MAHLE

# Automotive air conditioning

## A compact guide for the workshop

BEHR®

# What is thermal management?

*Thermal management means ensuring the optimal engine temperature in all operating conditions as well as heating and cooling the vehicle cabin. A modern thermal management system therefore consists of engine cooling and air conditioning components.*

*The components in these two assemblies, which interact with each other, often form a unit. This booklet covers modern air conditioning systems and their technical background. In this context, we also deal with the principles of operation, causes of failure, characteristic features, and diagnostic options.*

Did you know? MAHLE is one of the world's leading original equipment manufacturers for engine cooling and automotive air conditioning.

# Contents

# A/C check and A/C service

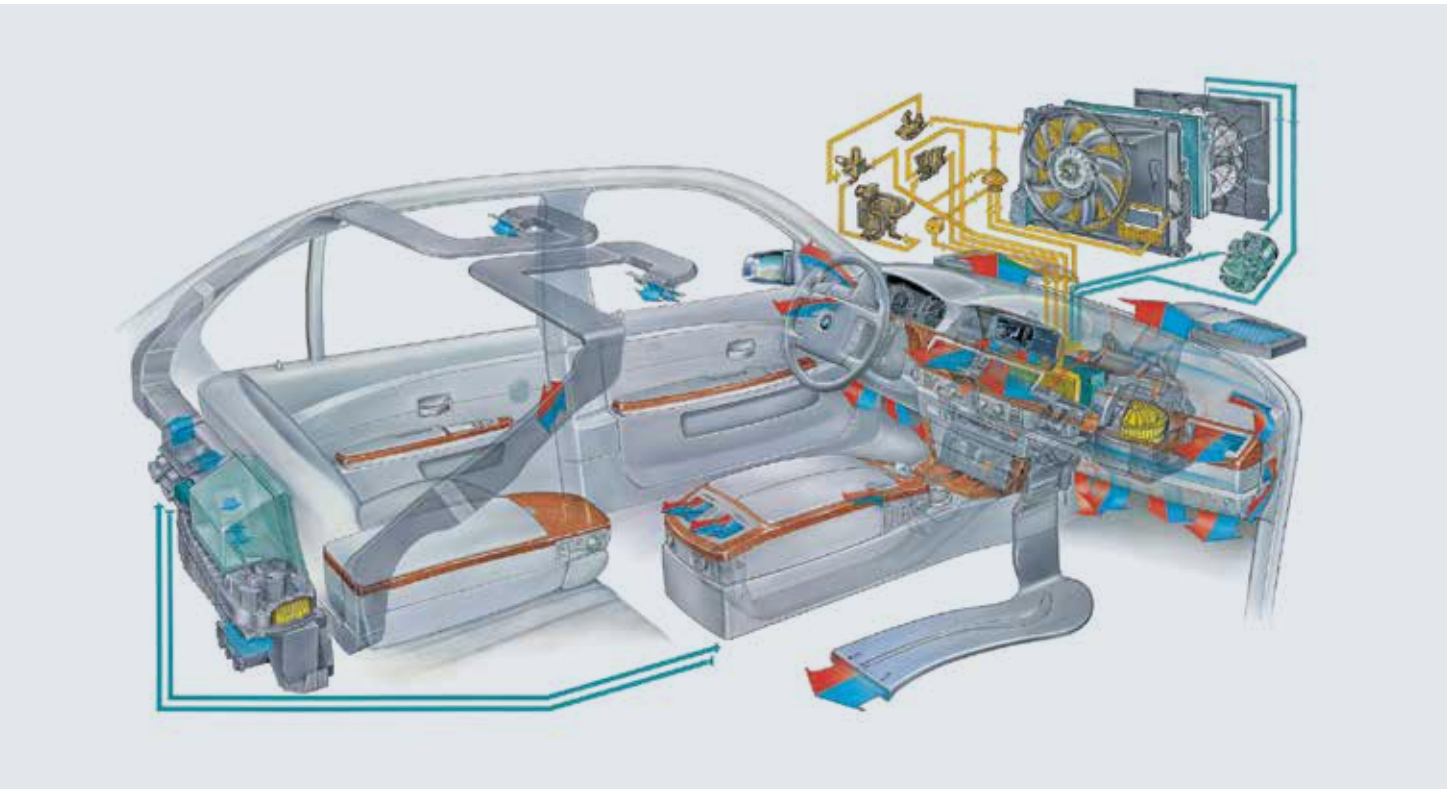
*The air conditioning check and air conditioning service are similar to minor and major inspections.*

> For passenger cars, MAHLE recommends an air conditioning check every 12 months and an air conditioning service every 2 years.

