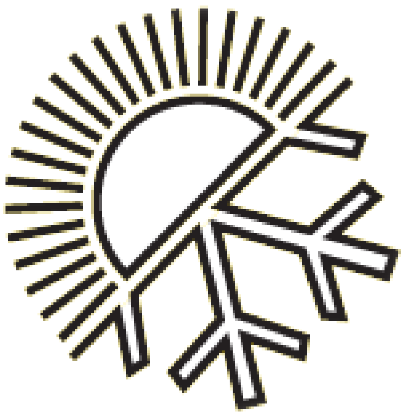
Technician
Service
Receptionist
Body
Specialist

Training Manual

Basic Climate Control

CT-L1005



Introduction

- **A/C** (**A**ir **C**onditioning) has been available for automobiles since the 1930's. Here in Europe in the last five years there has been a large increase in the number of vehicles equipped with A/C. This course does not just cover air conditioning, but also the heating system, hence the name **Basic Climate Control**. The climate control system in a vehicle does not only ensure the comfort of the passengers, there is also a safety aspect. Without a properly functioning climate control system, it might not be possible to keep the windscreen free from misting up during damp or cool weather.
- Mazda uses two different A/C systems on its vehicles; a system using an expansion valve, and a system using a fixed orifice. The components and operation of both systems will be covered.
- The majority of Mazda vehicles currently sold in Europe are equipped with an A/C system. On some models A/C is standard.
- Diagnosing and repairing climate control system related concerns requires working with a refrigerant under pressure. Improper handling of the refrigerant could lead to serious injuries. Follow the safety guidelines both here in this training manual, and in the service literature. This course is a theoretical and practical guide to gain general and Mazda specific knowledge about the different climate control systems, including their components, function, and diagnosis.
- Anyone associated with the diagnosis and repair of climate control systems **must** have the knowledge to deliver a "Fix it right first time" repair. Therefore, the Mazda Masters development and qualification path provides the following training courses required for servicing and diagnosing climate control systems:
  - Basic Climate Control CT-L1005
  - Advanced Climate Control CT-L2009
- The ranking of this course within the Mazda Masters educational system is Level 1 – 'Mazda Technician'. It is intended for technicians who already have experience in maintaining and repairing Mazda vehicles and have previously attended the course "New-To-Mazda" CT-L1001.

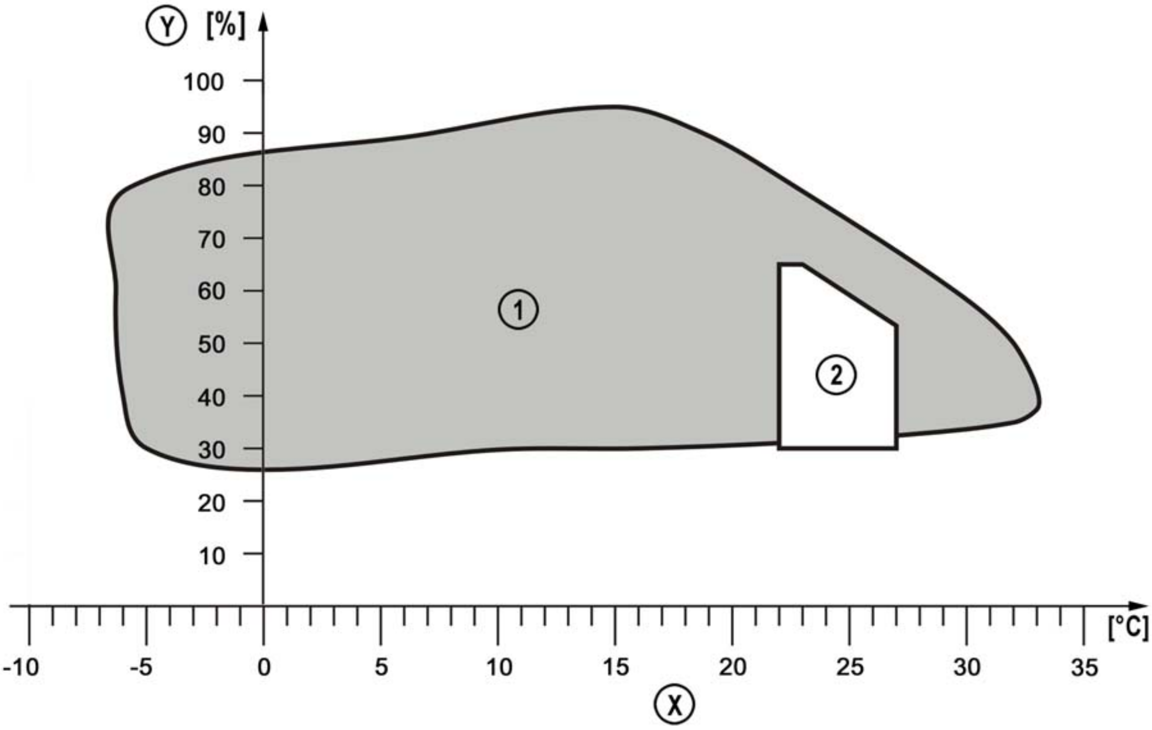
- The training manual “Basic Climate Control” is divided into the following main chapters:
  - Fundamentals
  - A/C System
  - Heating System
  - Diagnosis and Repair

NOTE: The data, tables, and procedures presented in this training manual serve only as examples. They are taken from the service literature and subjected to major or minor changes over the course of time. To prevent any mis-diagnosis, always refer to the current service literature while working on climate control systems.

Fundamentals

Physical Comfort

- When do we feel comfortable? What is comfort? When we aren't comfortable, how can we become comfortable?
- There is a norm that shows where most people find it comfortable based on the air temperature, and relative humidity. There are also other factors not shown on this graph that affect our comfort, such as how clean the air is and if there is an unpleasant draught, or perhaps a pleasant breeze.



L1005_044

X	Temperature	Y	Relative humidity
1	This area represents 90% of all outside conditions	2	This area shows the 'comfort zone'

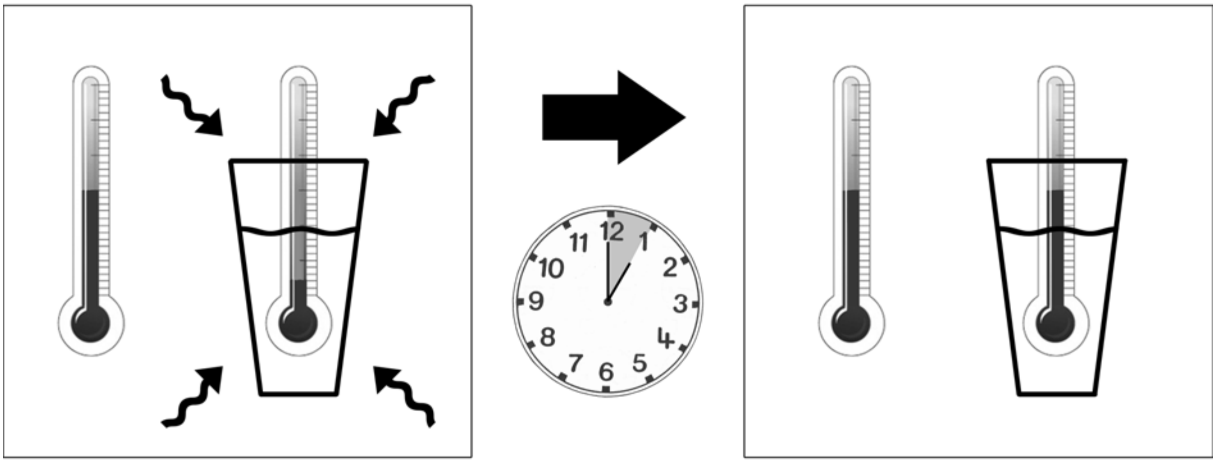
Getting Comfortable

- To change the level of comfort in a building there are several possibilities: open a window, turn on a fan, adjust the thermostat, take some clothes off, or put some clothes on. While it's possible to do all of these things in a vehicle, there are of course practical limitations. When driving in the rain, opening a window becomes impractical. The driver of the vehicle might also find it difficult to keeping taking clothes off, and putting clothes on.
- So a vehicle has a climate control system to allow the driver to create a comfortable climate. To allow the driver to do this it has to be possible to change the two main factors that affect our comfort: temperature and humidity. At the same time the air needs to be cleaned, and the direction and speed of the air stream must be controllable.

Changing the Air Temperature

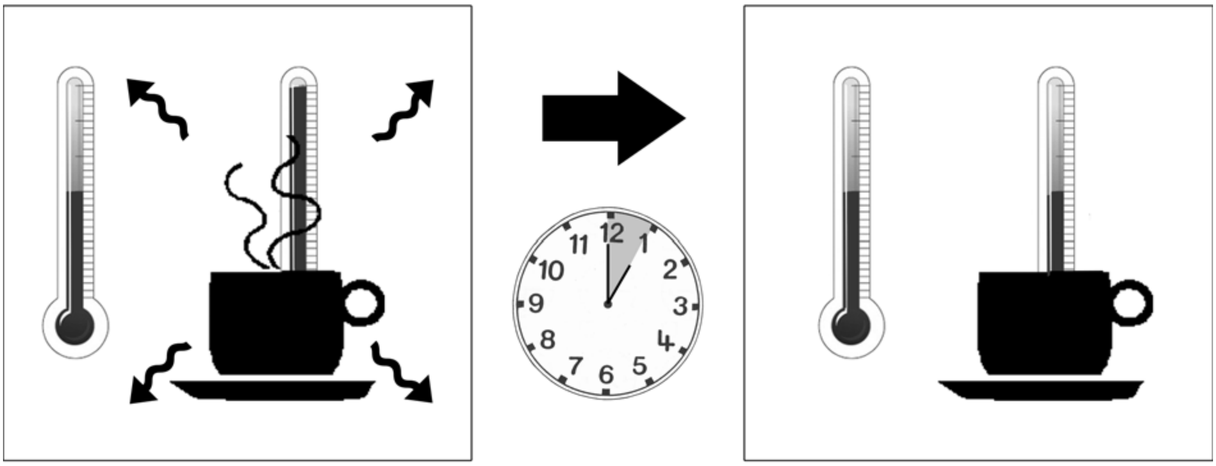
- The air entering the vehicle can be warmed, or the warmth can be taken from it. There is no way to create 'cold'. It is important to keep in mind that **heat always travels from warm to cold**. The two following examples illustrate this fact.

- In the first example a cold glass of water is brought into a warm room. The water will absorb some of the heat from the air in the room, and settle to the ambient temperature of the room. The heat travels from the warmer surroundings to the cooler water.



L1005_001

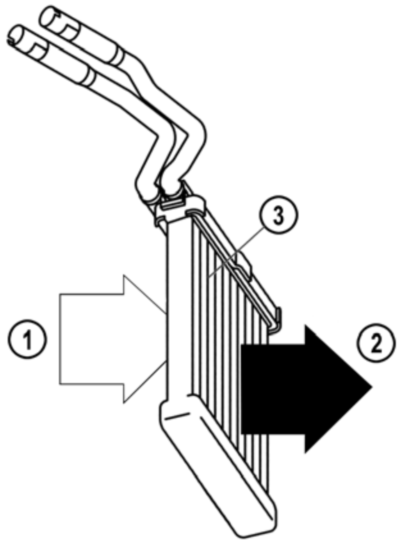
- In the second example a hot cup of coffee is brought into a warm room. The coffee gives off the heat to the air in the room, and will settle to the ambient temperature of the room. The heat travels from the hot coffee to the cooler surrounding air.



L1005_002

Warming the Air in the Vehicle

- To carry the second example across to the vehicle, think of the heater core as the cup of coffee being brought into a relatively colder room. The heater core gives its heat up to the outside air that comes in contact with the fins. The heat travels from the warm heater core to the cold air. Unlike the coffee in our example, the heater core receives a continuous flow of hot coolant from the engine, and so will continue to give off heat as long as the engine is running.

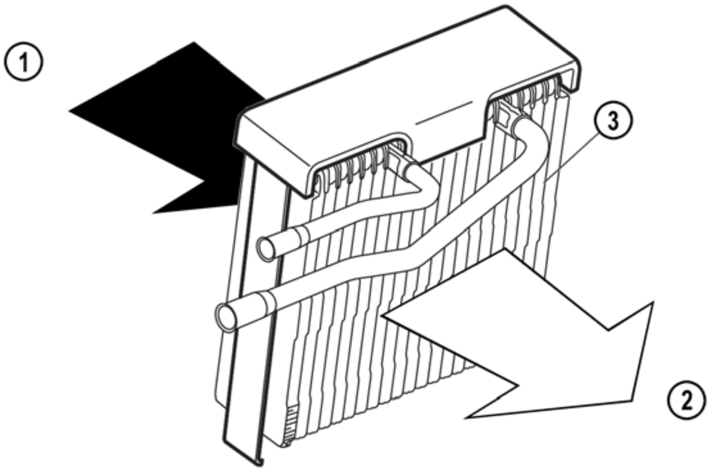


L1005_004

1 Cold air
2 Warm air
3 Heater core

Cooling the Air in the Vehicle

- The example of the cold glass of water can be partially compared to the evaporator. The evaporator is filled with a cold liquid, and this liquid absorbs the heat from the air as it comes in contact with the fins of the evaporator. The heat travels from the hot air to the cold evaporator.



