in the high-pressure side of the system. It can be placed in a selection of locations but it will always be found somewhere in the high pressure part of the circuit in between the compressor output and the thermal expansion valve. Two pressure sensitive switches (diaphragm operated) are located into the one unit. The two switches combined are able to indicate three conditions. The first switch (switch 1), under normal operating pressures (typically 15bar) will be in its closed or in its “on” state. If the pressure applied to it by the refrigerant is too high (26-30 bar), the switch contacts will open. Once the circuit is broken the amplifier detects the voltage change in this circuit and de-energises the magnetic clutch relay, turning the compressor off. This is done to prevent the system over-pressurising which could cause permanent damage to numerous components in the circuit. Conversely, if the pressure in the high pressure part of the circuit drops significantly (to 1 – 2 bar), the same switch opens in the other direction, again opening the contacts. This again leads to the same outcome of turning off the compressor. The most likely cause of such low pressure in the high pressure side of the system would be insufficient refrigerant. As the refrigerant is used as a ‘vehicle’ for the systems lubricating oil, this could lead to seizure, hence the action of switching off the compressor.

The second mechanical switch located in the switch unit is designed to close when the refrigerant pressure rises to just above normal operating pressure. (16 – 18 bar). When the switch closes, the A/C amplifier switches the condenser cooling fan to high speed. This increases the quantity of air flowing over the condenser causing the refrigerant to cool further and contract. This reduces the pressure back to a normal range (14-16 bar) leading to the heat energy being absorbed around the evaporator correctly.

Evaporator temperature sensor (anti-frosting device)



This is used to sense an excessively over-cooled evaporator condition to prevent frosting on the evaporator fins (ice is an excellent heat insulator and the efficiency of the air conditioning will reduce drastically if the evaporator becomes frosted).
The sensor is an NTC type thermistor and will therefore experience an increase in electrical resistance as its temperature reduces (and vice versa). This change in resistance provides a detectable temperature condition (measured by the amplifier). When the sensor indicates that the evaporator is at risk of frosting, the ECU will disengage the magnetic clutch to prevent this.



Operation

Much like the coolant temperature circuit on a typical engine management system, this uses 2 resistances in series, the first resistance inside the amplifier has a fixed value and the second resistance (the thermistor) has a varying value according to temperature. As current flows through the circuit a volt drop occurs across each resistance.
As the temperature drops, the thermistor resistance increases. Conversely, as the temperature increases the resistance of the thermistor drops. If the resistance inside the amplifier is equal to the resistance in the thermistor the volt drop across the first resistance would be 2.5 volts (the 5 volts applied is halved). The remaining 2.5 volts will drop to zero as current flows through the second resistance (the thermistor). As the voltage is monitored inside the

amplifier after the first resistance (where the arrow is located on the diagram) the voltage value can be interpreted as a temperature and the amplifier can act accordingly. As the temperature of the evaporator drops, the resistance of the thermistor will increase. This means that there will be a higher volt drop across the evaporator temp sensor than across the resistance inside the amplifier. Therefore the measured voltage value (at the arrow inside the amplifier) will be higher. This higher voltage reading will be interpreted by the amplifier that the temp sensor is detecting a colder temperature and again, the amplifier can act accordingly. The action will typically involve the opening of the A/C compressor relay. This will lead to a reduction of refrigerant flow around the system which will reduce the cooling effect of refrigerant evaporating inside the evaporator. Finally, as the evaporator warms up the resistance of the evaporator temp sensor will drop. This will mean comparatively there will be a larger volt drop across the resistance inside the amplifier and a smaller volt drop across the evaporator temp sensor. As there is a larger volt drop across the resistance inside the amplifier the voltage measured after it will be lower. This reduction in measured voltage at the arrow inside the amplifier will be interpreted by the amplifier that the temperature of the evaporator has increased to a level where frosting is no longer a risk and the magnetic clutch will be re-engaged through control of the relay.

In summary, study the diagram in detail and check the inputs and outputs of the A/C system. A good clear understanding of voltage in a circuit is essential to the accurate electrical diagnosis of the A/C system. It is only when the correct voltages are applied to the A/C amplifier from the key inputs, will the primary output (the A/C compressor relay) be energised.

Basic checks and diagnosis

Early detection of trouble can result in prolonged component life as well as the customer not being bothered by unnecessary problems.

Before you commence with a full diagnostic procedure there are some basic checks which it is good practice to carry out.

Basic checks

Drive Belt

Inspect the drive belt for tension, wear and damage. A slipping belt can have a significant effect on the system operation as the compressor will not rotate at the desired speed. This could result in a lower system operating pressure. Equally, if the drive belt is slipping it is going to wear at an increased rate. This is going to result in early belt failure.

Compressor

Is the compressor noisy? A noisy compressor can indicate an internal fault within the compressor causing the system to malfunction. A full system flush and oil change should be the first plan of attack in this situation. If this has not quietened down the compressor it will be necessary to replace it.

Condenser fins

Visually inspect the condenser, if the condenser fins are clogged with dirt or bent over the ability of the condenser to cool the refrigerant will be greatly reduced. This will result in the refrigerant not being in a fully liquefied state as it exits the condenser resulting in reduced cooling at the evaporator.

Oil stains around joints and gaskets

Stains on joints and gaskets usually indicate a leak from the o rings or gasket failure. If refrigerant has been leaking out if the system the A/C pressures will be down, again resulting in a reduced cooling effect at the evaporator.

Check sight glass

Ideally you should not be able to see any bubbles at the sight glass. Bubbles indicate the refrigerant is not being fully liquefied by the condenser. The relevance of the sight glass has reduced since the introduction of R134a refrigerant. It is common for manufacturers to no longer integrate a sight glass into the system. If it is there however, use it, as it’s another useful tool in the diagnostic technicians’ armoury.

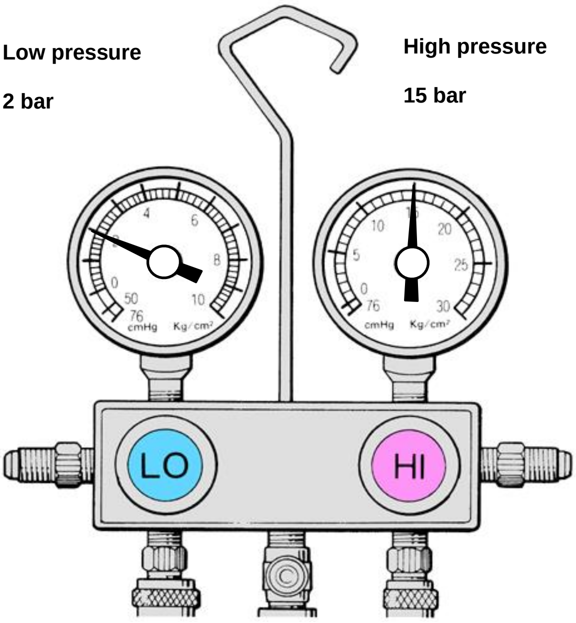
Performance testing

A useful test to ascertain the operating of the A/C system is to test it to see if it doing what it’s supposed to do in its basic form. This is simply to load up the system as much as possible and test to see if the air is actually cooling the air at the vents sufficiently. This is known as performance testing.

- A/C turned on and set to max cool
- Engine speed 1500 rpm
- Blower speed full
- Recirculation selected
- Doors open
- Centre face vents open

Place a thermometer (usually digital for accuracy and speed) at one of the face vents and measure the temperature. This isn’t a precise science but it would be normal to expect the temperature to be a maximum of 10 degrees C. The temperature at the vents will vary depending upon the temperature of the day. On a day with an ambient temperature of 15 - 20 degrees C it would be normal to expect the vent temp to be 6 – 8 degrees. If the temperature is above these example values it would be a fair assumption that the A/C system is not operating perfectly and further investigation is required.

Normal operation pressures

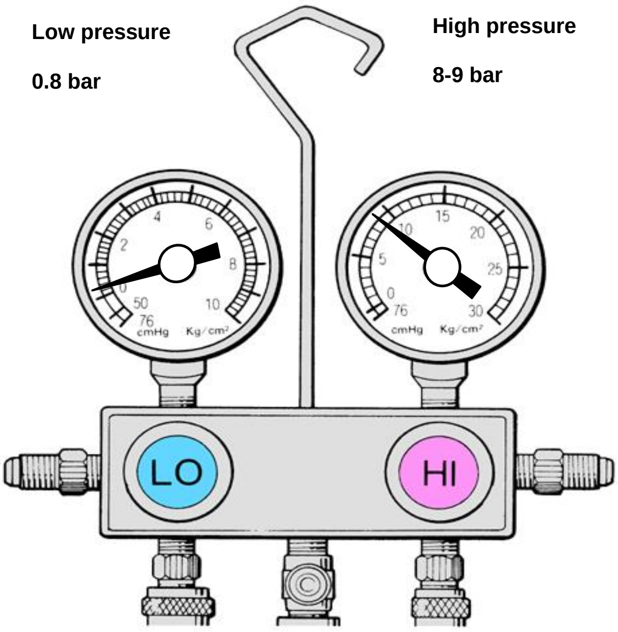


Standard pressures

Low pressure	1.5 – 2.5 bar
High pressure	14.0 – 16.0 bar

Note. These readings may vary due to the ambient temperature conditions and manufacturers specifications. It is always wise to cross reference with the manufacturers technical data.