## Alternating check and service

| What should be done when? | |
|---|---|
| **What?** | Air conditioning check |
| **When?** | Every 12 months for passenger cars |
| **Why?** | The cabin filter removes dust, pollen, and dirt particles from the air before it flows into the cabin, clean and cooled. As with any filter, its absorption capacity is limited. Every air conditioning system includes an evaporator. Condensation forms in its fins and, over time, bacteria, fungi, and micro-organisms will nest in the evaporator. It therefore requires regular cleaning and disinfection. |
| **What should be done?** | ▪ Visual inspection of all components<br>▪ Function and performance test<br>▪ Replacement of cabin filter<br>▪ Disinfection of evaporator, where necessary |

| What should be done when? | |
|---|---|
| **What?** | Air conditioning service |
| **When?** | Every 2 years for passenger cars |
| **Why?** | Even new air conditioning systems lose up to 10% of their refrigerant each year. This is normal, but results in loss of cooling performance and the risk of damage to the air conditioning compressor. The filter-drier removes moisture and contaminants from the refrigerant. |
| **What should be done?** | ▪ Visual inspection of all components<br>▪ Function and performance test<br>▪ Replacement of the filter-drier<br>▪ Disinfection of evaporator, where necessary<br>▪ Refrigerant change<br>▪ Leakage test<br>▪ Replacement of cabin filter |



# A/C and cooling units

## Air conditioning and cooling as a unit

Although air conditioning and engine cooling are two separate systems, they do affect each other. When the air conditioning is in use, there is a heavier load on the engine cooling system and the coolant temperature rises.

The additives in the coolant not only protect against frost, but also stop the engine from overheating. The correct composition of the coolant raises the boiling point of the medium to over 120°C, providing an enormous performance reserve. This is particularly important in summer, when the air conditioning and cooling systems are heavily stressed by the ambient temperature and long journeys. The coolant should therefore be checked when the air conditioning service is performed.

# A/C circuits

## Operating principle of air conditioning system with expansion valve

Both the refrigerant and cooling circuits are required to control the climate in the vehicle cabin. Using a mixture of cold and warm air, the desired climatic conditions can be achieved independent of the weather outside. The air conditioning system thus plays a vital role in safety and driving comfort.