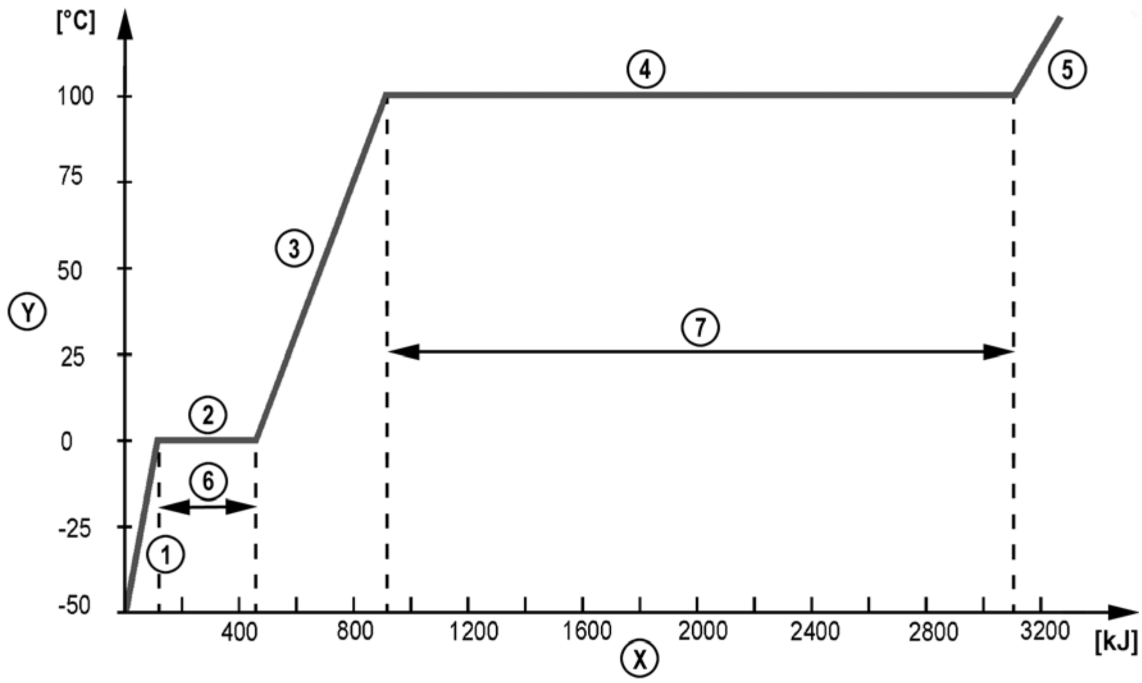
L1005_003

1 Warm air
2 Cold air
3 Evaporator

- This heat absorption process in the evaporator is a little more complicated than the heating process in the heater core. As the refrigerant passes through the evaporator, it is a low pressure, cold liquid. As the warm air comes in contact with the fins of the evaporator, the heat from the warm air is conducted through the metal fins and warms the refrigerant flowing through the internal passageways. This warmth causes the refrigerant to boil. During this boiling process the heat energy from the hot air entering the vehicle is transferred to the refrigerant.
- As the refrigerant leaves the evaporator is will be a low-pressure gas. The heat energy absorbed was used to change its state from a liquid to a gas (to boil it). The end effect for the air is that as it comes out the other side of the evaporator it is now colder. The two physical principles that allow this are the **latent heat of vaporization**, and the **pressure-temperature relationship** properties of the refrigerant.

Latent Heat

- The following graph shows the amount of heat added to 1 kg of water on the horizontal axis, and on the vertical axis shows the temperature of the water. In the first stage the water is frozen, and as heat is added to it, the temperature rises. As soon as the ice reaches 0 °C it starts to melt. At this point all the heat energy is used to change the ice to water; this is called the **latent heat of fusion**.
- Stage 2 shows that even though the entire energy (334 kJ) is added to the ice/water mixture, the temperature does not change. Only when all of the ice is melted, does the temperature start to rise again in direct relation to the amount of heat added (stage 3). This is because the energy added is no longer required to change the ice to water, and now the energy being added increases the temperature.
- At 100 °C the water starts to boil. At this point the temperature stops increasing, since all the energy is needed to change the state from a liquid to a gas. This is known as the **latent heat of vaporization**. This physical property is critical to the functioning of the A/C. Stage 4 shows that the entire energy (2,258 kJ) is absorbed without increasing the temperature of the water/steam mixture. This is the physical property that allows so much heat to be taken from the warm air entering the vehicle.



L1005_022

X	Heat energy	Y	Temperature
1	Ice being warmed	5	Steam being warmed
2	Ice changing to water	6	Latent heat of fusion
3	Water being warmed	7	Latent heat of vaporization
4	Water changing to steam		

Dehumidifying the Air

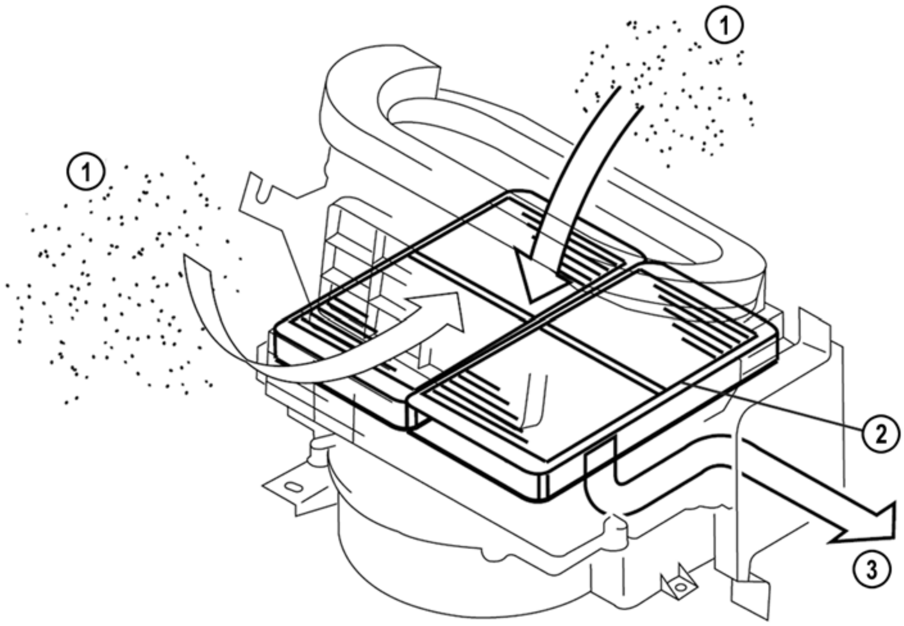
- The air entering the vehicle normally has a relatively high humidity. When this humid air comes in contact with the cool surface of the evaporator the moisture in the air will condense as tiny droplets of water. These water drops will accumulate and run down the evaporator, and leave the vehicle through the drain tube.
- There is no way to actively control how much moisture will be taken from the air, this is determined by the dew point, which depends on the current air temperature and the relative humidity of the air. Operating the A/C allows the evaporator to cool down, and for the moisture in the incoming air to condense. This process can also be performed when heating or defrosting, by turning the A/C on, and then selecting a warmer temperature. This is especially effective when demisting or defrosting.

NOTE: This is the only one of the comfort factors that cannot be directly influenced by the driver. The relative humidity can be indirectly reduced by operating the A/C and forcing the humid air through the evaporator.

Filtering the Air

- A mostly forgotten aspect of our feeling of comfort is how clean the air is. When the air is clean it feels comfortable even at warmer or colder temperatures than normal. Add to that the number of people today suffering from allergies (such as a pollen allergy etc.), and the benefit of a filter can quickly be seen.
- The filter in the **HVAC** (**H**eating, **V**entilation, **A**ir **C**onditioning) system filters both the fresh air and the recirculated air. A certain amount of smaller particles that pass the filter are also trapped in the condensed water, which accumulates on the evaporator.

NOTE: The cabin filters used in Mazda vehicles cannot be cleaned and must therefore be replaced at certain intervals (see the workshop manual). But if a customer drives in dusty areas, or often drives in heavy stop and go traffic, a more frequent change interval might be required.



L1005_009

1 Unfiltered air
2 Air filter
3 Filtered air

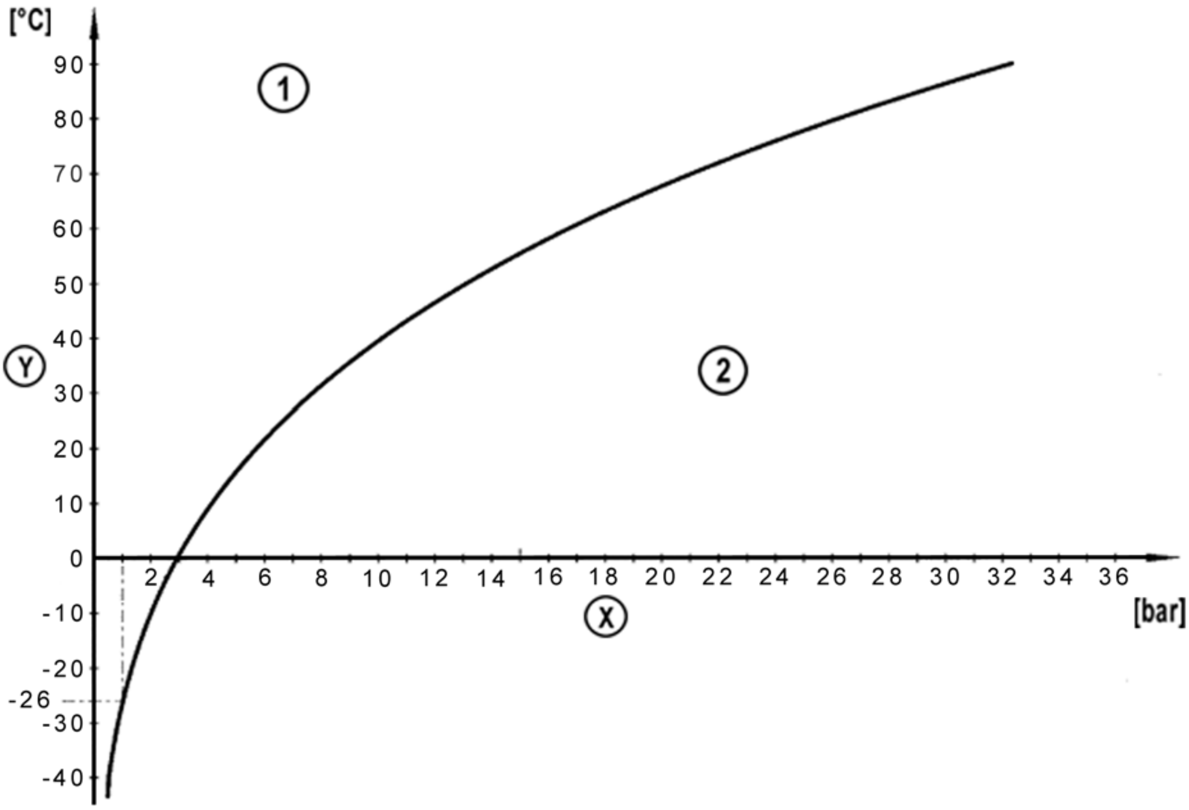
Refrigerant

- The refrigerant used in current Mazda vehicles is called R134a. It is a hydrofluorocarbon ($C_2H_2F_4$) that at normal atmospheric pressure boils at –26°C. This property, combined with the fact that it does not harm the ozone layer, makes it an almost perfect substance for A/C. However, R134a does still contribute to the greenhouse effect.

NOTE: Older Mazda vehicles use R12 refrigerant, which must not be used anymore. In addition, R12 and R134a must not be mixed.

Pressure-Temperature Relationship of R134a

- This chart shows the relationship between pressure and temperature for the refrigerant. At normal atmospheric pressure of 1 bar, refrigerant will boil at –26°C. Above this curve (area 1 in the diagram) the refrigerant is gaseous, below the curve (area 2 in the diagram) it is liquid.



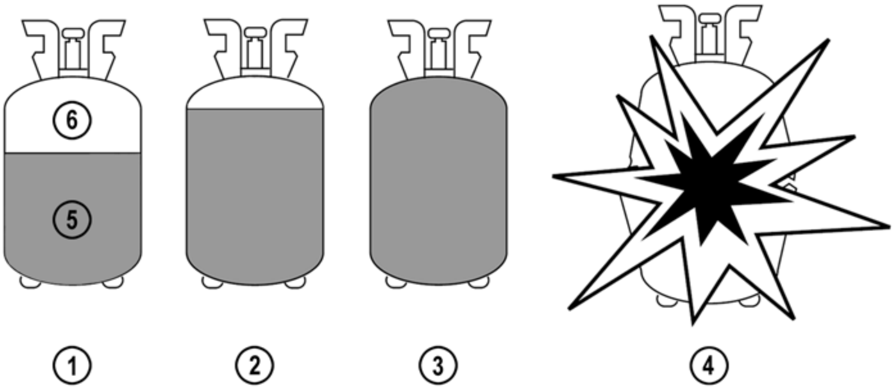
L1005_023

X	Pressure	Y	Temperature
1	Gaseous refrigerant (above the curve)	2	Liquid refrigerant (below the curve)

Refrigerant in a Closed Container

- When R134a is in a closed container, and the container is in a surrounding with an ambient temperature above –26°C, some of the liquid will boil off until pressure is developed. The pressure will be equal throughout the entire container, and the developed pressure will keep a portion of the refrigerant liquid. As the container heats up, the liquid refrigerant will expand in volume. If the container is allowed to warm up to the point where the liquid has expanded to fill the entire volume of the container, the pressure will then increase rapidly, and the container could rupture.

CAUTION: Filling a container more than 60%, and storing a container near sources of heat or in direct sunlight can cause serious injury.



L1005_041

1 Properly filled container
2 Overfilled / overheated container
3 Dangerously overfilled / overheated container
4 Ruptured container
5 Liquid refrigerant
6 Gaseous refrigerant

- In the event of a rupture, the resulting explosion is much more violent than say a comparable rupture with compressed air. The refrigerant leaving the container will be nearly instantaneously vaporized, causing a rapid increase in the volume of the refrigerant. For this reason the containers are delivered with a liquid fill volume of no more than 60% (at 20° C).

Handling Refrigerant

- Because R134a boils at –26°C, if a line is opened while there is refrigerant still in the system, the refrigerant will boil by absorbing heat from the surrounding area. This means that if your hand comes in contact with the refrigerant as it escapes, you will experience acute frostbite (a strong burning sensation). To avoid this, insulated rubber gloves should be worn. Normal cloth or leather gloves provide little protection, as the heat will be absorbed through the material.
- Protective safety glasses should be worn to protect against dirt being blown into the eyes in the event that a high-pressure line is opened.
- The A/C service equipment should be used in accordance with the manufacturers instructions.
- Keep in mind that R134a is heavier than air and will sink to the ground, that means that working in a pit or other low lying area while servicing the A/C is not recommended, because large amounts of released refrigerant could displace the air, and cause suffocation.
- While R134a is not flammable, it could develop into a toxic compound (hydrogen fluoride) when it comes in contact with an open flame, electrical arcing, or a source of extreme heat

Environmental Impact

- R134a is an improvement on its predecessor R12, but it still is harmful to the environment. R134a does not contribute to depletion of the ozone layer like R12 did, but it still contributes to the greenhouse effect. When one gram of R134a is released to the atmosphere, it has the same effect as 1.2 kg of CO_2 being released to the atmosphere. For reference, 1 g of R12 has the same effect as 8.5 kg of CO_2 being released to the atmosphere.
- It should also be kept in mind that any R134a that is released into the atmosphere will, on average, not break down for 14 years. While this is better than the 100 years it takes R12 to break down, it is still not desirable.