Poor cooling – pressures low



Under these conditions, the pressure is low on both the low pressure and the high pressure sides. These readings would indicate that the liquid refrigerant evaporates **before** the evaporator and will therefore absorb the heat energy in the wrong place thus resulting in insufficient cooling performance. By far the most likely outcome of this instance will be a lack of refrigerant within the system. Before the system is re gassed a leak detection process should occur. Leak detection should be carried out in line with DEFRA guidance. The environmental protection act of 1990 states that the deliberate release of refrigerant is banned. Oxygen free nitrogen pressure testing is now widely recommended.

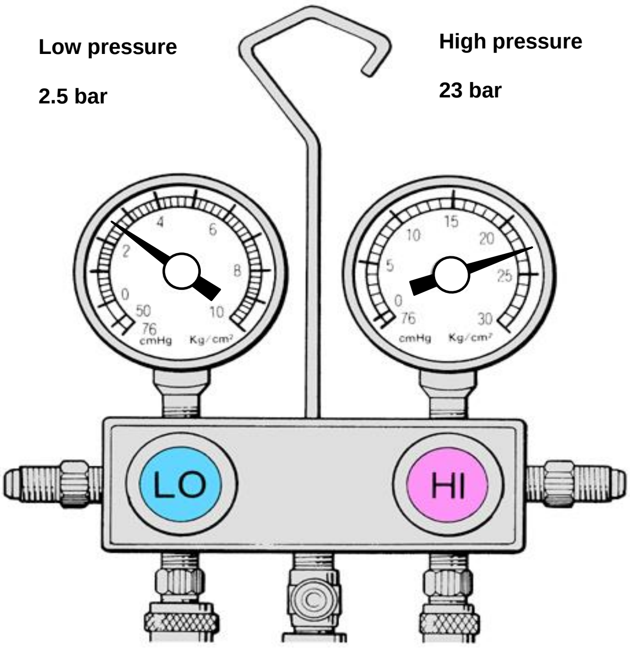
Poor cooling – pressures high

Low pressure

2.5 bar

High pressure

23 bar



Under these conditions the pressure is too high on both the low pressure side and the high pressure sides. These readings could indicate a selection of faults. Firstly there could be too much refrigerant in the system. This will lead to the refrigerant evaporating **after** the evaporator and will therefore absorb the heat energy in the wrong place thus resulting in insufficient cooling performance. An additional possible cause of this can be air in the system. This can result in the pressures being too high which will result in evaporation of the refrigerant occurring in the wrong location in the system. The final common possibility could be that the condenser is not managing to cool the refrigerant sufficiently. This could be caused by the cooling fan not working or the condenser being blocked / fins bent over.

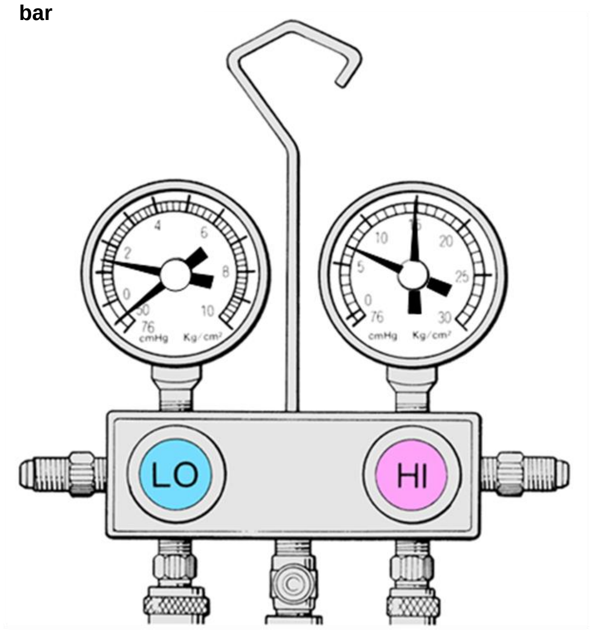
Poor refrigerant flow - Does not cool / c

Low pressure

50cmHg – 1.5 bar

High pressure

7 - 15 bar



Un

indicated on the low pressure side. Low pressure is indicated on the high pressure side. In most cases the refrigerant flow is being obstructed as moisture turns to ice at the expansion valve. This causes a temporary blockage resulting in the pressure in the high side fluctuating and the pressure in the low pressure side dropping due to a restricted supply to the compressor. There should not be any moisture in the system and it can be a clear indication that the dryer needs to be replaced along with the necessity to thoroughly vacuum down the system and recharge.

When working with air conditioning systems please be aware of safe working practices. Always wear appropriate personal protection and never vent refrigerant into the atmosphere. Leaks should always be detected using a DEFRA approved procedure.

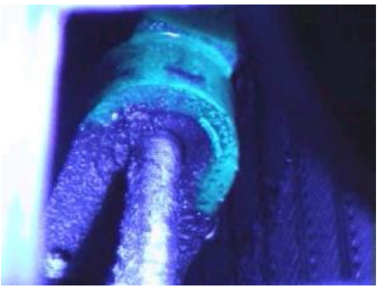
Leak detection

There are a number of ways of achieving this and if you are going to get seriously involved you will need to spend some money on equipment. The leaking could come literally anywhere in the system from tubing to an accumulator to a tiny pressure switch gone bad. Customers generally don't report leaks. They only report an inefficient or inoperative system

Ultra-Violet Leak Detection

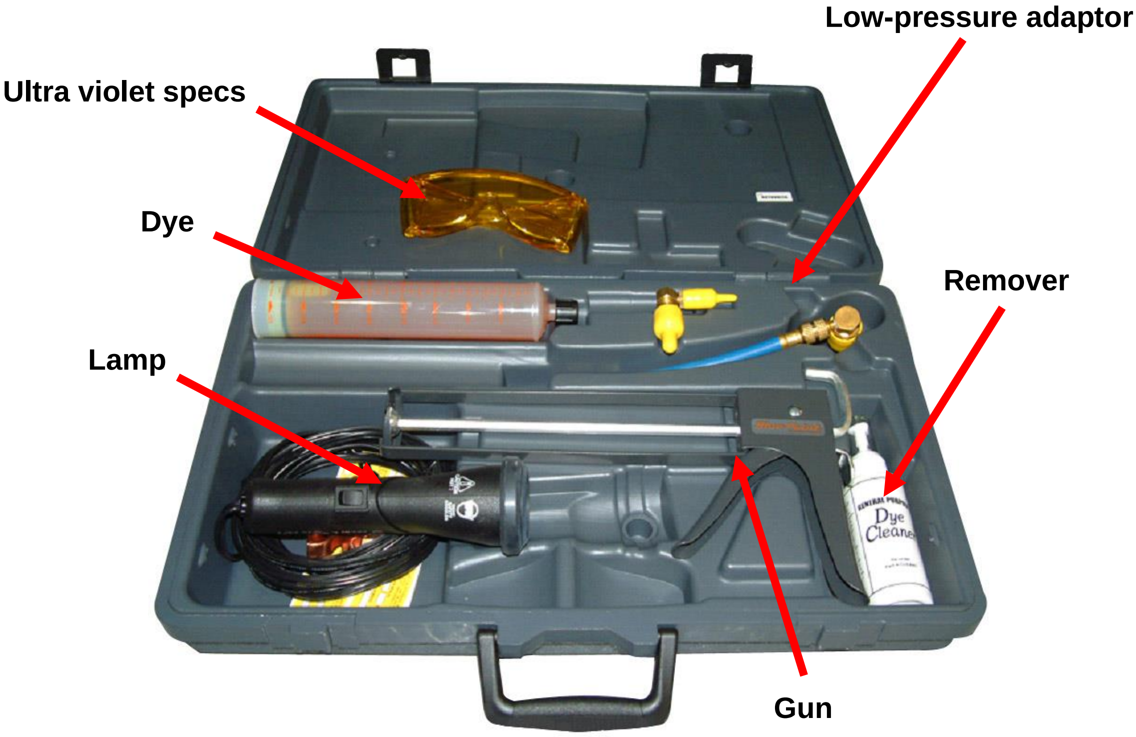
UV dye is injected into the system. It mixes with the lubricant and the liquid refrigerant in the system. When a refrigerant leak occurs, the dye comes out with it and leaves a stain around the point of exit. This makes leak detection remarkably easy as long as the leak is somewhere that can be seen. You will need a UV lamp, the brighter the better, and some UV glasses. The effects are quite remarkable.