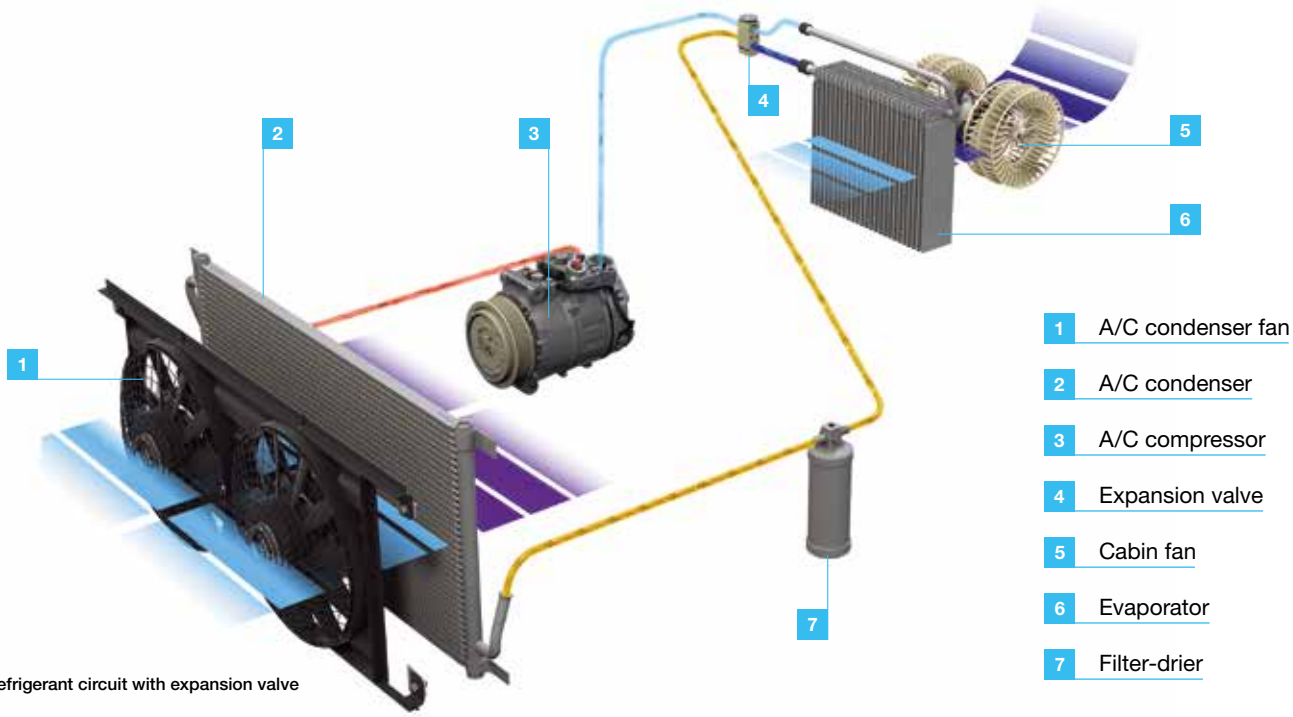
The individual components of the refrigerant circuit are connected by hoses and/or aluminum lines to form a closed system. Refrigerant and refrigerant oil circulate around the system, driven by the air conditioning compressor. The circuit is divided into two parts:

- The high-pressure side (red/yellow) between the air conditioning compressor and expansion valve
- The low-pressure side (blue) between the expansion valve and the air conditioning compressor

The air conditioning compressor compresses the gaseous refrigerant, heating it up in the process, and then forces it through the condenser at high pressure. In the condenser, heat is extracted from the refrigerant, causing it to condense (change in state from gas to liquid).

The next station is the filter-drier, where contaminants and entrapped air are separated out from the now liquid refrigerant and moisture is removed. This ensures the effectiveness of the system and protects the components from damage by contaminants.

The refrigerant now passes from the filter-drier to the expansion valve, which can be thought of as a weir. Upstream of the weir, a constant pressure is maintained, but downstream of it, the increase in volume causes the pressure to drop. Since the expansion valve is located directly in front of the evaporator, the expansion of the refrigerant passes into the evaporator. During evaporation (the change of state from liquid to gas), evaporation cooling is released. This cold air is blown into the vehicle cabin by the ventilation system, where it is used to keep the passengers comfortable. On the low-pressure side, the refrigerant (which is now in gaseous form once again) travels back to the air conditioning compressor, where the cycle starts all over again.




Refrigerant circuit with expansion valve

# Components of the A/C system

## Air conditioning compressors

The air conditioning compressor is generally driven by the engine via a V-ribbed belt. It compresses or circulates the refrigerant in the system. There are different types of air conditioning compressors.

The compressor sucks in gaseous refrigerant from the evaporator at low temperature and then passes it to the air conditioning condenser at high temperature and pressure.

The size of the air conditioning compressor must be adapted to the size of the system. It is filled with special oil for lubrication, some of which circulates through the air conditioning system with the refrigerant.

**Air conditioning compressors are described in detail from page 20.**

Insufficient lubrication caused by leakage and the associated loss of refrigerant and oil as well as inadequate maintenance can lead to failure of the air conditioning compressor (leaking shaft seal, leaking housing seal, bearing damage, piston seizure, etc.).

# Air conditioning condensers

The air conditioning condenser is needed to cool down the refrigerant heated during compression in the air conditioning compressor. The hot refrigerant gas flows into the air conditioning condenser, discharging heat to the atmosphere via the pipe and fins. As the refrigerant cools, its state changes from gaseous to liquid.