Compressor Oil

- The compressor oil in the A/C circuit is required to lubricate the moving parts of the compressor. The oil is carried throughout the system by the refrigerant. The compressor oil is highly hygroscopic **PAG** (**P**oly-**A**lkaline **G**lycol), meaning it easily absorbs moisture (much like brake fluid does).

NOTE: Older Mazda vehicles with R12 refrigerant use mineral compressor oil, which must not be used anymore. In addition, mineral oil and PAG oil must not be mixed.

- The current range of Mazda vehicles all use PAG oils, but there are several different types available. They can have differing characteristics such as different viscosity. For this reason, the different compressor oils are not interchangeable. This means that when servicing a vehicle, the correct oil needs to be put into the A/C system.

NOTE: Compressor oil needs to be properly disposed of just like any other environmentally harmful fluids (brake fluid, engine coolant, etc.). Consult the local authorities to find out if there are special requirements for discarding the oil in your country.

Moisture in the A/C System

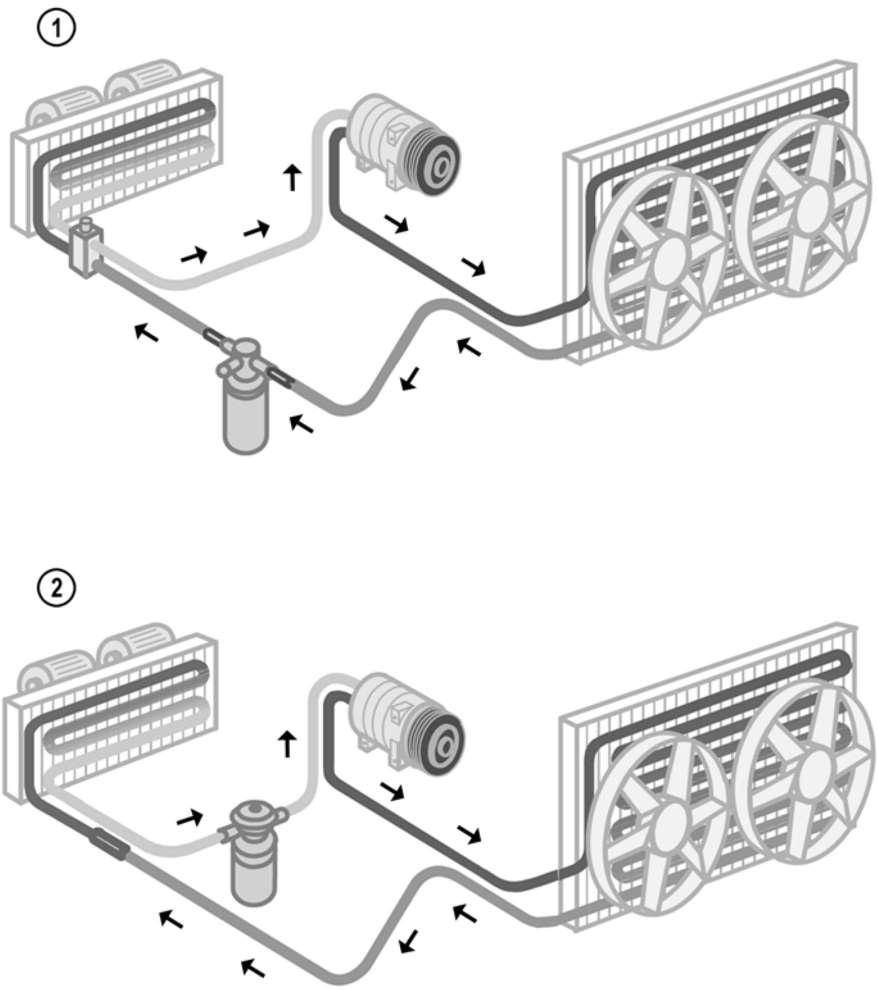
- Water in the closed A/C system is an undesired substance, because it causes corrosion on the system components. The only way that water should be able to enter the system is being transported as moisture in the air. When a system still has refrigerant in it, there is pressure, and there is no way for moisture to enter the system. When a system is opened, and the refrigerant is removed (during service), or the system is open to the atmosphere (as a result of an accident), then it is possible that air enters the system. In the air is moisture, and this moisture can be trapped in the system.

Notes:

A/C System

- There are two different types of A/C systems used on Mazda vehicles. The most common system uses an **expansion valve**. The expansion valve separates the high pressure side of the system from the low pressure side, and throttles the refrigerant bringing it to its coldest temperature. The other system used is the **fixed orifice** system, which has the same function as the expansion valve, but no moving parts. The functions of all components, for both systems, are explained on the following pages.

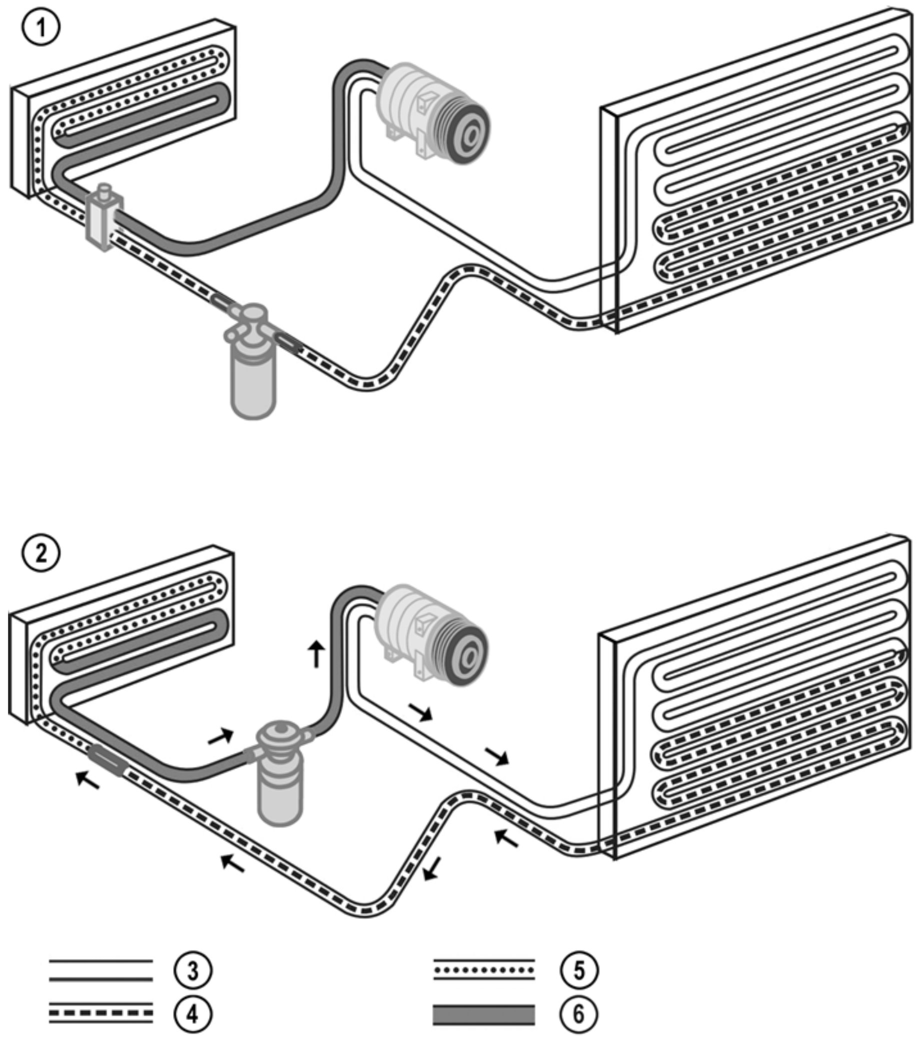
System Overview



L1005_053

1	A/C system with expansion valve	2	A/C system with fixed orifice

- In the A/C system the refrigerant is found in two different states, and two different temperatures. As the refrigerant leaves the compressor it is a warm and high-pressure gas. It then travels through the condenser where the outside air coming in contact with the fins of the condenser absorbs the heat from the refrigerant, cooling it and liquifying it. The liquid then travels to the expansion valve, or the fixed orifice where it is reduced in pressure.



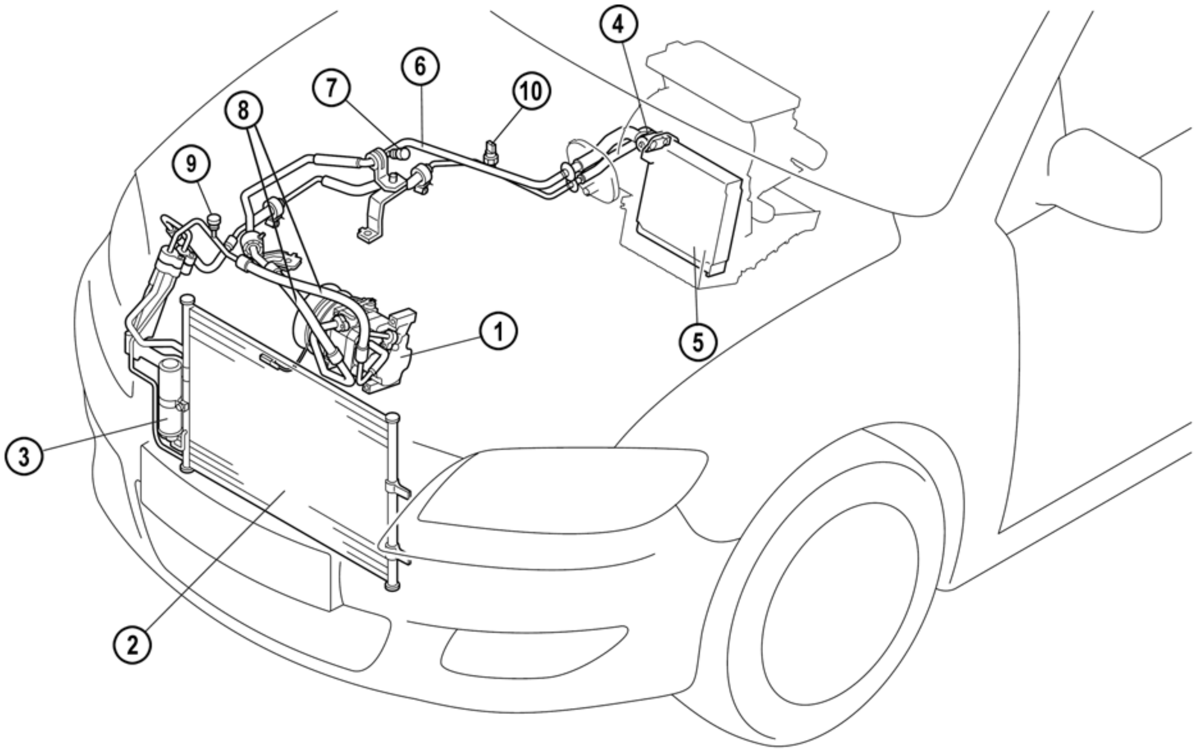
L1005_056

1 A/C system with expansion valve
2 A/C system with fixed orifice
3 High-pressure gaseous refrigerant
4 High-pressure liquid refrigerant
5 Low-pressure liquid refrigerant
6 Low-pressure gaseous refrigerant

- The now low pressure, and even colder refrigerant travels to the evaporator where the heat from the air passing by the fins of the evaporator boils the refrigerant, changing it to a cool low-pressure gas. This gas then moves into the compressor where the pressure and temperature are increased. The cycle then continues.

A/C System with Expansion Valve

Parts Location

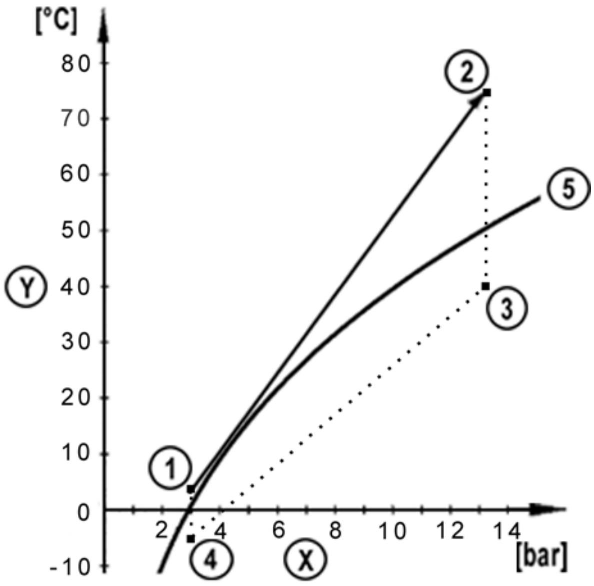


L1005_029

1	Compressor	6	Rigid refrigerant lines
2	Condenser	7	Low-pressure service valve
3	Receiver / Drier	8	Flexible refrigerant lines
4	Expansion valve	9	High-pressure service valve
5	Evaporator	10	Refrigerant pressure switch

Compressor

- The compressor has the task of increasing the refrigerant pressure, as well as circulating the refrigerant through the system. During this process the temperature of the refrigerant rises. To do this it is driven by the engine via a belt. To make sure that the compressor is not driven all the time, and that no unnecessary load is generated, there is a magnetic clutch to decouple the compressor load from the engine (see the section ‘Control’). The compressor is one of the two components that separate the high-pressure side of the A/C system from the low-pressure side.



Compression Plotted on the Refrigerant Curve

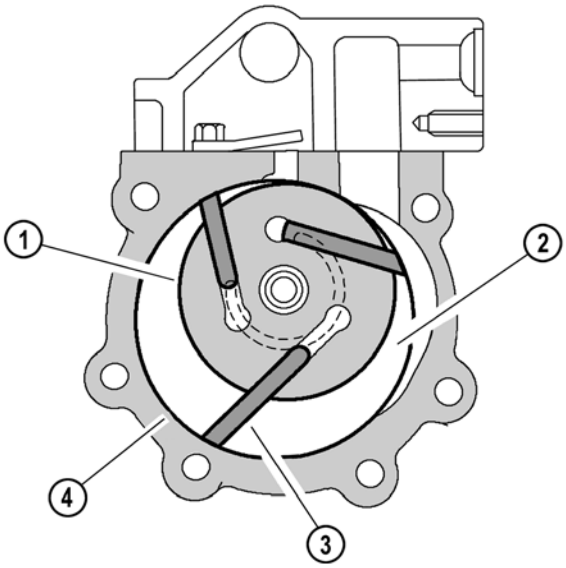
L1005_023a

X	Pressure	Y	Temperature
1-2	**Compression**	4-1	Vaporisation
2-3	Condensation	5	Refrigerant liquid / gas curve
3-4	Expansion		(above is gaseous, below is liquid)

- The compressor is mounted on the engine. To allow for the motion of the engine, the refrigerant lines to and from the compressor are flexible.
- The different types of compressors used in Mazda vehicles are explained on the following pages.