Without U-V lamp



With U-V lamp

This of course relies on there being U-V dye in the system when the leak occurs so it is in your interest to make sure there is. Check there is dye in the system on service. Look at the service valves with the UV gasses and lamp and you should see it. Any recovered PAG oil will have luminescent glow to it but, if you are unsure, put some in!
It is normally introduced by injecting 5 -10ml into the **low** pressure side when the engine is running and the AC working. It can be a messy affair and the kit should contain some remover. Always clean any spills as this could confuse any later diagnosis. You can also buy the refrigerant with the dye in it so it goes into every vehicle you service. Some recycling machines have the option of automatic dye injection which is very handy



What to do when the system has no gas pressure?

Remember the mantra **"deliberate release of refrigerant is banned"** so putting in a couple of hundred grams of refrigerant into the system and seeing if it comes out could see you with a hefty fine. If the system is empty or of such a low pressure i.e. less than 2 bars at around 20 C you must initially consider it to have a leak. The only approved method of diagnosing a system that is open to the atmosphere is by using Oxygen Free Nitrogen.

Oxygen Free Nitrogen (OFN)

Nitrogen represents 78% of the atmosphere and it's what makes the creamy head on some beer, so it's safe. The reason it's oxygen free is that oil, oxygen and compressors are a good way to make an explosion. Think of a diesel engine.

To test for leaks the system is pressurised to 10 bar (147 psi). A major leak will be apparent by the noise it makes. If no leaks are apparent, a valve is closed and the pressure in the system is monitored using the equipment gauge. An ultra-sonic leak detector can be used to detect smaller leaks. There are a few on the market but reviews are mixed. An electronic leak detector may find any residual traces of refrigerant or oil forced out by the increased pressure of the nitrogen. Small leaks are best found by using soap and water in a sprayer and looking for bubbles. Don't forget to check the service connectors.

Practically, if the leak is very small and in an area you can't get at, around the evaporator for instance they can be very elusive.

Once you have finished OFN testing, vent the nitrogen to atmosphere and vacuum the system for 30 minutes to remove any moisture. Now charge the system with refrigerant and introduce 5-10ml of U-V dye.

Remove the service hoses and check using an electronic leak detector, especially around the service connectors. Run the system for 10 minutes for the dye to mix and circulate and check for leaks using a combination of the U.V lamp and goggles and an electronic leak detector. If a leak is discovered at this late stage. Recover the refrigerant and fix it

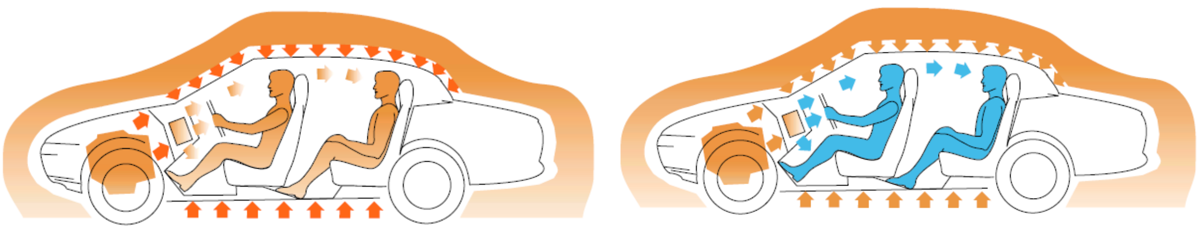
Electronic Leak Detectors

The electronic leak detector is an absolute must for any technicians using AC servicing equipment. When a system has been serviced and the service connectors removed, the service port should be blown out with compressed air and checked for leaks. (I have recharged many systems over the years and have come across lots of leaky Schrader valves). A good detector when used properly will show up the smallest of leaks with pinpoint accuracy. One thing to remember, R134a as a gas is 3 and a half times heavier than air so wherever it comes from, it falls. Always check underneath the suspected leak. Start from underneath the vehicle and move upwards. When checking the evaporator, put the probe in the airflow of the lower vents set the blower to low. Then turn the AC off and push the probe up under the trim to the area where the evaporator sits.

Remember when working with air conditioning systems please be aware of safe working practices. Always wear appropriate personal protection and never vent refrigerant into the atmosphere. Leaks should always be detected using a DEFRA approved procedure.

Heating, ventilation and air conditioning (HVAC)

Air Conditioning is a means of creating and maintaining comfortable conditions within a vehicle. The Air Conditioning system is operational when the engine is running, but functions regardless of vehicle speed. It is only possible to “produce a cold cabin”, i.e., cool a substance, by removing heat from it. The Air conditioning system transfers the heat from inside the vehicle to the outside, thus reduces the temperature within the vehicle.



An automotive Air Conditioner must perform four distinct functions within the Passenger compartment:

1. It must cool the air.
2. It must dry the air.
3. It must clean the air.
4. It must circulate the cooled and dried air around the vehicle interior

To understand the processes taking place within an air conditioning system, it is necessary to explain four fundamental concepts of the refrigeration process:

- Heat Transfer
- Temperature / Heat
- Humidity, Relative Humidity
- Latent Heat / Sensible Heat

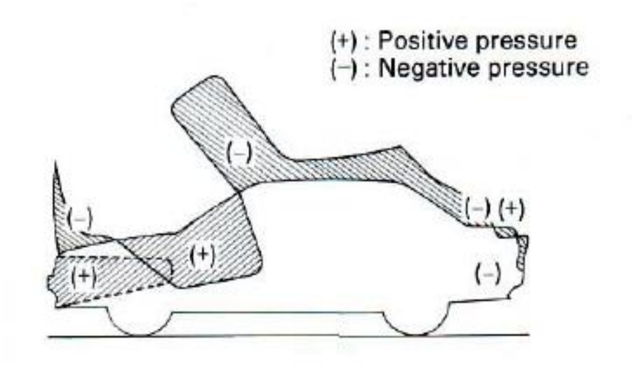
Heat transfer is a physical process constantly taking place in the air conditioning system. Heat transfer takes place when two substances at differing temperatures come into contact and heat is transferred from the hotter to the cooler substance. This exchange lasts until temperature equilibrium is established (both temperatures are the same).

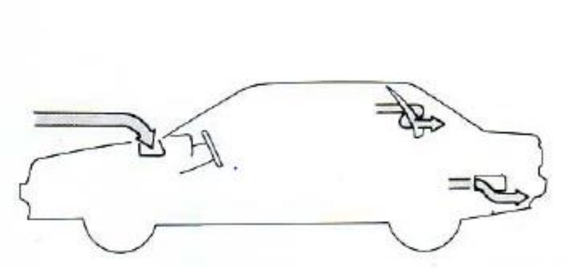
Ventilation

A ventilator is a device used for introducing fresh outside air into the cabin area to ventilate the interior. Two such systems are used, the natural flow through and the forced air type ventilator.

Natural flow ventilator

The intake of the external air from outside the vehicle takes place due to the air pressure generated by the vehicles movement. The intake vents are located at various places where the air pressure is positive and the ventilation exhaust vents are located where the pressure is negative.



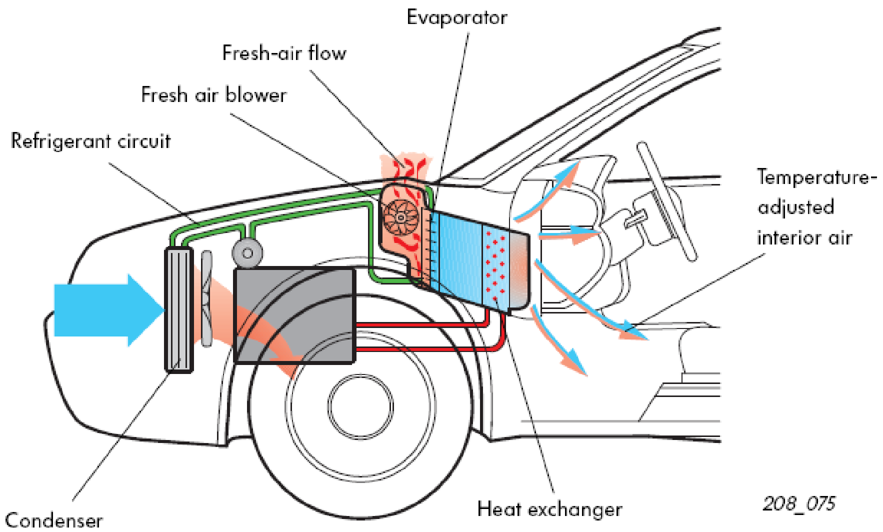


Forced air ventilation

This type of system uses an electric fan to force air through the vehicle. This type of system is common on modern vehicles and is usually featured as part of a heater/cooling system. This type of system often features a pollen/cabin filter. This device can purify the air by removing dust and odour particles from the air.