## Principle of operation

The hot refrigerant gas flows into the top of the air conditioning condenser, where it releases its heat to the atmosphere via the pipe and fins. Having cooled down, the now liquid refrigerant exits the air conditioning condenser at the lower connection.

## Impact in the event of failure

**A defective air conditioning condenser may exhibit the following symptoms:**

- Poor cooling performance
- Failure of the air conditioning system
- Continuously running air conditioning condenser fan

**Causes of errors may include:**

- Leaks at the connections or due to damage
- Inadequate heat exchange due to contamination

## Troubleshooting

**Test steps for error elimination:**

- Check air conditioning condenser for contamination
- Test for leaks
- Pressure test on the high- and low-pressure sides

The installation location can lead to failures due to environmental influences such as contamination or stone chips. Defects caused by accidents with frontal impact are particularly common.

# Filter-drier

The filter elements of the air conditioning system are known as the filter-drier or accumulator, depending on the system type. The filter-drier is designed to remove foreign objects and moisture from the refrigerant.

## Principle of operation

The liquid refrigerant enters the filter-drier, flows through a hygroscopic drying medium, and exits the filter-drier in liquid form. The upper part of a filter-drier also serves as a compensation chamber, while the lower part stores refrigerant to compensate for pressure fluctuations in the system.

Due to its design, the filter-drier can only extract a certain amount of moisture before the drying medium becomes saturated and can no longer bind any more moisture.

## Impact in the event of failure

**The failure of the filter-drier may give rise to the following symptoms:**

- Poor cooling performance
- Failure of the air conditioning system

**Causes of a filter-drier failure may include:**

- Excessive aging
- Defective filter pad inside
- Leaks at the connections or due to damage

## Troubleshooting

**The following steps should be considered during troubleshooting:**

- Check maintenance intervals (every two years for passenger cars)
- Check for leaks/correct attachment of connections/damage
- Pressure test on the high- and low-pressure sides

For passenger cars, the filter-drier generally needs to be replaced every two years or every time the refrigerant circuit is opened. Excessive ageing of the filter-drier can lead to significant defects in the air conditioning system. Filter-driers can be integrated in the air conditioning condenser. It is not always possible to replace the filter-drier individually.

# Expansion/throttle valve

The expansion valve separates the high- and low-pressure sections of the refrigerant circuit. It is fitted upstream of the evaporator. To optimize the cooling performance of the evaporator, the expansion valve controls refrigerant flow based on the temperature. This ensures complete evaporation of the liquid refrigerant, so that only gaseous refrigerant reaches the air conditioning compressor. Expansion valves differ depending on their type.

## Principle of operation

Liquid refrigerant from the air conditioning condenser passes through the filter-drier and then flows through the expansion valve and is injected into the evaporator, where it evaporates releasing evaporation cooling. This causes the temperature to drop. To optimize the evaporator's cooling performance, the refrigerant flow is controlled by the expansion valve depending on the temperature. At the end of the evaporator, the refrigerant passes through the expansion valve to the air conditioning compressor. If the refrigerant temperature rises at the end of the evaporator, the refrigerant expands in the expansion valve, increasing the refrigerant flow to the evaporator (injection quantity). If the refrigerant temperature drops at the end of the evaporator, the volume in the expansion valve decreases and the flow of refrigerant to the evaporator is reduced.

## Impact in the event of failure

**The following symptoms may indicate a defective expansion valve:**

- Poor cooling performance
- Failure of the air conditioning system

**Causes of failure can have various reasons:**

- Temperature problems due to overheating or icing
- Contamination in the system
- Leaks at the component or connecting lines

## Troubleshooting

**The following steps apply in the event of a malfunction:**

- Visual inspection
- Acoustic testing
- Check that the connecting lines are correctly and securely attached
- Check the component and connections for leaks
- Temperature measurement on the pipework system
- Pressure measurement with air conditioning compressor engaged and engine running

Moisture and contamination in the air conditioning system can severely impair the function of the expansion or throttle valves and lead to malfunctions. Regular maintenance is therefore important.