Vane Rotary Compressor

- A vane-rotary compressor has an eccentrically mounted rotor with vanes that are 'thrown' out by centrifugal force to create a seal against the housing. As the rotor moves through its eccentric path, the chamber becomes smaller, compressing the refrigerant.

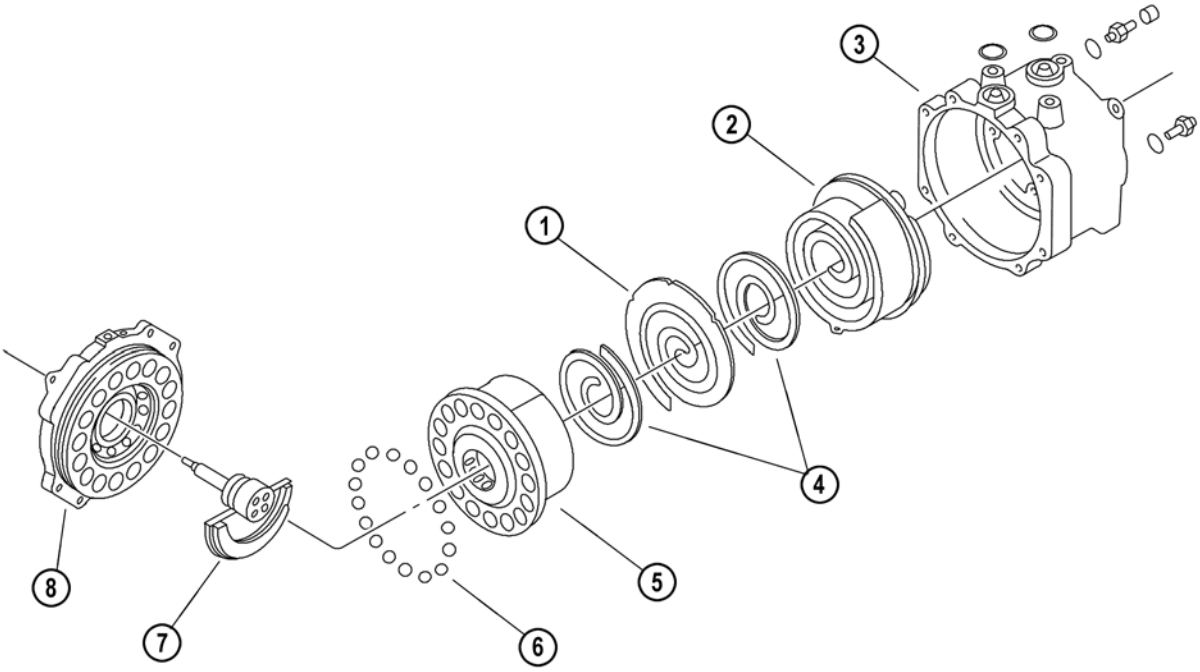


L1005_035

1	Rotor	3	Vane
2	Pump chamber	4	Housing

Scroll Compressor

- A scroll compressor uses a fixed helix, and a moving helix mounted so that the moving helix creates a chamber that draws the refrigerant in, seals the chamber off, and compresses the refrigerant.

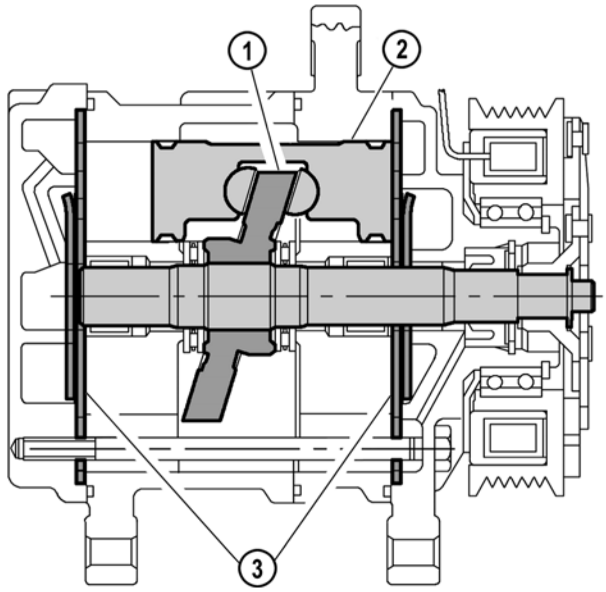


L1005_036

1 Thrust plate
2 Fixed helix
3 Housing
4 Seals
5 Moving helix
6 Ball bearings
7 Driving shaft with counterweight
8 Housing cover

Swash Plate Compressor

- This compressor uses a swash plate, which is mounted at an angle on a shaft. The swash plate moves a number of double acting pistons to draw in and compress the refrigerant. Reed valves control the induction and compression of the refrigerant.

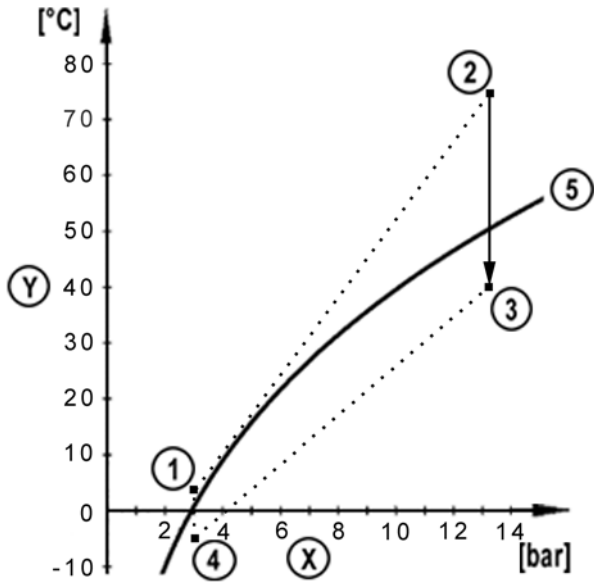


L1005_034

1 Swash plate
2 Double-acting piston
3 Valve plate with reed valves

Condenser

- The condenser receives heated refrigerant from the compressor and reduces the temperature, thereby liquifying it. Refrigerant normally boils at –26°C, but under pressure the boiling point is increased, so accordingly the condensation point is increased. This means that as the relatively cool outside air passes the condenser, it absorbs the heat from the refrigerant, allowing it to change state. As a result, the air passing by the fins of the condenser increases in temperature as it absorbs the heat from the refrigerant.
- The condensation process is plotted on the graph below. Point 2 represents the stage in the A/C system after the refrigerant has left the compressor and before it enters the condenser. At this point the refrigerant is a high pressure, high temperature gas. Between 2 and 3 is the condensation process. Notice that the path crosses below the liquid / gas curve; meaning at point 3 the refrigerant is in a liquid state. It should also be noted that during condensation the pressure does not change.



Condensation Plotted on the Refrigerant Curve

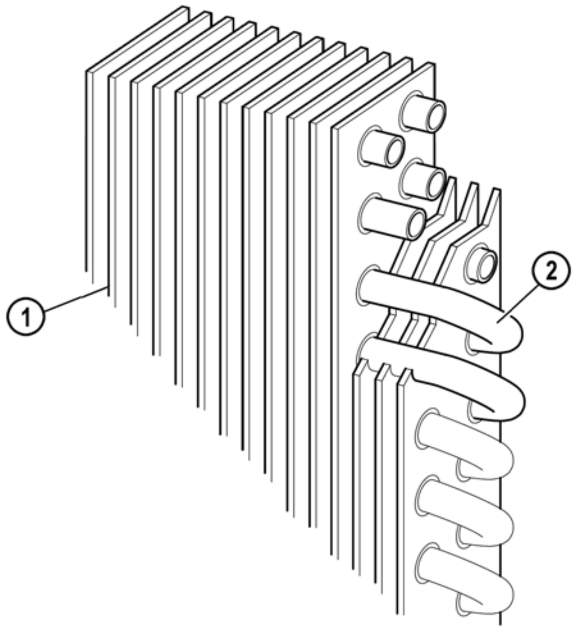
L1005_023b

X	Pressure	Y	Temperature
1-2	Compression	4-1	Vaporisation
2-3	**Condensation**	5	Refrigerant liquid / gas curve
3-4	Expansion		(above is gaseous, below is liquid)

- The three different types of condensers are explained on the following pages. The condensers are all mounted forward of the radiator.

Fin and Tube Condenser

- The refrigerant flows through tubes laid out in a serpentine path. The fins brazed to the tubes increase the transfer of heat from the refrigerant to the ambient air.



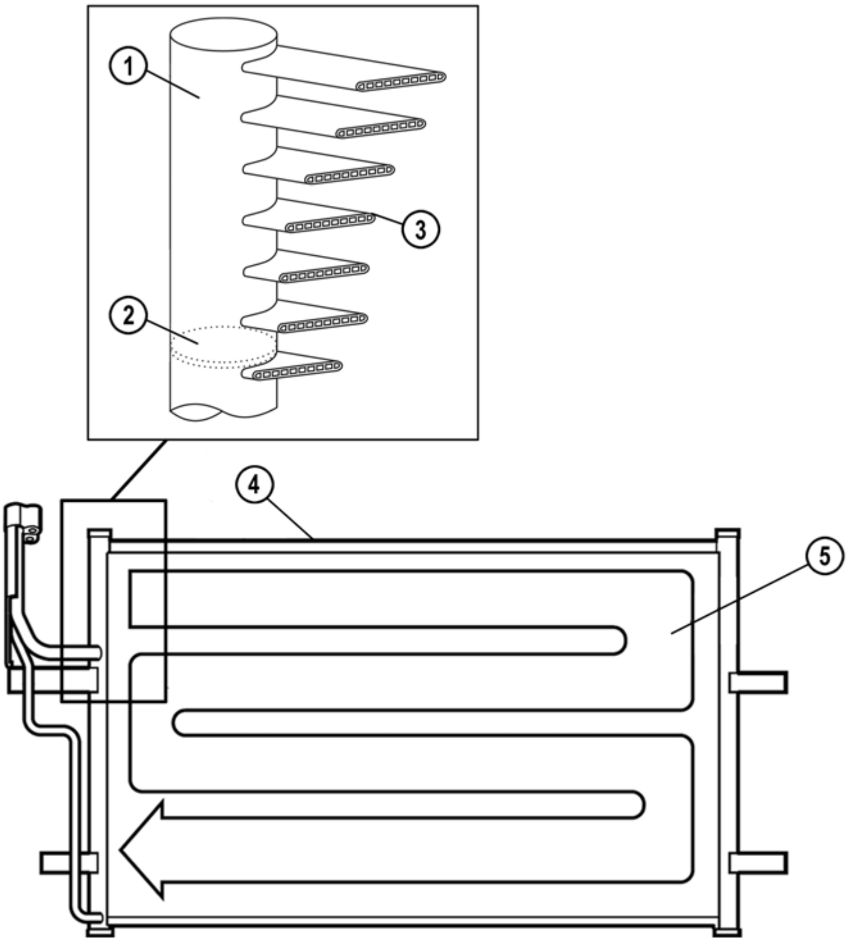
L1005_042

1 Fins

2 Refrigerant tubes

Multiflow Condenser

- The multiflow condenser sends the refrigerant through smaller channels, resulting in more heat transfer than in a fin and tube condenser. In addition, the refrigerant is sent through the condenser in a parallel flow, increasing the cooling performance even more.



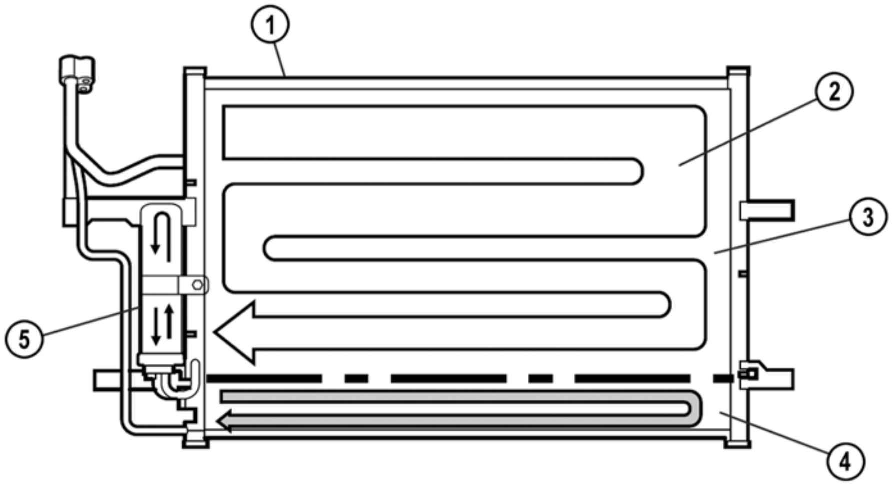
L1005_045

1 Manifold
2 Baffle
3 Multiple channels
4 Condenser
5 Refrigerant Flow

Multiflow Condenser with Sub-cooler

- The multiflow condenser with a sub-cooler sends the refrigerant to the receiver / drier and then back into the lower sub-cooling portion of the condenser. Incorporating the receiver / drier into the condenser ensures that at this last sub-cooling stage (no.4 in the illustration) only liquid refrigerant is being cooled.

NOTE: Depending on the model the receiver / drier cannot be replaced separately, i.e. the condenser must be replaced as a unit.

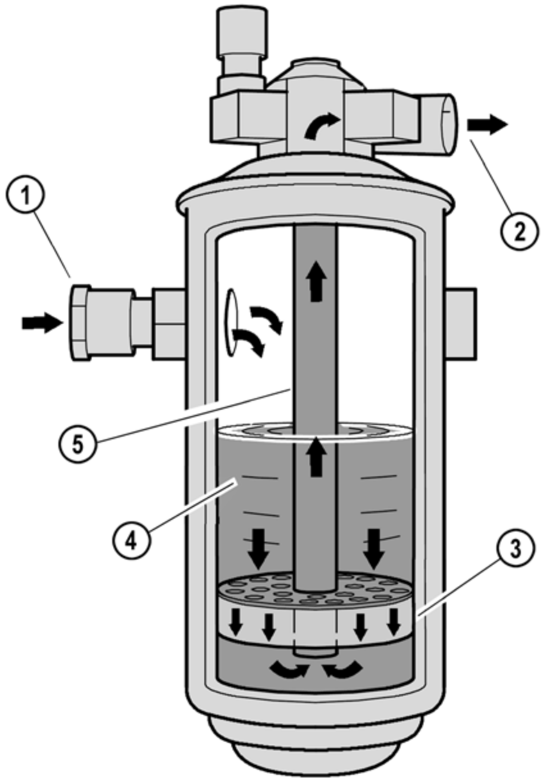


L1005_008

1	Condenser
2	Refrigerant flow
3	Cooling section
4	Sub-Cooling section
5	Receiver/Drier

Receiver / Drier

- The receiver / drier has three main roles in the system. It acts as a reservoir for liquid refrigerant, it makes sure that no gaseous refrigerant travels to the expansion valve, and it removes moisture from the system. In acting as a reservoir, the liquid refrigerant in the receiver / drier helps to compensate when there are changes in the cooling demands, and the amount of liquid refrigerant needed in the evaporator fluctuates. To make sure that there is no gaseous refrigerant passed on to the expansion valve, the liquid refrigerant is drawn from the bottom of the receiver / drier.