Temperature control manual

A basic heating/ventilation system features an electric fan used to boost the air flow and a heater unit that is connected to the engines coolant system. The fan speed can be varied by changing the applied voltage at the motor. The



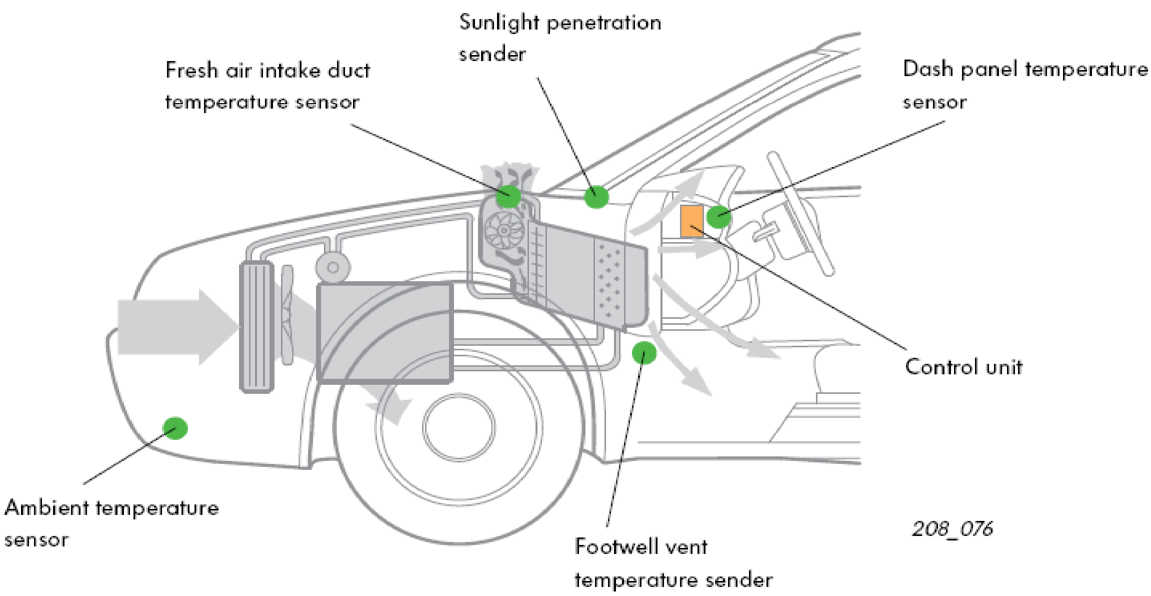
temperature of the air entering the vehicle can be controlled by either mixing hot and cold air together or by controlling the amount of coolant that flows through the heat exchanger (also referred to as the heater matrix).

The fresh air flow is cooled down at the evaporator is pumped into the passenger cabin by the fresh air blower. The air is usually cooler than necessary due to the size of the blower being designed for maximum cooling capacity. To obtain the desired temperature a portion of cold fresh air is ducted over the heat exchanger (matrix) and heated up. The negative side to this is that, temperature fluctuations can also be caused by differing ambient temperatures, road speeds, coolant temperatures and fresh air supplies.

With a manual system the driver has to regulate the temperature control. Regulation is carried out based on the senses of the driver who performs an evaluation based on comfort. The driver has to decide if the temperature is to be adjusted, in what direction and by how much. The driver is the sensor, control unit and actuator.

Temperature control automatic

Automatic air conditioners relieve the driver of having to regulate the cabin temperature. Automatic air conditioners have the advantage that they can include many more parameters in the control system and calculate the thermal result of your adjustment in advance.



Various names are used to describe electronic air conditioner controls:

- Digital temperature control
- Climatronic
- Air conditioner with automatic control

What they all have in common is:

- a control unit
- ambient temperature sensor (one or two)
- interior temperature sensor
- additional senders (not in every system), e.g.
- sunlight penetration sender
- Positioning motors on the heater/air conditioner

The digital control unit is the master station. It processes all input signals from the sensors (information sender), interference-suppresses them and feeds them to the microcomputer in the control unit. The microcomputer calculates the output signals in accordance with the pre-programmed set points. The output signals are fed to the actuators via output stages.

The actuators are the positioning motors on the
Heater/air conditioner. Suitable positioning motors are assigned to the flaps. Air conditioners of the current generation are linked to other vehicle control units either directly or via the CAN-BUS. Information on road speed, on engine speed and on «time parked« are also included in the evaluation of the air conditioner control unit in this way.

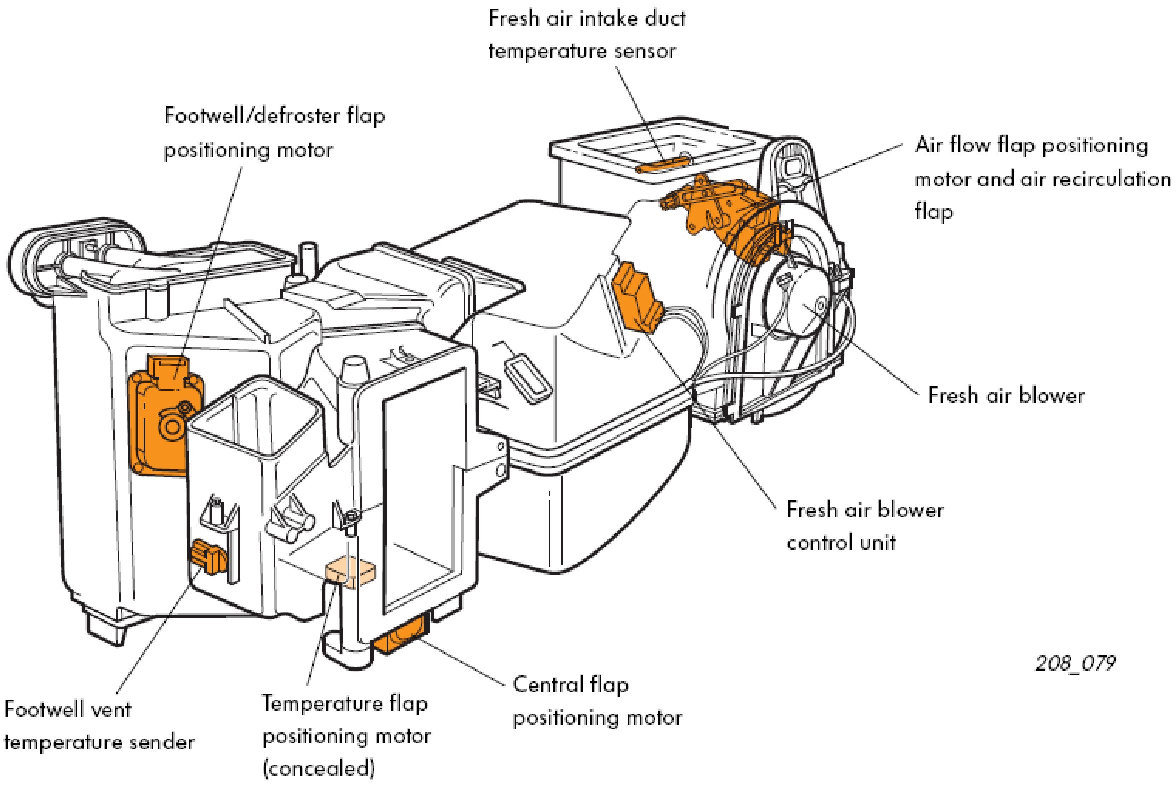
The control unit is combined with the operating and display unit which is adapted to the design of the vehicle. A vehicle interior temperature sensor is also integrated in the control unit.

Function

The control unit receives information from the electrical and electronic components (sensors). These signals are processed by the control unit in accordance with the set points. The output signals of the control unit then control the electrical actuators.

The control unit is equipped with a fault memory. Failure of a component or an open circuit can be detected quickly via the self-diagnosis. No matter what fault occurs, the control unit will remain in operation and maintain the temperature settings in emergency mode.

Sensors and Actuators

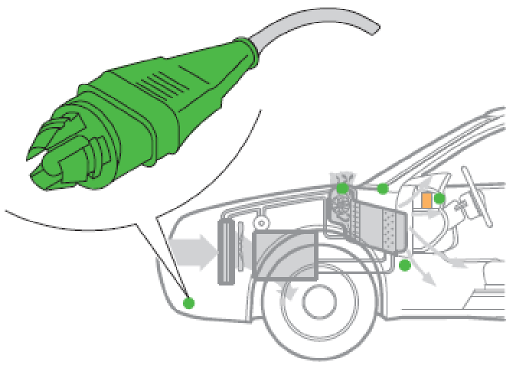


A positioning motor is assigned to each flap for air ducting in the heater/air conditioner. The air flow flap and air recirculation flap are driven by a positioning motor. These flaps are adjusted separately by a driving pulley with two guide rails.
In other systems, the air recirculation flap can also be adjusted by means of vacuum and solenoid valves.
In the diagram above, the fresh air blower and fresh air blower control unit are separate components. However, they can also be combined to a unit.