Further details on the required workshop equipment from MAHLE Service Solutions can be found from page 72.

# Evaporator

The evaporator takes care of the heat transfer between the ambient air and the refrigerant in the air conditioning system.

## Principle of operation

Liquid refrigerant at high pressure is injected into the evaporator via the expansion or throttle valve. The refrigerant expands, generating evaporation cooling that is then released into the environment through the large surface of the evaporator and blown into the vehicle cabin by the fan.

## Impact in the event of failure

**A defective evaporator exhibits the following symptoms:**

- Inadequate cooling performance
- Failure of the air conditioning system
- Poor blower capacity

**Causes of an evaporator failure may include:**

- Pipework in the evaporator blocked
- Evaporator leaking (at connections, due to damage)
- Evaporator clogged (air passage obstructed)

## Troubleshooting

**The following test steps should be considered during troubleshooting:**

- Check evaporator for contamination
- Check evaporator for damage
- Check that the connecting lines are correctly attached
- Leakage test
- Pressure measurement with air conditioning compressor engaged and engine running
- Temperature measurement on the inlet and outlet line

Temperature problems, contamination, moisture, and lack of maintenance can lead to defects in the evaporator. To avoid such defects, the air conditioning system must be regularly serviced or disinfected.

# Pressure switches and sensors

Pressure switches and sensors protect the air conditioning system from damage due to excessively high or low pressures. There are three different switches: the low-pressure switch, the high-pressure switch, and the trinary switch. The trinary switch comprises the high- and low-pressure switches plus an additional switch contact for the condenser fan.

## Principle of operation

The pressure switch (pressure-sensing switch) is generally fitted on the high-pressure side of the air conditioning system. It switches off the power supply to the coupling of the air conditioning compressor when the pressure is too high (approx. 26–33 bar) and back on again when it drops (approx. 5 bar). When the pressure is too low (approx. 2 bar), the power supply is interrupted to prevent damage to the air conditioning compressor due to lack of lubrication. The third switch contact in the trinary switch controls the electric air conditioning condenser fan to ensure optimal condensation of the refrigerant in the condenser.

## Impact in the event of failure

**The following symptoms may indicate a defective or inoperative pressure switch:**

- Poor cooling performance
- Inoperative air conditioning system
- Air conditioning compressor coupling switches on/off frequently

**There are various possible reasons for an inoperative air conditioning system:**

- Contact fault at electrical connections
- Contamination in the system
- Housing damage due to vibration or accidents

## Troubleshooting

**Test steps for failure diagnostics:**

- Visual inspection
- Check connector plug is correctly attached
- Check component for damage
- Pressure measurement with air conditioning compressor engaged and engine running
- Testing of disassembled components with nitrogen cylinder, pressure reducer, and multimeter

Pressure switches and sensors can fail due to contacting problems or contamination. Regular maintenance of the system can prevent failure. The range is rounded off by other air conditioning switches such as on/off switches.

## Blower fans

The blower fan is used to ventilate the car. It ensures a clear view and a pleasant climate inside the vehicle—essential prerequisites for safety and comfort.

The failure of the fan leads to an uncomfortable climate inside the vehicle and can impair the driver's concentration. This poses a significant safety risk. Lack of ventilation can also cause the front windshield to fog up, which restricts visibility and is a major safety hazard.

## Air conditioning condenser fans

The air conditioning condenser fan helps to ensure that the refrigerant liquefies optimally in any operating condition of the vehicle. It is fitted before or after the air conditioning condenser or engine radiator as an add-on or combination fan.

Air conditioning condenser fans can fail due to electrical or mechanical faults. This results in insufficient liquefaction of the refrigerant and causes the performance of the air conditioning system to drop off.