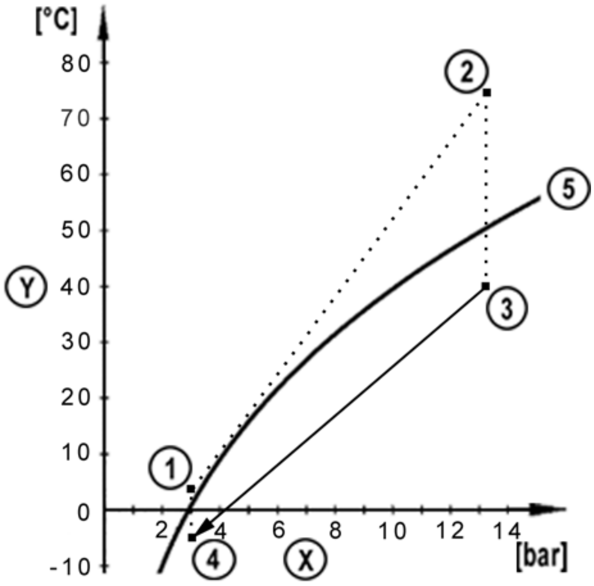
L1005_038

1 Inlet from condenser
2 Outlet to expansion valve
3 Desiccant
4 Liquid refrigerant
5 Refrigerant uptake

- To remove the moisture from the system a desiccant is incorporated into the receiver / drier. The desiccant is a chemical substance that absorbs moisture, but cannot release it. The amount of water that the desiccant can absorb is relatively tiny, since it is primarily there to absorb the unavoidable moisture that enters the system during manufacturing.
- If the system is opened to the atmosphere for an extended period of time (more than 3 hours), the desiccant will be saturated and the surplus moisture will cause the PAG oil to break down. Any water not able to be trapped by the desiccant can also mix with the refrigerant, creating a corrosive acid. The process of moisture absorption is a one-way process; during the evacuation process with the A/C service machine none of the trapped moisture will be removed from the desiccant. When the desiccant is saturated, the receiver / drier will need to be replaced.
- For practical purposes, this means that when replacing components on the system make sure that the system is sealed to avoid the desiccant being saturated with moisture.

Expansion Valve

- The expansion valve is the second barrier between the high-pressure and the low-pressure side of the A/C system (the compressor is the first). The expansion valve throttles the high-pressure liquid refrigerant, reducing the pressure and the temperature of the refrigerant. In acting as a restriction in the system the expansion valve allows the compressor to build up pressure. The expansion valve uses feedback from the temperature of the gaseous refrigerant exiting the evaporator to control the flow rate of the refrigerant through the expansion valve. In this way, the heat absorbing performance of the evaporator is adapted to the actual demand.



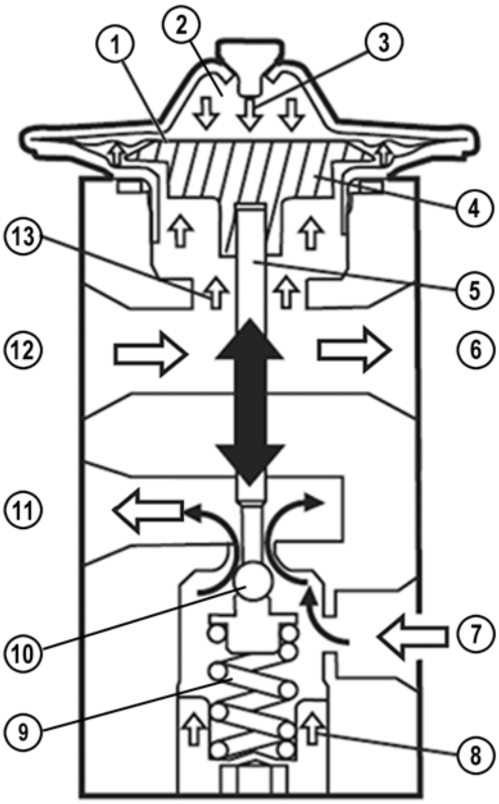
Expansion Plotted on the Refrigerant Curve

L1005_023c

X	Pressure	Y	Temperature
1-2	Compression	4-1	Vaporisation
2-3	Condensation	5	Refrigerant liquid / gas curve
3-4	**Expansion**		(above is gaseous, below is liquid)

- The temperature of the refrigerant leaving the evaporator determines how much the ball valve will open or close. When the refrigerant is cold, the reference pressure will decrease, making the opening smaller, and reducing the amount of refrigerant passed on to the evaporator. There will now be less refrigerant in the evaporator to absorb the heat from the passing air, and the refrigerant temperature will rise.

- This warmer refrigerant will transmit its heat through the heat-conducting element on to the refrigerant in turn causing the reference pressure to increase. This pressure will push on the ball valve, making the opening larger, and allowing more refrigerant to travel to the evaporator. Now there is more refrigerant in the evaporator to absorb heat, and the refrigerant temperature will decrease. Then the process continues.



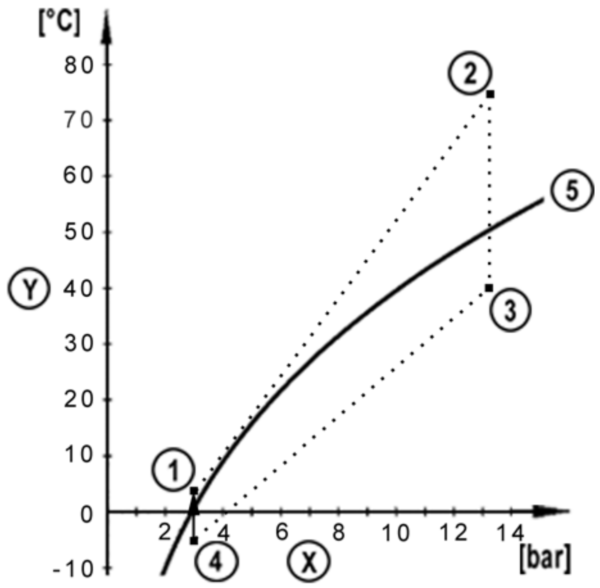
Expansion Valve

L1005_011

1 Diaphragm
2 Reference chamber filled with refrigerant
3 Reference pressure
4 Heat-conducting element
5 Rod
6 Gaseous refrigerant to compressor
7 Liquid refrigerant from condenser (high pressure)
8 Spring force
9 Ball valve
10 Spring
11 Liquid refrigerant to evaporator (low pressure)
12 Gaseous refrigerant from evaporator
13 Evaporator discharge pressure

Evaporator

- The hot air entering the vehicle passes though the fins of the evaporator, and gives its heat up to the refrigerant travelling through the inside of the evaporator. The heat is absorbed by the refrigerant as it changes its state from a liquid to a gas.

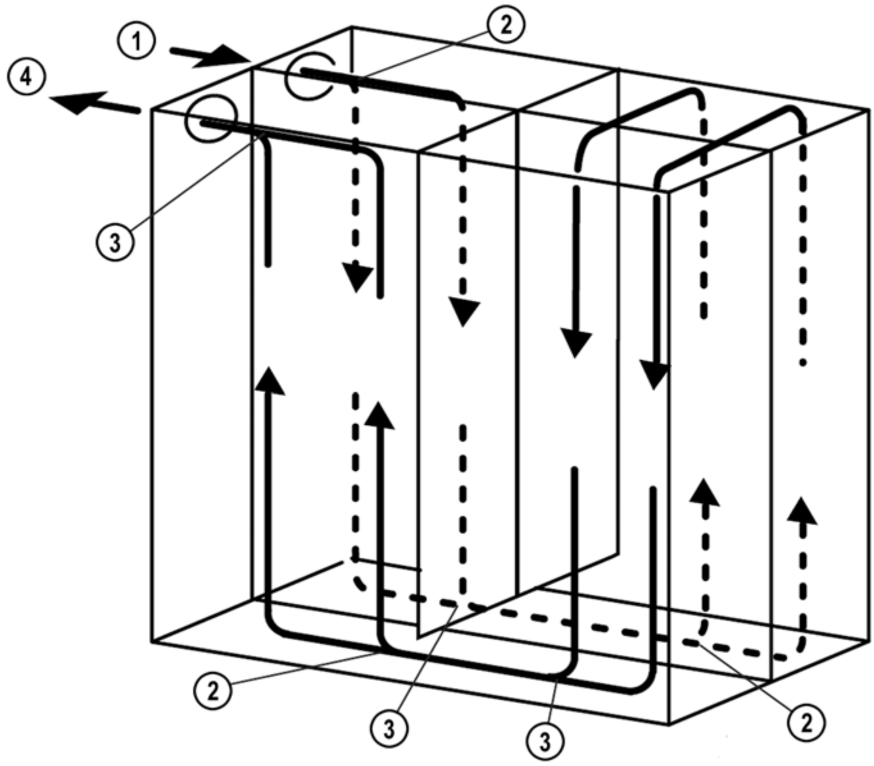


Vaporisation Plotted on the Refrigerant Curve

L1005_023d

X	Pressure	Y	Temperature
1-2	Compression	4-1	**Vaporisation**
2-3	Condensation	5	Refrigerant liquid / gas curve
3-4	Expansion		(above is gaseous, below is liquid)

- The construction of the evaporator is similar to that of a radiator. The refrigerant flows through tubes that have fins attached to them to allow for heat dissipation.



Internal flow of refrigerant through the evaporator

L1005_010

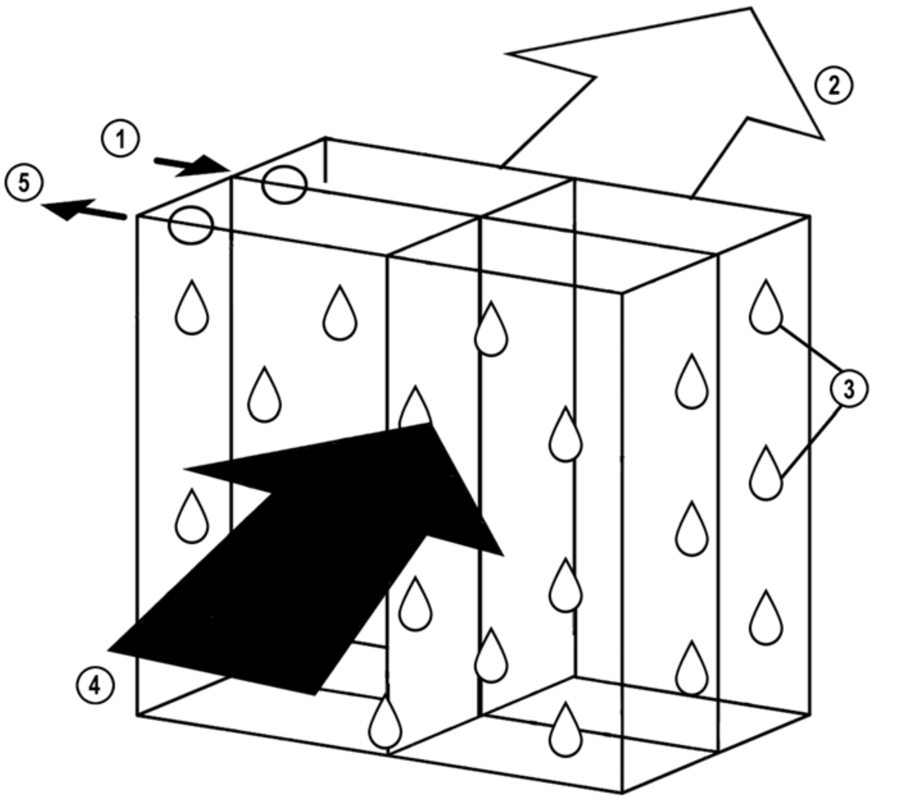
1 Liquid refrigerant from expansion valve

2 Separation point

3 Rejoining point

4 Gaseous refrigerant to compressor

- The condensed water that forms on the surface of the evaporator comes from the moisture in the air passing through the fins of the evaporator. The moisture being removed from the air also has the added benefit of reducing the relative humidity of the air entering the vehicle. The moisture collected on the fins of the evaporator will drain off, and leave the vehicle through the drain tube. It is normal that during operation of the A/C a pool of water may appear underneath the vehicle.
- If the condensed water on the surface of the evaporator does begin to freeze, then it could lead to reduced cooling by restricting the airflow. The evaporator temperature sensor makes sure that the condensed water does not freeze. The function of the sensor is covered in the Advanced Climate Control course.