The main temperature sensors

Ambient temperature sensor

The temperature sensor is positioned in the vehicle front section. It registers the actual ambient temperature.



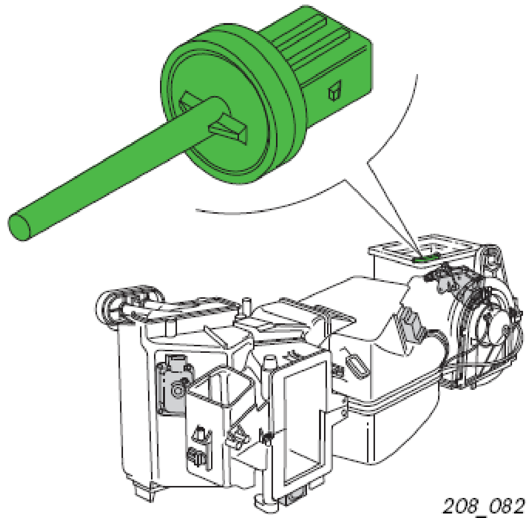
Signal utilisation

The control unit controls the temperature flap
and the fresh air blower in dependence upon the temperature.

Effects of signal failure

If the signal fails, the measured value of the second temperature sensor (temperature sensor in fresh air intake duct) is utilised. If this signal also fails, the system continues to operate by assuming a substitute value of +10 oC. Air recirculation is not possible. The temperature sensor has self-diagnostic capability.

Fresh air intake duct temperature sensor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The temperature sensor is located directly inside the fresh air intake duct.
It is the second actual ambient temperature measuring point.

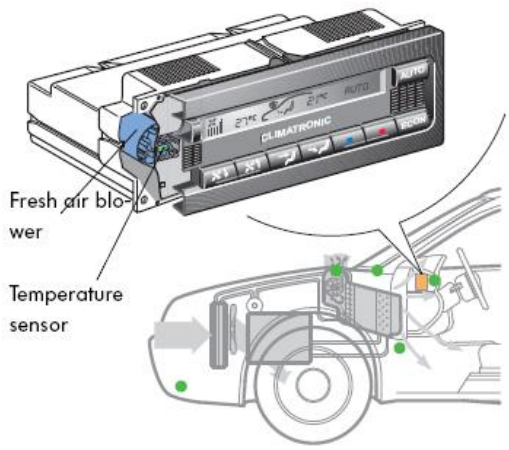
Signal utilisation

The control unit controls the temperature flap and the fresh air blower in dependence upon the temperature.

Effects of signal failure

If the signal fails, the measured value of the first temperature sensor (ambient temperature sensor) located in the vehicle front section is utilised. The temperature sensor has self-diagnostic capability.

Dash panel temperature sensor with temperature sensor blower



The temperature sensor is usually integrated directly in the control unit and transfers the actual interior temperature to the control unit.
It is located in the air stream of a fresh air blower which is used to draw off interior air.
The fresh air blower is activated by the operating and display unit.
It draws off the interior air in order to avoid measurement errors at the temperature sensor.

Signal utilisation

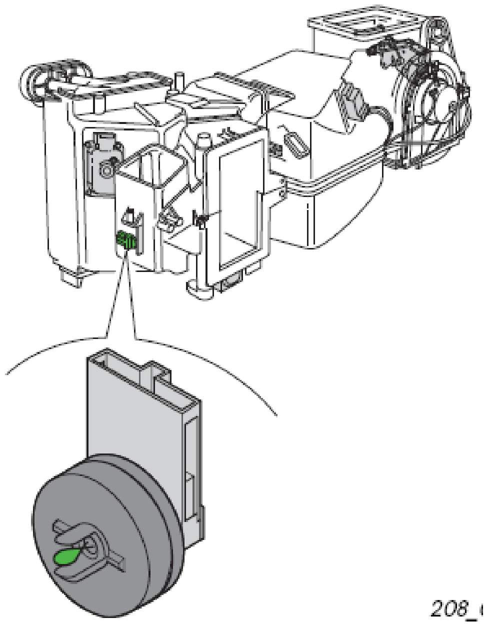
The measured value is used for comparison with the set point. The temperature flap and the fresh air blower are controlled accordingly.

Effects of signal failure

In the event of signal failure, a substitute value of +24 oC is assumed. The system remains in operation. The temperature sensor has self-diagnostic capability.

Foot well vent temperature sender G192

The temperature of the air flowing out of the heater/air conditioner (and into the vehicle interior) is measured. The temperature is registered with a temperature-dependent resistance. The electrical resistance increases as the temperature drops.



Signal utilisation

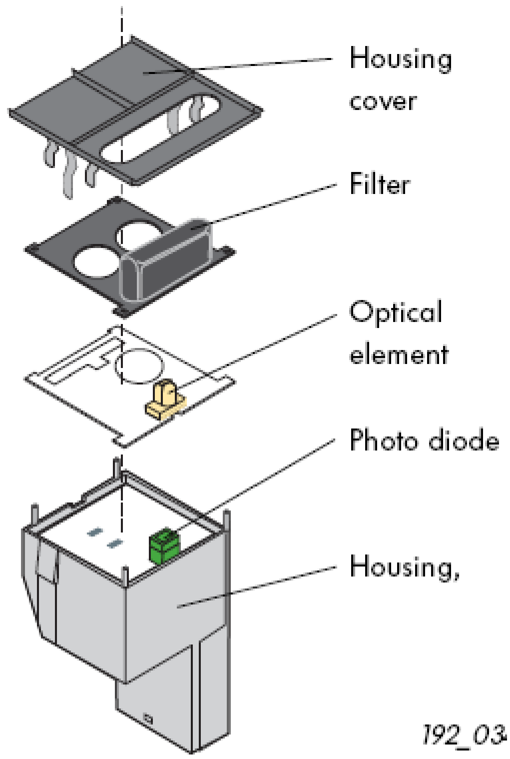
The signal is evaluated by the control unit. The signal is used to control the defrost/foot well air distribution and the volumetric capacity of the fresh air blower.

Effects of signal failure

In the event of signal failure, the control unit calculates a substitute value of +80 oC. The system remains in operation. The sender has self-diagnostic capability.

Sunlight penetration photo sensor

Air conditioner temperature is controlled by means of photo sensors.
They register the direct sunlight exposure of the vehicle occupants.
Depending on air conditioner type, they can measure sunlight penetration via one or two sensors and separately for the left- and right hand sides of the vehicle.



Function

The sunlight passes through a filter and an impinges upon an optical element on the photo diode. The filter functions in much the same way as sunglasses and protects the optical element against UV radiation. Photo diodes are light-sensitive semiconductor elements. When there is no incident light, only a small current can flow through the diode. This current increases when the photo diode is exposed to sunlight. The stronger the incident sunlight, the higher the current. When the current increases, the air conditioner control unit recognises that the sunlight is stronger and regulates the interior temperature accordingly. The temperature flap and fresh air blower are controlled accordingly. In the version with two sensors, the side of the vehicle exposed to stronger sunlight is cooled more

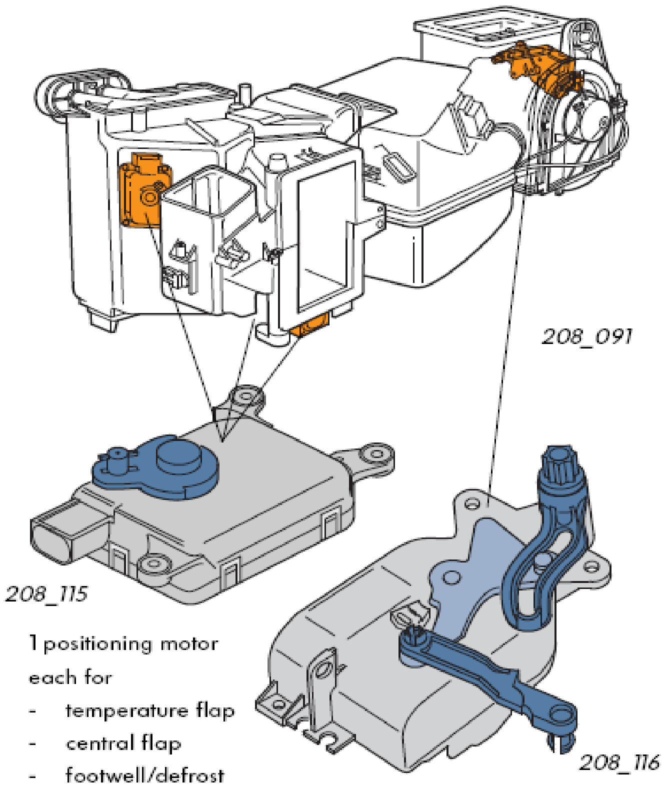
Positioning motor (servo motors)