# Repair and service

## Safety instructions/handling refrigerants

- Always wear protective goggles and gloves! At normal ambient temperatures and atmospheric pressure, liquid refrigerant evaporates so suddenly that contact with the skin or eyes can cause the tissue to freeze (risk of blindness).
- In case of contact, rinse the affected areas with plenty of cold water. Do not rub. Consult a doctor immediately!
- Ensure that the workplace is well ventilated when working on the refrigerant circuit. Inhalation of high concentrations of gaseous refrigerant causes dizziness and risk of suffocation. Do not work on the refrigerant circuit from the service pits. Since gaseous refrigerant is heavier than air, it can accumulate there in high concentrations.
- Do not smoke! The smoldering end of the cigarette can cause the refrigerant to break down into toxic substances.
- Do not allow refrigerant to come into contact with open flames or hot metal. This can produce lethal gases.
- Never allow refrigerant to escape into the atmosphere. If the refrigerant tank or air conditioning system is opened, the contents will escape at high pressure. The pressure depends on the temperature. The higher the temperature, the higher the pressure.
- Do not expose the components of the air conditioning system to heat. Vehicles must not be exposed to temperatures above 75°C after painting (drying oven). Otherwise, the air conditioning system must first be drained.
- When removing the service hoses from the vehicle, do not hold the connectors pointing toward your body. Residual refrigerant may leak out.
- When cleaning the vehicle, do not point the steam jet directly at the components of the air conditioning system.
- Never change the factory setting of the regulating screw on the expansion valve.

Work on air conditioning systems may only be carried out by qualified technicians (certificate of competence). The relevant EU regulations (307/2008, 517/2014, 2006/40) must be observed.

# Instructions for removal and installation

## Air conditioning system

Before removing or fitting a replacement part, check that the connections, fastenings, and other characteristics relevant to installation are identical.

When replacing components, always use new O-rings that are compatible with the refrigerant.

The air conditioning compressor oil has a powerful hygroscopic effect. The system should therefore be kept closed most of the time, or the oil should only be added shortly before the refrigerant circuit is closed.

Lubricate O-rings and gaskets with refrigerant oil or special lubricants before assembly to make them easier to install. Do not use any other grease or silicone spray, as this will immediately contaminate the new refrigerant.

The filter-drier must be replaced every time the refrigerant circuit is opened because of its highly hygroscopic effect. If the filter-drier or accumulator is not replaced regularly, the filter pad may disintegrate, causing silicate particles to be distributed throughout the system, which would result in severe damage.

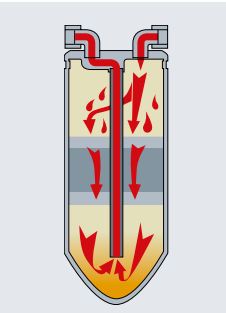
The connections of the system must be sealed immediately with caps or plugs and should never be left open for an extended period of time. Otherwise, moisture will enter the system with the air.

Always use two spanners when tightening and loosening connections to ensure that connecting lines and components are not damaged.

When routing hoses and cables, make sure that they cannot be damaged by the vehicle edges or any other moving components.

When replacing a component of the air conditioning system, make sure that the system has the correct amount of oil. Top the oil up or drain some out, if necessary.

Always check that the system is leakproof before refilling it. Then evacuate the system sufficiently (approx. 30 minutes) to ensure that all moisture has been completely removed.



**Filter-drier**

**Pressure gauge**

Electronic leak detector


PAO 68 oil

After filling with the quantity of refrigerant specified by the vehicle manufacturer, check the system for proper functioning and leaks (electronic leak detector). At the same time, monitor the high- and low-pressure values on the pressure gauges and compare with the prescribed values. Compare the outlet temperature at the center nozzle with the values specified by the manufacturer.

After the service connections have been fitted with protective caps, mark the date of maintenance by attaching a service label sticker to the front crossbar.

## Instructions for the installation of air conditioning compressors

Make sure that all contaminants and foreign bodies have been removed from the refrigerant circuit by flushing the system before installing the new air conditioning compressor. Depending on the contamination level, it is recommended to use refrigerant R134a or R1234yf or a special flushing solution. Air conditioning compressors, filter-driers (accumulators), and expansion or throttle valves cannot be flushed. Because system contamination (abrasion particles, chips) is always assumed or cannot be ruled out when the air conditioning compressor is defective, the system must always be flushed when replacing these components. Ensure that no residues of flushing solution remain in the system. Dry the refrigerant circuit with nitrogen, if necessary.

Replace the filter-drier or accumulator and the expansion or throttle valve (orifice tube).