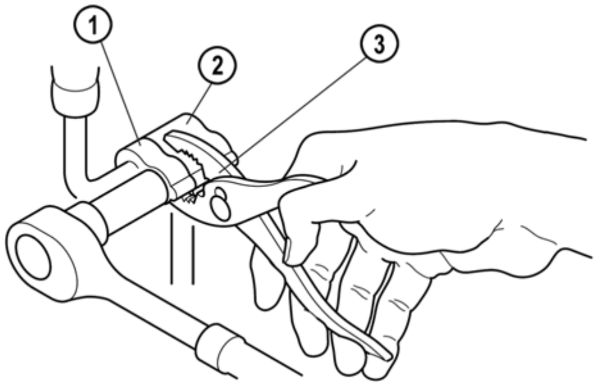
L1005_037

Condensed water forming on the surface of the evaporator

1 Liquid refrigerant from expansion valve
2 Cool dry air
3 Condensed water
4 Hot moist air
5 Gaseous refrigerant to compressor

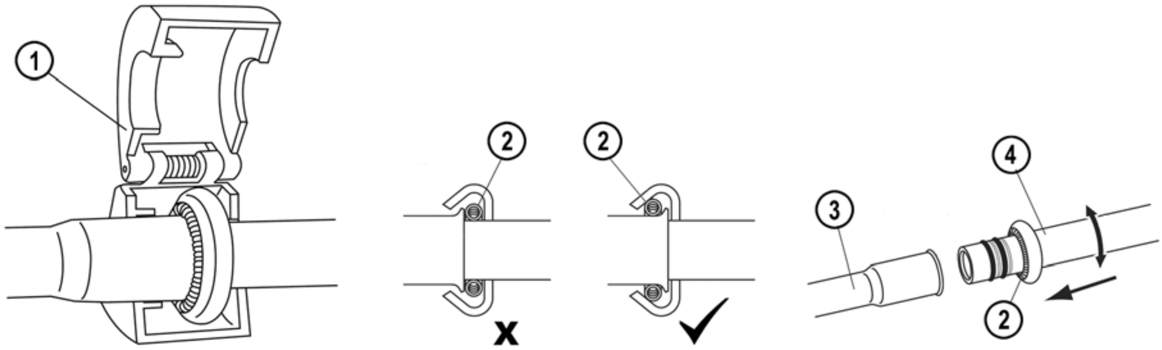
Refrigerant Lines

- The refrigerant lines to and from the compressor are flexible lines; the other lines in the A/C circuit are rigid. Depending on the type of connection, there may be a special procedure or a special tool required.



L1005_026

1 Male side block
2 Female side block
3 Pliers to hold the female side



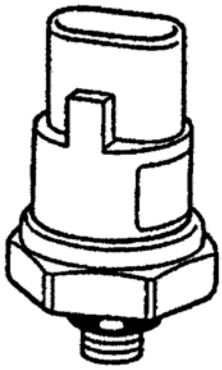
L1005_046

1 Special tool
2 Garter spring
3 Female side connection
4 Male side connection

Control

Refrigerant Pressure Switch

- The triple-type refrigerant pressure switch is located on the high-pressure side of the A/C system, and consists of the low and high pressure switch and the medium pressure switch.



L1005_060

Low / High Pressure Switch

- The low / high-pressure switch protects the A/C system by outputting an A/C cut-off signal to the **PCM** (**P**owertrain **C**ontrol **M**odule) when the pressure in the system is abnormally low or high. The PCM then controls the magnetic clutch through the A/C relay to shut the compressor off in the event of too little or too much pressure in the system.
- When the pressure in the A/C system is either too low or too high, it can cause damage to the rest of the system. For example when the pressure is too low, there will be less refrigerant delivered to the compressor. Because the compressor oil is carried along with the refrigerant, this means that the compressor could be starved of lubrication, and damage could result. When too much pressure develops in the system there could be a rupture in a component (e.g. at a line or a connection). If this were allowed to happen, it might cause injury or damage to other components.

NOTE: The A/C circuit is equipped with a fusible plug to protect the system against excessive pressure (in case the magnetic clutch cannot be disengaged because of a malfunction). If the pressure in the A/C system becomes too high, the plug opens and refrigerant is released to the atmosphere.

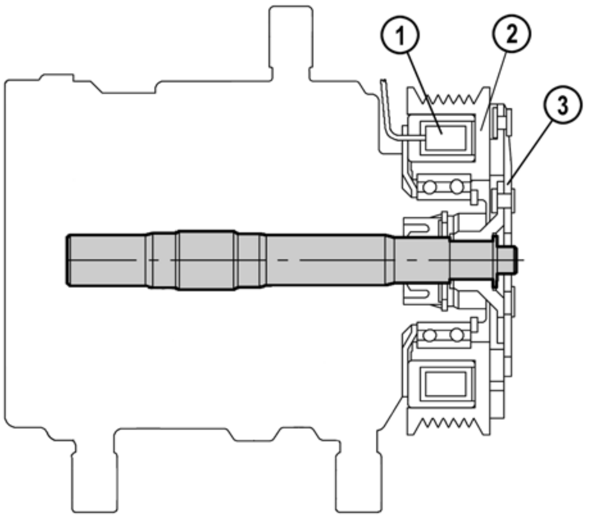
Medium Pressure Switch

- The medium-pressure switch outputs a cooling fan control signal to the PCM depending on the condenser load. The PCM then controls the cooling fan(s) to draw extra air through the condenser in case a higher cooling performance is needed.

Magnetic Clutch

- The magnetic clutch has the task to connect the compressor pulley to the compressor drive shaft. When electrical current flows through the field coil, a magnetic force is created, which pulls the drive plate against the rotating compressor pulley. Consequently, the clutch is engaged and the engine drives the compressor.

NOTE: The magnetic clutch can be replaced independent of the compressor. Care must be taken to ensure the air gap is correct when installing a new magnetic clutch. See the workshop manual for the specific values.

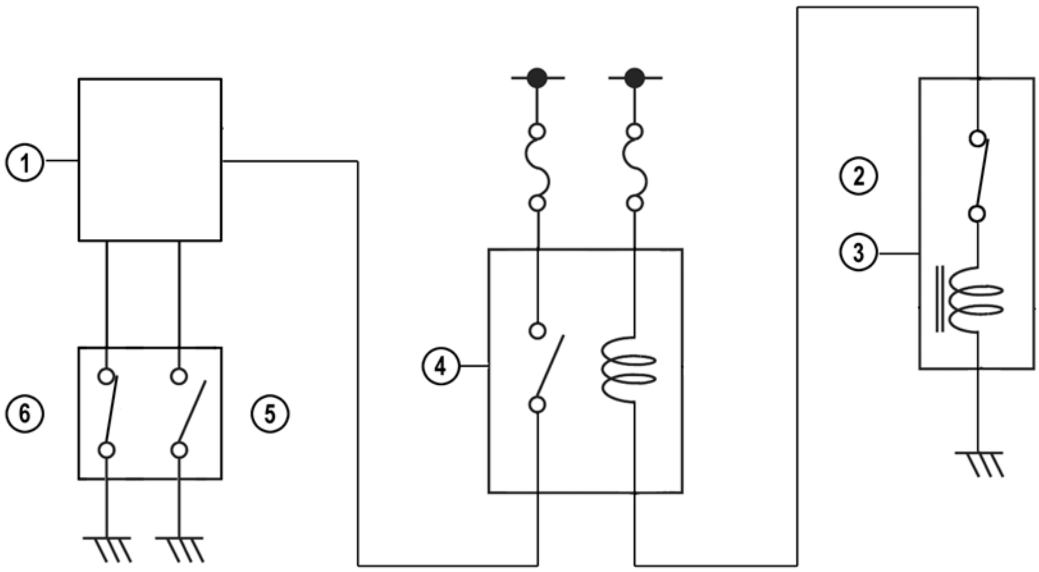


L1005_057

1 Field coil
2 Compressor pulley
3 Drive plate

- Once the driver activates the A/C, the climate control unit sends a signal to the PCM. If the pressure in the system is neither too low nor too high, the PCM in turn energizes the A/C relay that supplies power to the magnetic clutch.
- The PCM uses a variety of signals to determine if the compressor should be turned on. For example under certain operating conditions such as high engine load, high coolant temperature or high engine speed the PCM will not turn the compressor on.
- The magnetic clutch is equipped with a thermal protector switch to protect the compressor against excessive temperature. If the temperature of the compressor becomes too high, the switch opens and the magnetic clutch is de-energized.

Wiring Diagram



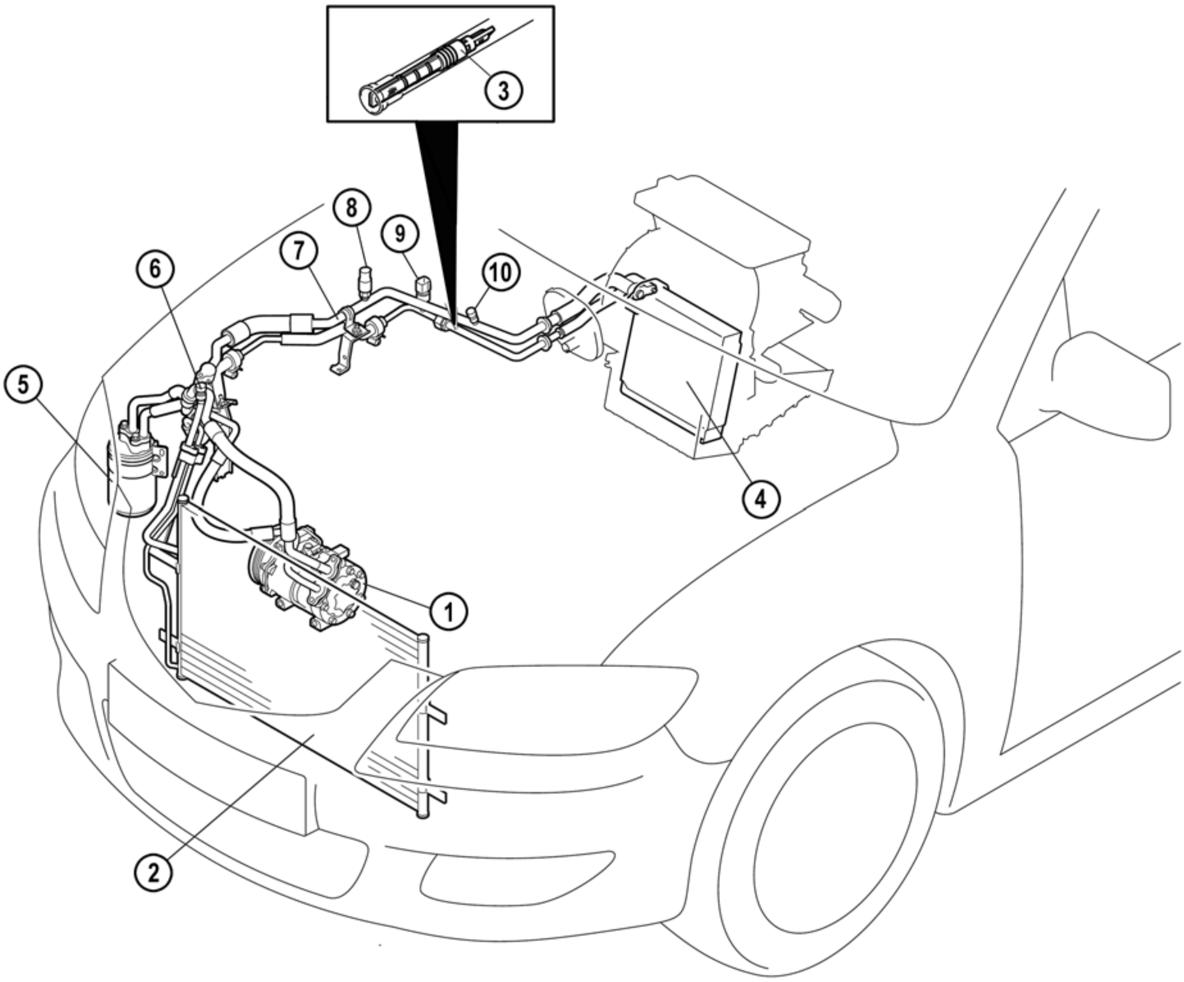
L1005_049

1	PCM	4	A/C relay
2	Thermal protector switch	5	Medium-pressure switch
3	Magnetic clutch	6	Low-/High-pressure switch

A/C System with Fixed Orifice

- This section only describes the components that differ from those found in the A/C system with expansion valve.

Parts Location



L1005_030

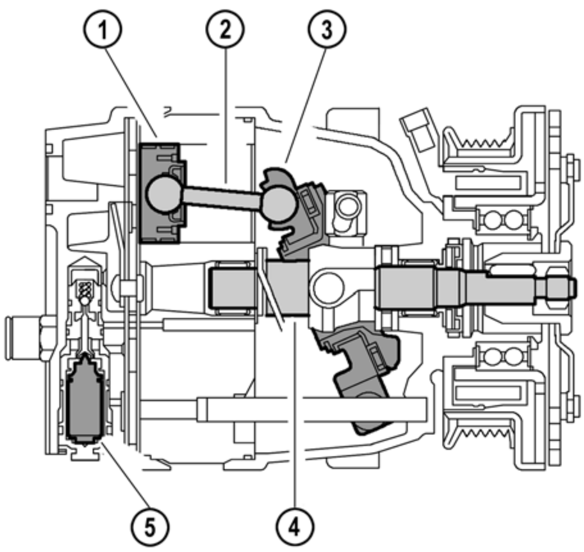
1	Compressor
2	Condenser
3	Fixed orifice
4	Evaporator
5	Accumulator
6	High-pressure service valve
7	Rigid refrigerant lines
8	A/C cycling switch
9	Refrigerant pressure switch
10	Low-pressure service valve

Compressors

- The Tribute is equipped with a swash-plate compressor with fixed displacement, while the Mazda3 Diesel and the Mazda2 use variable displacement compressors. The main difference between both compressor types is that the variable displacement compressor does not cycle on and off during normal operation.

Variable Displacement Swash Plate Compressor

- The variable displacement swash plate compressor functions similar to the standard swash plate compressor described earlier. The two major differences are the variable swash plate and the control valve. The control valve controls the pressure on the rear side of the pistons based on the low and high pressure. The pressure difference between the front and the rear side of the pistons determines the angular position of the variable swash plate and hence the piston stroke. The benefit of this is that the compressor does not cycle on and off under normal operation.



L1005_051

1 Piston
2 Connecting rod
3 Variable swash plate
4 Driving shaft
5 Control valve

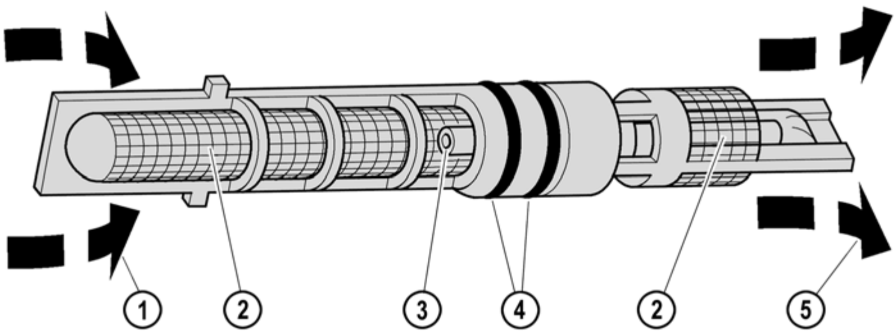
Variable Displacement Scroll Compressor

- The variable displacement scroll compressor functions similar to the standard scroll compressor described earlier. The only difference is an additional control valve that enables the compressor to reduce the delivery to as little as 30% of maximum output. The control valve varies the delivery by passing refrigerant from a chamber between the two helices back to the low-pressure side.