In a manual air conditioner, air-ducting flaps
Such as:

- the temperature flap
- the central flap
- the foot well/defrost flap

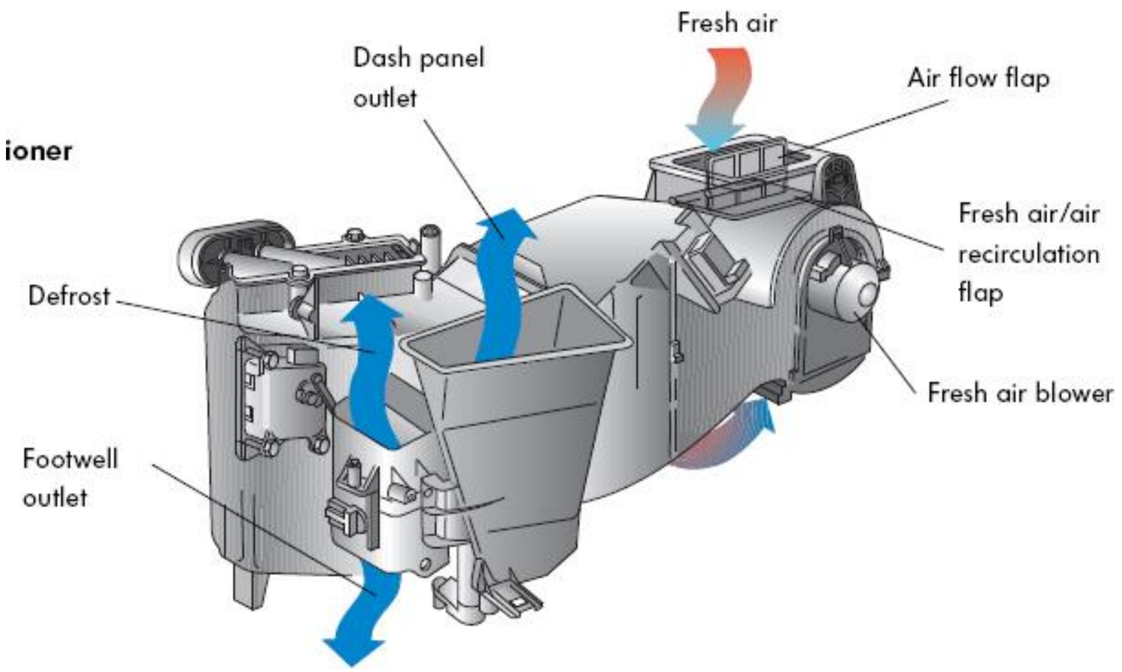
are adjusted individually by the driver by means of Bowden cables.

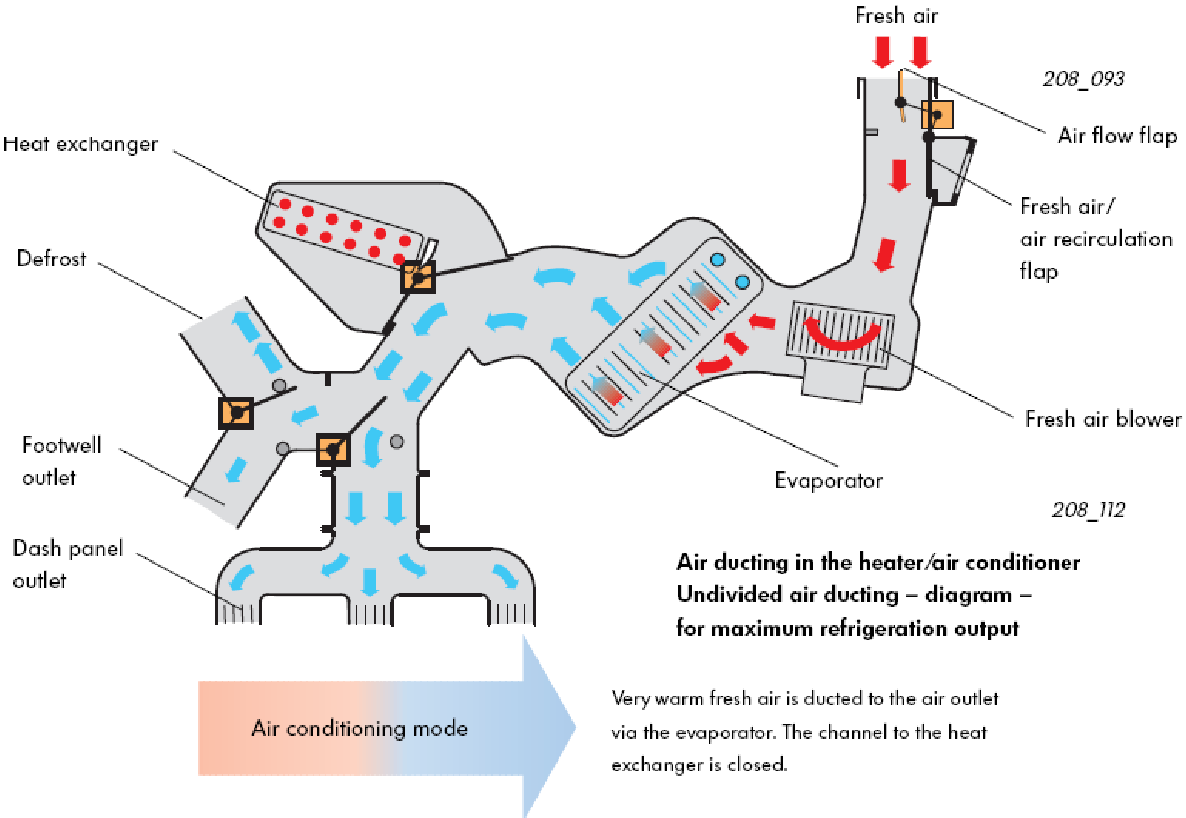
In the automatically controlled air conditioner, the flaps are operated by electrically activated positioning motors. The air recirculation flap is also positioning motor operated. The positioning motors are always positioned level with the flap axis on the heater/air conditioner. All motors receive the corresponding control signals from the air conditioner control unit. Each positioning motor has a potentiometer. The potentiometer signals the position of the flap to the control unit in the form of a feedback value. Thus, the electrical output signals are converted to mechanical quantities by means of positioning motors (actuators).



Positioning motor for fresh air
recirculation flap and air flow flap

Air ducting



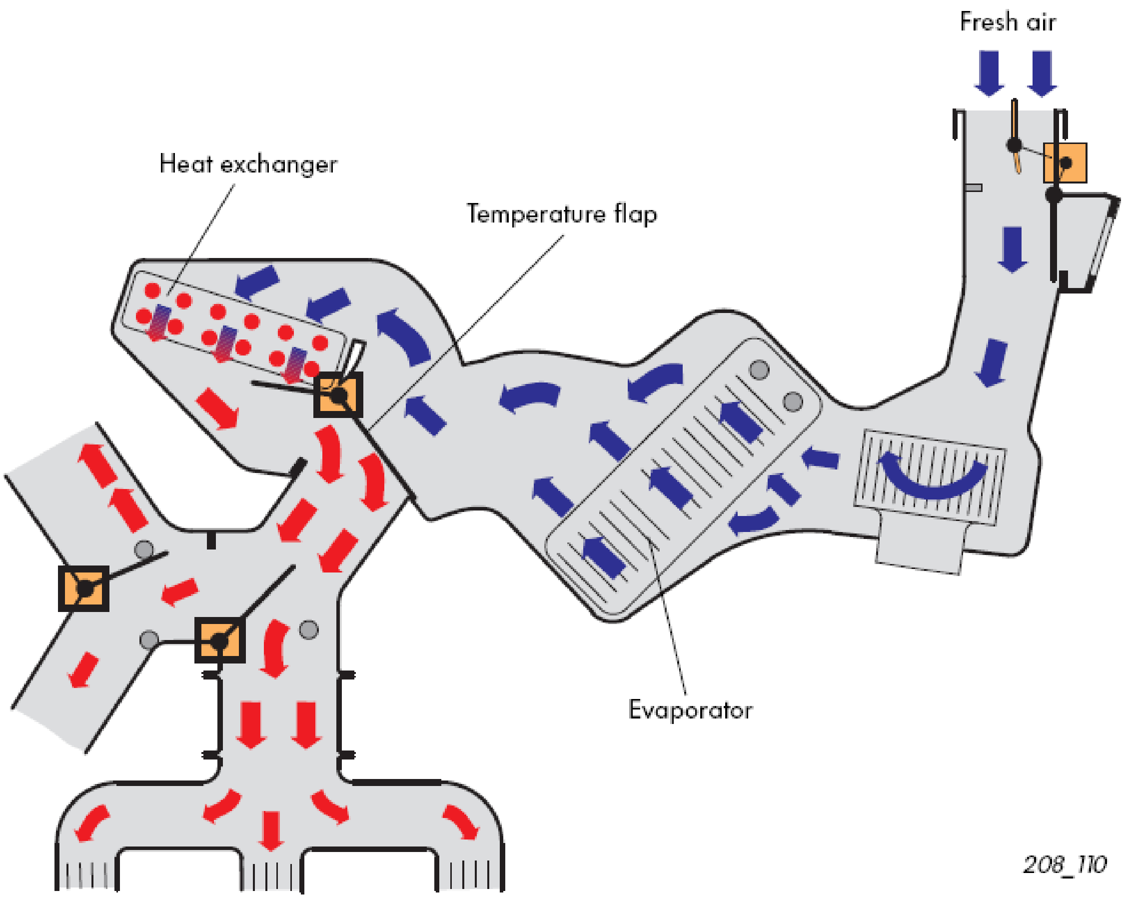


Air ducting in the heater/air conditioner
Undivided air ducting – diagram –
for maximum refrigeration output

Very warm fresh air is ducted to the air outlet via the evaporator. The channel to the heat exchanger is closed.