Fixed Orifice

- The fixed orifice has a similar function to that of the expansion valve, except that there are no moving parts. There is no feedback required from the evaporator, so the fixed orifice can be located a bit further away from the evaporator. On the Tribute the flow rate of the refrigerant through the fixed orifice is determined by the cycling of the compressor. On the Mazda2 and Mazda3 Diesel the refrigerant flow through the fixed orifice is controlled via the delivery of the variable displacement compressor. Both times, the heat absorbing performance of the evaporator is adapted to the actual demand.
- The position of the fixed orifice in the refrigerant line can be recognized by the indent in the line.

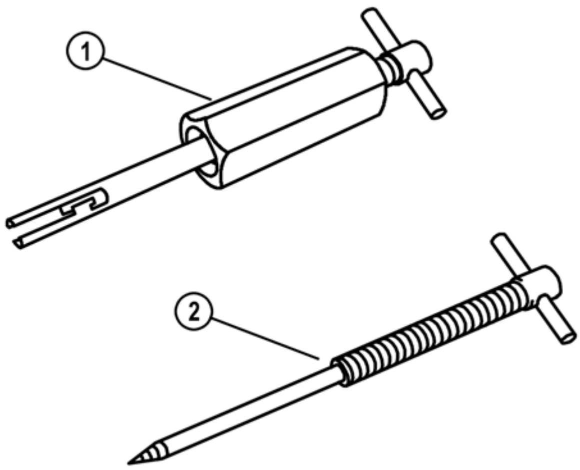
NOTE: The diameter of the fixed orifice varies depending on the model. The fixed orifices for different models can be distinguished by the color of the housing.



L1005_039

1 Inlet: high-pressure warm refrigerant
2 Filter screen
3 Fixed orifice
4 O-ring seal
5 Outlet: atomised low-pressure cold refrigerant

- The tools shown below are required to service the fixed orifice.



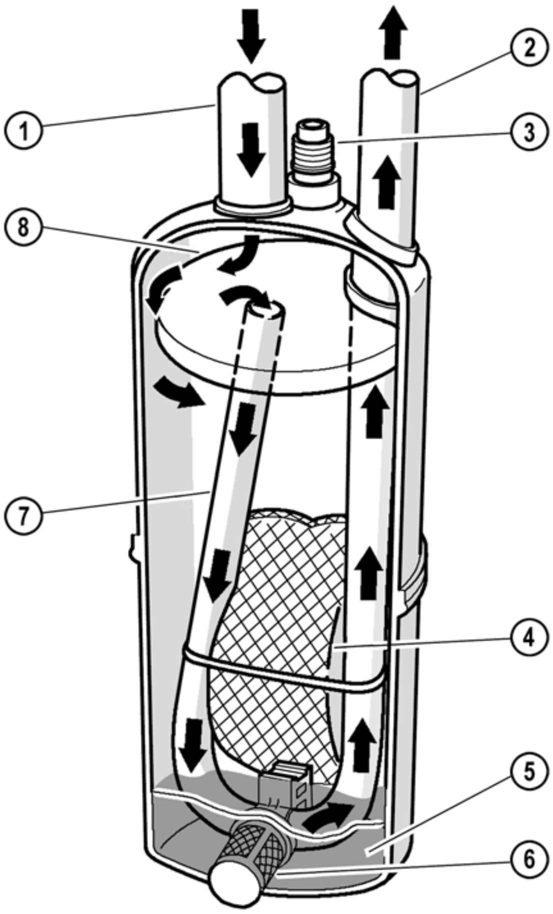
L1005_047

1 Removal and installation tool

2 Damaged orifice removal tool

Accumulator / Drier

- The accumulator / drier serves a similar function to that of the receiver / drier. One difference is the location in the A/C circuit. The accumulator / drier is located between the evaporator and the compressor. Vehicles equipped with a fixed orifice may, under certain operating conditions, allow liquid refrigerant to exit the evaporator. Because of this, the accumulator / drier also functions as a second evaporator to ensure that no liquid refrigerant is passed on to the compressor. For this reason, the gaseous refrigerant is drawn from the top of the accumulator / drier.



L1005_040

1	Inlet from evaporator	5	Compressor oil
2	Outlet to compressor	6	Filter screen
3	Connection for low pressure switch	7	Pick up tube
4	Desiccant	8	Baffle

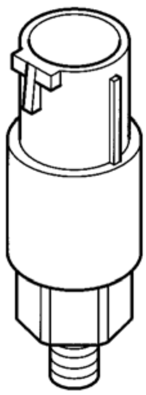
- To move the compressor oil accumulating in the accumulator / drier further along in the system it uses a small orifice in the bottom of the pick up tube. As the gaseous refrigerant moves past this opening, the oil is drawn through the small oil pick up orifice. At the same time the oil is atomised ensuring that it enters the stream of the refrigerant, and is carried along to the rest of the system.

NOTE: Refer to the workshop manual when replacing an accumulator / drier. Depending on the model there may be special procedures required to determine the amount of compressor oil to be added to the new accumulator / drier, such as draining the compressor oil from the old accumulator / drier.

Control

A/C Cycling Switch

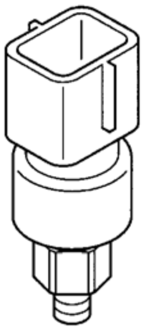
- The A/C cycling switch is located on the low-pressure side of the A/C system and detects the discharge pressure of the evaporator. The PCM processes the signal of the A/C cycling switch and controls the operation of the A/C compressor accordingly, so that the evaporator surface temperature is maintained slightly above freezing. This compensates for the fact that the system has no evaporator temperature sensor.
- In addition, the A/C cycling switch prevents operation of the A/C compressor when the pressure in the system is abnormally low.



L1005_059

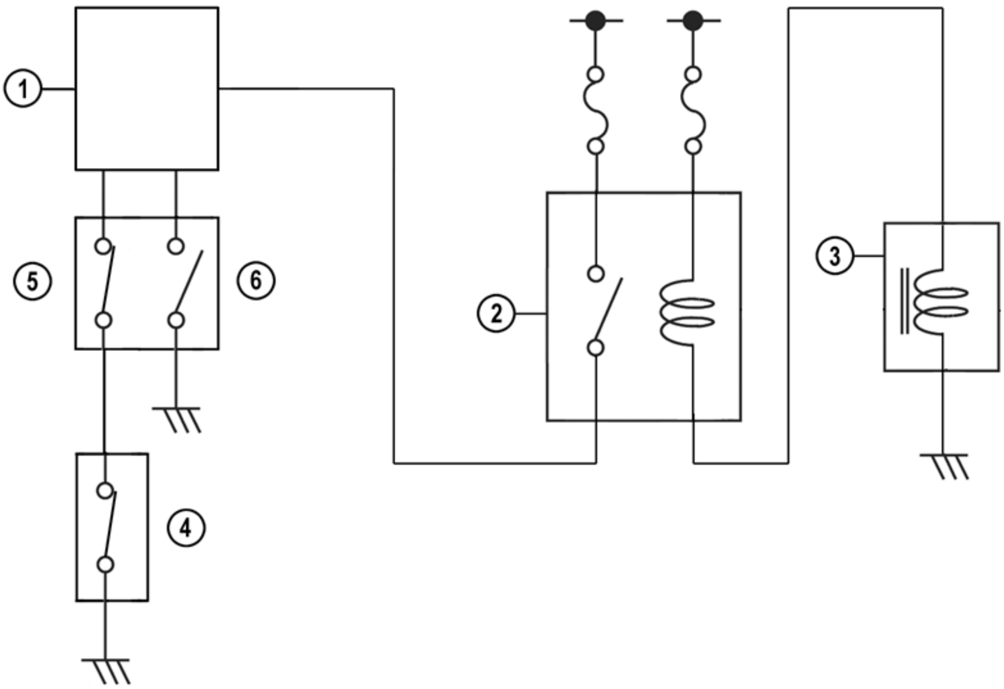
Refrigerant Pressure Switch

- The dual-type refrigerant pressure switch is located on the high-pressure side of the A/C system and consists of a medium- and a high-pressure switch. The medium-pressure switch outputs a cooling fan control signal to the PCM depending on the condenser load.
- The high-pressure switch is connected in series to the A/C cycling switch. It protects the A/C system by outputting an A/C cut-off signal to the PCM when the pressure in the system is abnormally high.



L1005_058

Wiring Diagram



L1005_048

1	PCM	4	A/C cycling switch
2	A/C relay	5	High pressure switch
3	Magnetic clutch	6	Medium pressure switch

Component Overview

Model	Expansion Valve	Fixed Orifice	Compressor Type	Condenser Type	Integrated Drier*
Mazda2 Petrol		x	Variable displacement Swash Plate	Multiflow	
Mazda2 Diesel		x	Variable displacement Scroll	Multiflow	
Mazda3 Petrol	x		Vane-rotary	Multiflow (sub-cooling type)	
Mazda3 Diesel		x	Variable displacement Swash Plate	Multiflow	
Mazda5	x		Vane-rotary	Multiflow (sub-cooling type)	
Mazda6	x		Vane-rotary	Multiflow (sub-cooling type)	x**
MPV (LW)	x		Scroll	Multiflow (sub-cooling type)	x
Tribute		x	Swash plate	Fin and tube	
B-Series (UN)	x		Swash plate	Multiflow	
MX-5 (NC)	x		Vane-rotary	Multiflow (sub-cooling type)	
RX-8 (SE)	x		Scroll	Multiflow (sub-cooling type)	x

*An **x** indicates that the drier can not be ordered separately.
**Only with heavy duty radiator

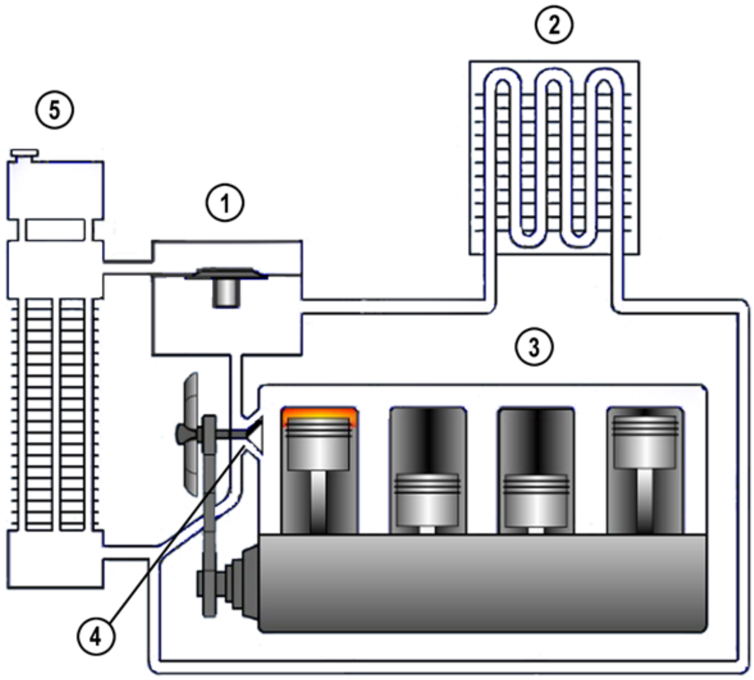
L1005_T002

Notes:

Heating System

- To warm the passenger compartment during cold weather the heat from the engine is indirectly used. The heat is transferred to the engine coolant, and the engine coolant passes through the heater core in the passenger compartment, which gives the heat up to the incoming air. The coolant circulates in two circuits, the ‘small’ and the ‘big’ circuit. In the small circuit, the water pump circulates the coolant past the engine and through the heater core. In the ‘big’ circuit, the thermostat opens allowing the radiator to transfer the captured heat to the passing air.

System Overview



L1005_054

1 Thermostat
2 Heater core
3 Engine
4 Water pump
5 Radiator

Thermostat

- When starting a cold engine, the thermostat stays closed to ensure that the coolant flows only through the ‘small circuit’. This ensures that the engine reaches its operating temperature as quickly as possible, and that heat is available for the heater core to heat up the air as quickly as possible. When the engine temperature exceeds a certain value, the thermostat opens to allow the coolant to flow through the radiator (‘big circuit’). In this way, the optimum engine temperature is maintained and overheating of the engine is prevented.

Heater Core

- The heater core has essentially the opposite function of the evaporator. The hot coolant flowing through the tubes of the heater core releases its heat to the air passing through the fins of the heater core. The fins, which are brazed to the tubes, allow for efficient heat transfer between the hot coolant and the cool air. The air mix door will determine how much of the airflow passes through the fins of the heater core, and accordingly how much warmth will be transferred to the air. The control strategy is covered in depth in the ‘Advanced Climate Control’ course.

Water Pump

- The water pump is driven by the engine and circulates the coolant through the system.

Radiator

- The radiator functions just like the heater core, except that it is much larger to allow it to release the engine heat to the air passing through the fins.

Diagnosis and Repair

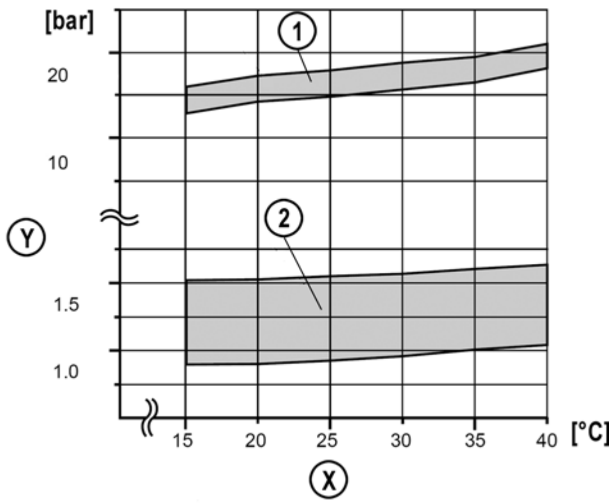
Pressure Gauges

- Mazda special tool 49 C061 001A consists of a low- and high-pressure gauge for the A/C system that allows the refrigerant pressures to be monitored during operation. After attaching the pressure gauges the first thing that should be seen is that the pressures on the high- and low-pressure side are equal. Once the A/C is activated, the pressure on the high-pressure side will increase, and the pressure on the low-pressure side will settle to its operating condition. Until this occurs, there can be no cooling effect expected, as the required pressure differential across either the expansion valve or the fixed orifice will not be present.
- In the event the A/C does not function, the pressure gauges can be used to assist in diagnosing the problem.

NOTE: Most A/C service machines have pressure gauges incorporated. If this is the case, there is no need to attach additional pressure gauges.

Refrigerant Pressure Check

- Mazda service literature provides a procedure for checking the refrigerant pressure in the A/C system. The procedure involves making sure the engine is at operating temperature, and taking pressure and temperature readings while the A/C is operating (see the workshop manual for the vehicle specific procedure). The measurements are then compared to values in a graph, such as the sample graph shown below.

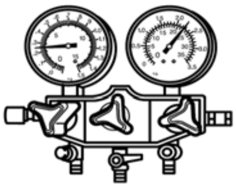
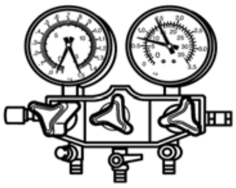
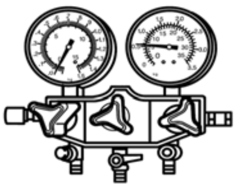
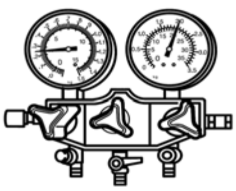
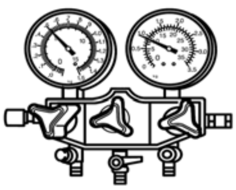


L1005_055

Excerpt from Mazda3 Workshop Manual

X	Ambient temperature	Y	Refrigerant pressure
1	High-pressure side	2	Low-pressure side

- If the pressure readings are out of specification, the table on the following page provides information about the possible cause. See the procedures in the workshop manual to pinpoint the fault.

Measured Pressure		Possible Cause
	Low-pressure side: Below 0.08 MPa (0.8 bar) High-pressure side: 0.8 MPa (8 bar)	Insufficient refrigerant
	Low-pressure side: 0.25 MPa (2.5 bar) High-pressure side: 2.0 MPa (20 bar)	Excessive refrigerant or insufficent condenser cooling
	Low-pressure side: 0.25 MPa (2.5 bar) High-pressure side: 2.3 MPa (23 bar)	Air in system
	Low-pressure side: 0.05 MPa (0.5 bar) to 1.5 MPa (15 bar) High-pressure side: 0.7 MPa (7 bar) to 1.5 MPa (15 bar)	Moisture in system
	Low-pressure side: 0.075 MPa (0.75 bar) High-pressure side: 0.6 MPa (6 bar)	No refrigerant circulation
	Low-pressure side: 0.25 MPa (2.5 bar) High-pressure side: 2.0 MPa (20 bar)	Expansion valve stuck open
	Low-pressure side: 0.5 MPa (5 bar) High-pressure side: 0.85 MPa (8.5 bar)	Faulty compressor

L1005_T001

Leak Testing

- The amount of refrigerant in automotive A/C systems has been steadily decreasing. The lower fill volumes mean that leaks present in the system are going to be noticeable earlier, as a reduction in cooling performance, compared to previous systems filled with more refrigerant.
- An automotive A/C system has weak spots that cannot be easily avoided. For example, because the compressor is mounted on the engine, which has to move relative to the vehicle body, the refrigerant lines need to be flexible. These flexible hoses allow a small amount of refrigerant to leak. The connections between the various components also have a small leakage rate. The single largest source of leakage is the shaft seal on the compressor.
- Compare all of these potential leaks to a stationary A/C unit, such as your household refrigerator. In a refrigerator, which has the same function, and the same basic components, there is no need to use flexible hoses, and there is no need to have serviceable connections between the various components. All of the connections are soldered, and the result is a system that rarely requires service, and where leak checking plays a very unimportant role. The normal seepage of an automotive A/C system cannot be stopped, and these minuscule leaks should not be taken into consideration during leak testing.
- Leaks that have caused a reduction in cooling performance must be found and repaired. There are a number of ways to check a system for a leak. If there is still refrigerant in the system and a leak is suspected, the complete refrigerant circuit can be visually inspected for oily accumulation. Some compressor oil will escape with the refrigerant, and this can be a good indicator of a leak.
- A leak detection solution can be sprayed on the suspected leak, and bubbles will form.
- An electronic leak detector can also be used to detect the refrigerant leaks.
- The MX-5 and the Tribute use compressor oils with an added dye, which is visible when an ultraviolet lamp is shone on it.
- If there is no refrigerant left in the system, and the leak cannot be located visually, then refrigerant will need to be added.
- Most A/C service machines also have a leak detection function. A vacuum is applied to the system, and if the vacuum does not hold for a specified amount of time, then this indicates a leak in the system. Of course this still does not remove the need to pinpoint the location of the leak using one of the other methods mentioned above.

Control System Check

- Using the Datalogger of the WDS, the PCM control strategy for the A/C system can be checked:
  - The input signal from the low- / high-pressure switch to the PCM can be checked using the PID **AC_REQ**. If the pressure in the A/C system is within specification (see the workshop manual for the specific values), AC_REQ should display ON.
  - The output signal from the PCM to the A/C relay can be checked using the PID **ACCS#**. When all conditions for the activation of the compressor are met, ACCS# should indicate ON.
  - The input signal from the medium pressure switch to the PCM can be checked using the PID **COLP**. If the pressure in the A/C system exceeds a certain value (see the workshop manual for the specific value), COLP should read ON.

- In addition, the user can actively send an output signal to the A/C relay to check the integrity of the control circuit. To do this, the PID **ACCS#** must be activated using the **OSC** (**O**utput **S**tate **C**ontrol) function of the WDS. Then a cut-in / cut-out noise should be audible from the magnetic clutch when ACCS# is set to ON / OFF.

NOTE: Depending on the model, the availability of the PIDs varies. In addition, different PID names are used for identical parameters (see the workshop manual for details).

A/C Service Machine

- The A/C service machine is used to drain and refill the refrigerant in the A/C system.
- An A/C service machine also requires maintenance, and this should be done in accordance with the manufacturer’s guidelines.

NOTE: The differences between the compressor oils are not so drastic as to require that the service equipment be flushed between servicing two vehicles with different types of PAG oil.

Draining the A/C System

- Before a component of the A/C system can be removed, the refrigerant needs to be drained from the system.

NOTE: Failure to drain the refrigerant from the system before removing a component could cause injury, and also lead to unnecessary environmental pollution.

- Before draining, make sure there is enough space left in the refrigerant container to accept the expected refrigerant amount from the vehicle. Also make sure that there is enough space left in the oil container to capture any compressor oil drawn out during the draining process.
- To drain the A/C system, connect the A/C service machine to the low- and high-pressure ports of the system, and use the vacuum pump to draw the refrigerant out. During this process the machine will either manually or automatically weigh the amount of refrigerant taken from the system. This is the only 100% reliable way of verifying how much refrigerant was in the system. The amount of refrigerant and compressor oil removed should be noted.

NOTE: The compressor oil removed from the A/C circuit must not be re-used.

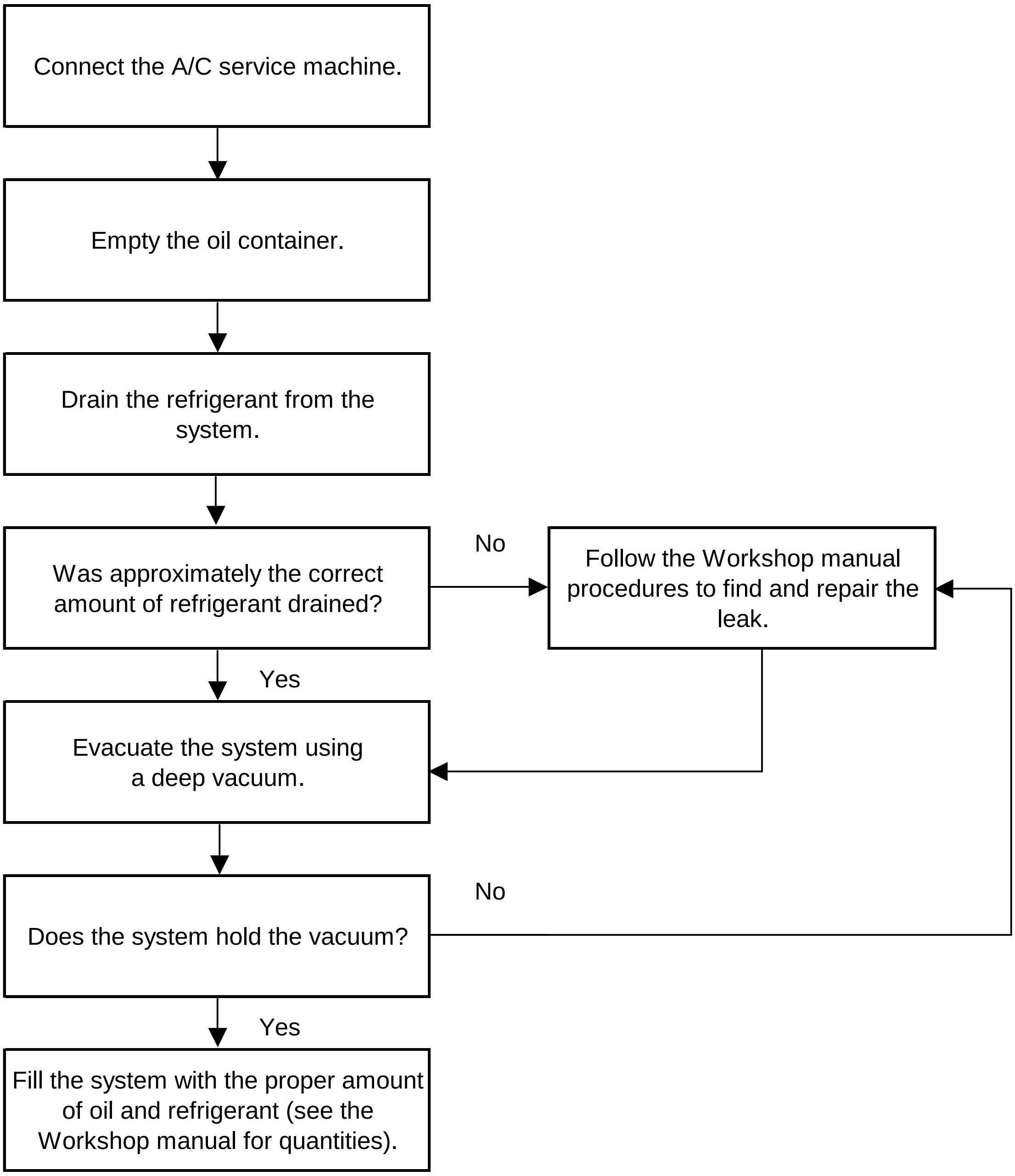
Evacuating the A/C System

- During the evacuation stage the A/C service machine applies a deep vacuum to the system to remove any unnecessary air or moisture. This should be done before filling the system with refrigerant.

Filling the A/C System

- The A/C system has been emptied, the component has been replaced, and now the refrigerant needs to be refilled.
- Before filling, make sure that the oil container of the A/C service machine is emptied, and then filled with the correct compressor oil for the vehicle being serviced.

Summary of Refrigerant Draining and Filling Procedures



L1005_T003

Component Replacement

- Once the refrigerant has been drained from the A/C system, the component in question can be removed. When a component is removed, the refrigerant lines to the rest of the system should be plugged to ensure that moisture does not enter the system.

NOTE: If there is no refrigerant left in the system this means that air has entered the system, and the drier is exposed to moisture. If the system is open for more than 3 hours, the drier will need to be replaced.

- Since the compressor oil is carried throughout the system by the refrigerant, each component contains a certain amount of oil. When replacing a component, the oil that is trapped in the component in question must also be replaced. For each component to be replaced in the system, the workshop manual will give an amount of oil that should be added. This ensures proper lubrication of the compressor.

NOTE: When lubricating the O-rings with compressor oil, use a lint free cloth to apply the oil. Using a finger to apply the oil will give the PAG oil a chance to absorb the moisture from the skin, resulting in moisture entering the A/C system.

- When replacing the compressor a special procedure is required, since new compressors are pre-filled with compressor oil. Before installing the new compressor, the compressor oil from the old and new compressor should be drained into separate measuring containers. Since a certain amount of the oil from the old compressor is contained in the various system components, the amount of compressor oil removed from the old compressor determines the amount of oil to be added when installing the new compressor (see the workshop manual for the specific values).

NOTE: Refer to the workshop manual for the correct type and amount of compressor oil.

Compressor Damage

- The most serious compressor damage arises from lack of lubrication. In this case, there is a possibility that metal particles will be carried throughout the system.

NOTE: Burnt compressor oil and metal particles in the oil are reliable indicators of a seized compressor.

- When the A/C system is contaminated with metal particles, these must be removed from the complete system (with compressed air for example) before the compressor is replaced. Especially, components with restrictions or narrow passages (multiflow condenser, expansion valve/fixed orifice, drier) should be inspected carefully. If the particles cannot be removed, the affected components must be replaced. Failure to do so may result in the new compressor being damaged again.

NOTE: On an A/C system with a fixed orifice, the accumulator / drier can be especially succeptible to blockage from metal particles due to the small size of the oil pick up orifice.

Odours from the A/C System

- Musty damp odour coming from the air vents may arise from micro-organisms forming on the surface of the evaporator. The formation of micro-organisms is promoted by the moist warm climate in the housing of the A/C unit, which is created when the A/C is turned off.
- Modified coatings on the evaporator and better drainage of the condensed water mean that these effects have been practically eliminated. In the event a customer complains of an odour, the evaporator and the housing of the A/C unit should be inspected, and cleaned and disinfected as required.

Diagnosis on the Heating System

- The key element in diagnosing the heating system is determining the integrity of the cooling system. The primary tool to do this is the radiator cap tester in conjunction with the correct adapter. This will help determine if the cooling system is leaking or not.

NOTE: A coolant mixture with too much ethylene glycol reduces the heat capacity of the coolant and hence the heating performance of the heater core. See the service literature for the correct mixture.

Thermostat

- If the thermostat is stuck open it can cause the coolant to flow only through the ‘big circuit’. This will result in the engine reaching its operating temperature very slowly, and less heat being available for the heater core to transfer to the air.

Heater Core

- A heater core can develop a leak, which could result in a noticeably sweet odour coming from the air vents.

A/C	**A**ir **C**onditioning
HVAC	**H**eating **V**entilation & **A**ir **C**onditioning
OSC	**O**utput **S**tate **C**ontrol
PAG	**P**oly-**A**lkaline **G**lycol
PCM	**P**owertrain **C**ontrol **M**odule
PID	**P**arameter **Id**entification
WDS	**W**orldwide **D**iagnostic **S**ystem

Notes