Air ducting and distribution are always dependent upon the design of the heater/air conditioner and by the required level of driving comfort.
A basic distinction is made between

- undivided air inflow into the passenger cabin
- Divided air inflow for the left- and right-hand sides of the passenger cabin.



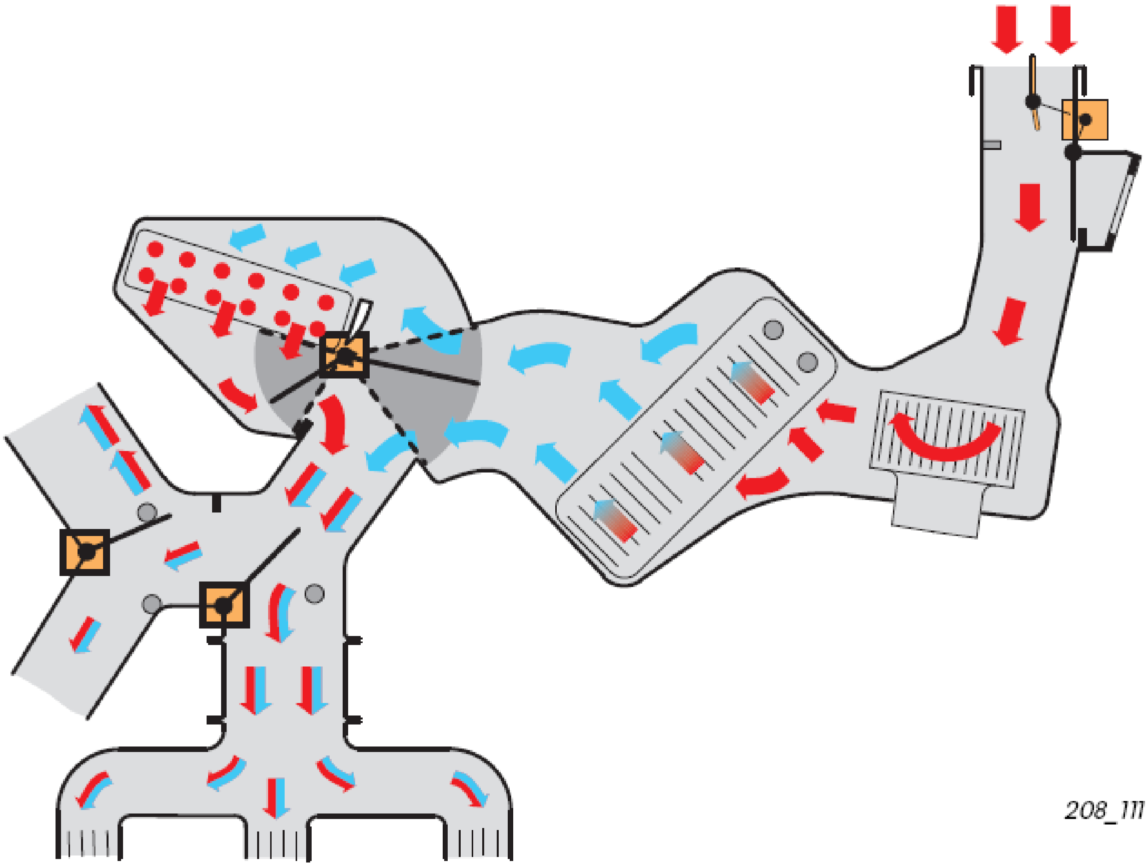
Air ducting in the heater/air conditioner
Undivided air ducting – diagram–
for maximum heat output

All heaters/air conditioners are basically designed as shown in the diagram:

- Air inlet for ambient air
- Air inlet for air recirculation mode (if provided)
- Fresh air blower
- Evaporator (for cooling the air down)
- Heat exchanger (for heating the air up)
- Regulating flaps and ducts for selective air ducting (foot well, defrost, dash panel outlet).

Air conditioner OFF,
heating ON

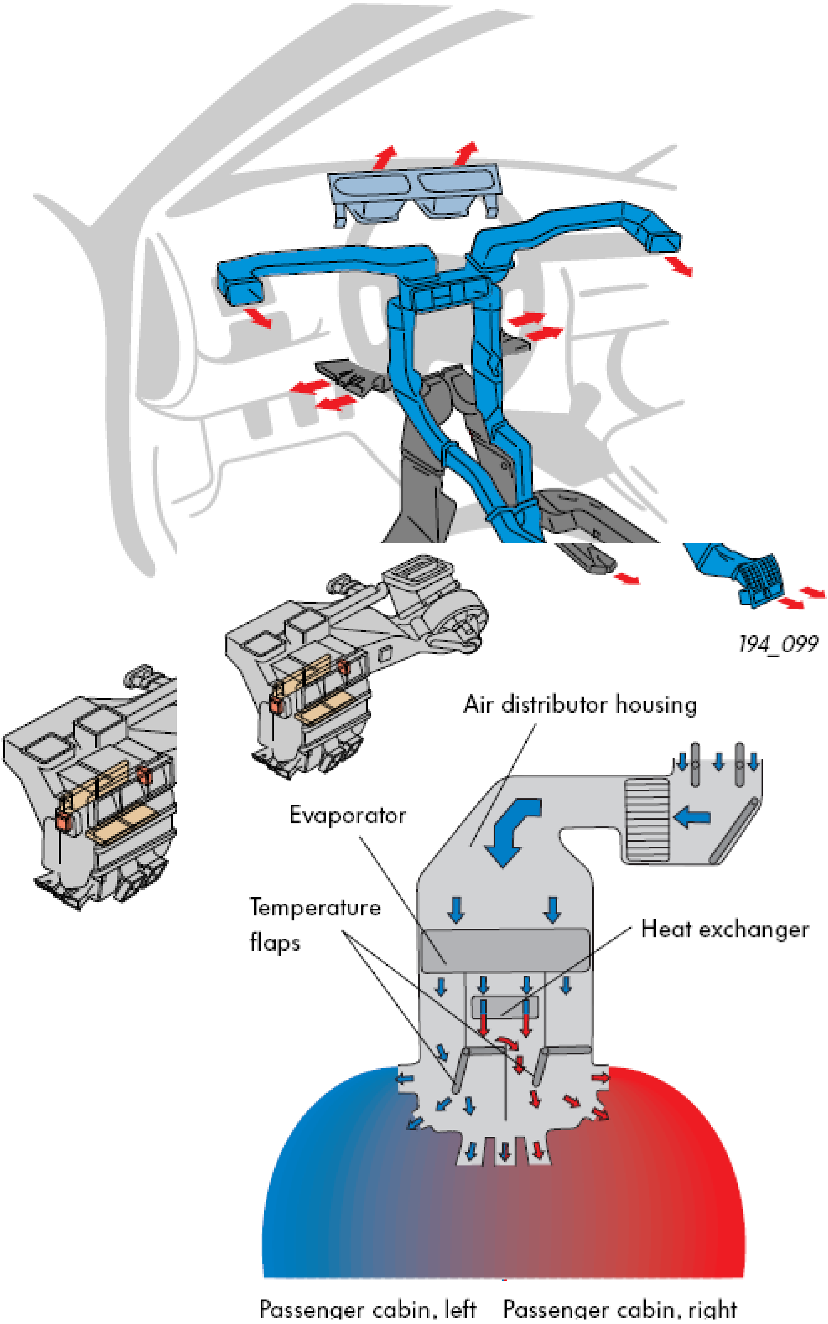
Very cool fresh air flows through the evaporator; evaporator is not working.
Fresh air is passed over the heat exchanger and heated.



Air ducting in the heater/air conditioner
Undivided air ducting – diagram–
for mixed operation

Air conditioner ON,
heating ON

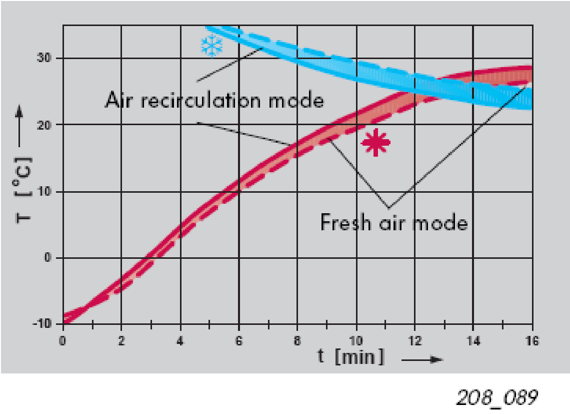
Warm fresh air flows through the evaporator in order to cool down. The fresh air is too cool, therefore a partial air flow is ducted over the heat exchanger in order to attain the individually selected vent temperature.



Air distribution

In this case, air distribution inside the vehicle is regulated by air-side flaps in the air conditioner.
Depending on flap control, the air flow is ducted to the individual air outlets.
All flaps are actuated electrically by the positioning motors.
The flaps are adjusted either automatically according to program flow, or manually at the

Air recirculation



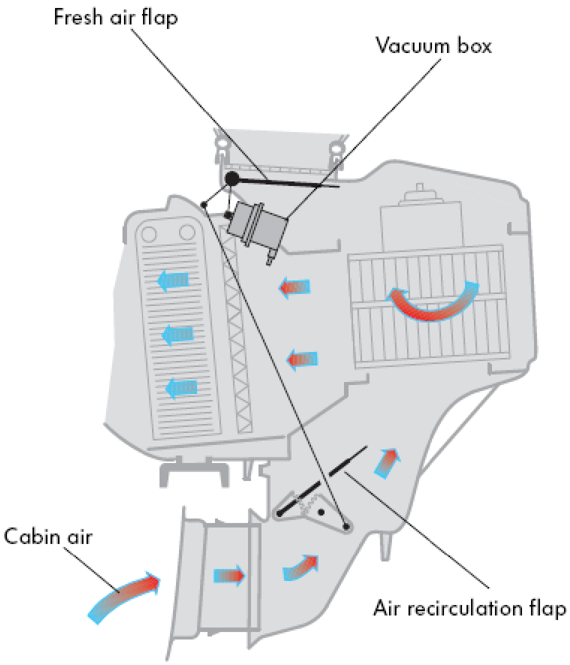
Average values for vehicle temperature reduction/ increase in the air recirculation and fresh air modes

What do we mean by air recirculation mode?

The air conditioner processes two types of air,
namely ambient air and cabin air (air recirculation). In air recirculation mode, the air used for cooling the passenger compartment is not extracted from the outer atmosphere, rather from the vehicle interior. Therefore, the system only recirculates and controls the temperature of the air which is available inside the vehicle.

Why air recirculation mode?

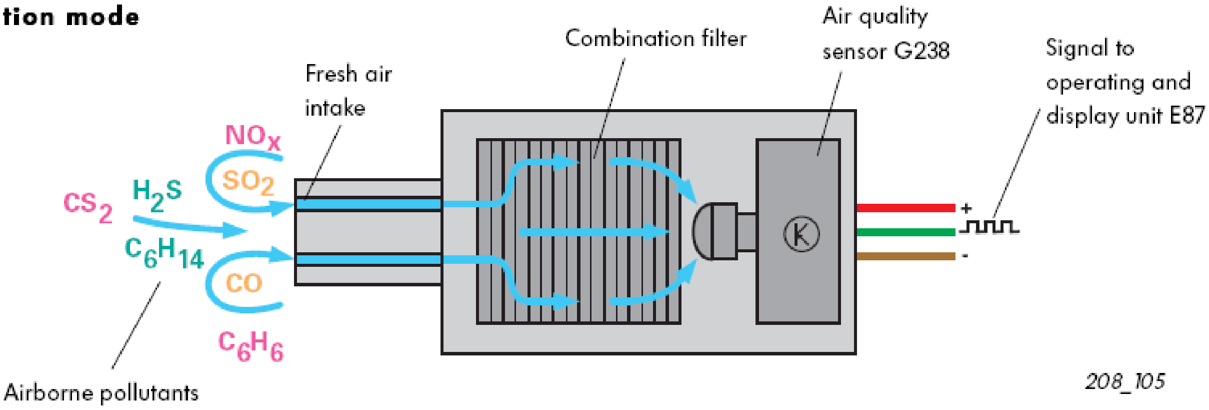
Air recirculation mode is the quickest way to cool down the vehicle interior. This is done by recycling the cabin air, which is always cooler. When heating the vehicle interior, the converse effect occurs, i.e. the air is heated more rapidly. An advantage of air recirculation is that the evaporator output or compressor drive output required is more than halved in air recirculation mode. In addition to rapid cooling/heating, air recirculation mode can be used to avoid breathing in polluted ambient air (unpleasant odours, pollen).



Does air recirculation mode have any drawbacks?

In air recirculation mode, there is no air
exchange. The air will be ‘used up’. Therefore, air recirculation mode should not be used any longer than is necessary, and for no more than 15 minutes. In air recirculation mode, the atmospheric humidity in the passenger cabin rises due to moisture released with the air respired by the occupants. When the dew point of the interior air exceeds the temperature of the windows, the windows will inevitably mist up.

Automatically controlled air recirculation mode



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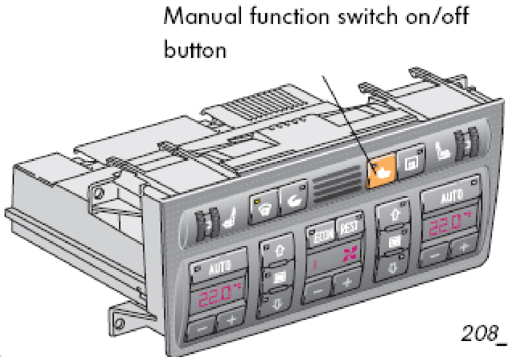
In systems with a manually operated air recirculation mode, the changeover is logically not performed by the driver until an odour nuisance occurs, by which time the air inside the vehicle will have already been fouled.
In systems with an automatic air recirculation mode, the vehicle ventilation system will be closed as soon as pollutants in the air have been detected (by a sensor), i.e. before an odour nuisance occurs. The automatic air recirculation function can be switched on and off manually.



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Operating and display unit with automatically controlled air recirculation mode

The system components

Air quality sensor

An electronic component which is located in the area of the fresh air intake upstream of the combination filter.

Combination filter

The combination filter replaces the dust and pollen filter. It comprises a particle filter containing activated charcoal.

The operating principle

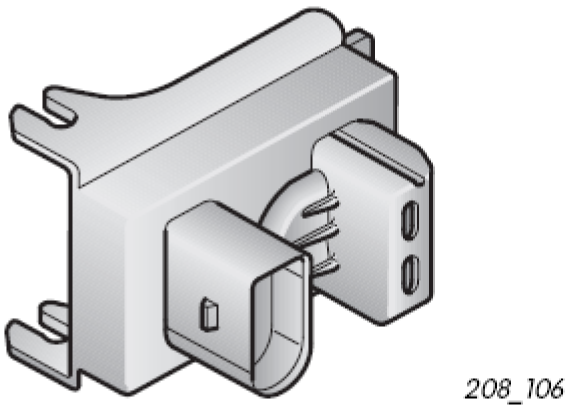
A gas sensor detects pollutants in the ambient air. When a high pollutant concentration occurs, the air conditioner control unit implements the signal which the gas sensor generates by changing over from fresh air mode to recirculation mode. If the pollutant concentration drops below a given threshold, then fresh air is again supplied to the vehicle interior.

Air quality sensor

The sensor operates, in principle, in much the same way as a lambda probe. The metering element is a mixed oxide sensor which uses semiconductor technology (stannic oxide - SnO_2). The sensitivity of the air quality sensor is increased by catalytic additives of platinum and palladium.
The operating temperature of the sensor is approx. 350 oC. Its power consumption of 0.5 watts is very low.

The evaluation electronics in the sensor

The evaluation electronics integrated in the ultrasonic sensor module react to changes in sensor conductivity. High sensitivities are achieved. The system is self-learning. The electronics determine the average pollutant concentration in the ambient air and sends information on the type and quantity of the materials by means of a digital square-wave signal to the air conditioner control unit. The control unit now closes the air recirculation flap at peak pollution levels depending on the ambient temperature and air pollution level. This ensures that the ventilation system does not remain stuck in air recirculation mode in heavily polluted areas. Regardless of the electronic evaluation, several systems switch to air recirculation mode when the wash/wipe system is operated.



Air quality sensor G238