As the same air conditioning compressor may be used for different vehicles or systems, it is crucial to check the oil filling quantity and viscosity according to the manufacturer specifications, and adjust if necessary, before installing the compressor. All oil must first be drained and collected. The air conditioning compressor must then be refilled with the total quantity of oil specified by the vehicle manufacturer (system oil volume).

You can find all the depicted products and much more in the MAHLE and MAHLE Service Solutions range.

Oil is drained and filled via the “oil drain plug” provided for this purpose. If the air conditioning compressor does not have such a plug, the oil is drained via the high- and low-pressure connections and refilled through the low-pressure connection. The shaft of the air conditioning compressor must be turned several times.

To ensure that the oil is distributed evenly, the air conditioning compressor must be turned ten times by hand before installation. When mounting the drive belt, make sure that it is properly “aligned.” Some air conditioning compressors are designed for “multiple use.” This means that they can be installed in various vehicles. Apart from the number of grooves on the magnetic clutch, the part is exactly the same as the “old part.”

After installing the air conditioning compressor and refilling the refrigerant circuit, start the engine and allow it to run at idle-running speed for a few minutes.

Further specifications (package inserts, manufacturer specifications, start-up instructions) must be observed separately.

Due to their design, the oil cannot be drained from the Denso 5SE/5SL and Hanon VS16 air conditioning compressors. These come prefilled with the required system oil filling quantity. Follow the separate product and installation instructions.

# Failure diagnostics

## Checking the cooling performance

*In addition to testing equipment and special tools, every workshop also needs the relevant expertise, which can be acquired through training courses, for example. This applies in particular to air conditioning systems. Due to the variety of systems, these instructions serve only as a guide.*

**1** Start the engine. Cycle through the blower speed settings. Is the fan working?

Yes

No

**2**

- Check fuse
- Check relay, switch, cabling of all components

**3** Temperature at maximum cooling. Is the magnetic clutch activated?

Yes

No

**4**

- Check cabling/electrical connections, electrical power supply (+/-)
- Check temperature switch/sensor, pressure switch
- Refrigerant charge not correct

Continue to **5**

**5** Run the system for several minutes at maximum cooling capacity and medium blower speed setting. Air exit temperature at the middle nozzle 3–8°C.

Yes

No

**6** If exit temperature too high:

- Heating switched off?
- Cabin filter condition?
- Check temperature switch/sensor, thermostat (if present)
- Check ventilation doors, heating valves, condenser ventilation

**7** Check low pressure (LP) and high pressure (HP) at 2,000–2,500 rpm: LP = 0.5–3.0 bar, HP = 6.0–25.0 bar; for output-controlled air conditioning compressors: LP = approx. 2 bar, constant.

Yes

No

**8** See troubleshooting table

A/C system working

*The correct evaluation of the pressure gauge display is particularly important. The following are some examples:*

## Air conditioning systems with expansion valve

| Low pressure | High pressure | Exit temperature at the middle nozzle | Possible causes |
|---|---|---|---|
| High | High | Higher, up to ambient temperature | Engine overheated, condenser clogged, condenser fan defective, incorrect direction of rotation, system overfilled |
| Normal to low, intermittent | High, intermittent | Higher, possibly fluctuating | Expansion valve stuck, intermittently closed |
| Normal | High | Slightly higher | Filter-drier aged, condenser clogged |
| High | Normal to high | Higher, depending on bottleneck | Line from air conditioning compressor to expansion valve narrowed |
| Normal | Normal | Higher | Excessive refrigerant oil in the system |
| Normal, but irregular | Normal, but irregular | Higher | Moisture in the system, defective expansion valve |
| Fluctuating | Fluctuating | Fluctuating | Expansion valve or air conditioning compressor defective |
| Normal to low | Normal to low | Higher | Evaporator clogged, not enough refrigerant |
| High | Low | Higher, almost ambient temperature | Expansion valve stuck, open; air conditioning compressor defective |
| Low | Low | Higher, up to ambient temperature | Insufficient refrigerant |
| Low pressure and high pressure the same | Low pressure and high pressure the same | Ambient temperature | Insufficient refrigerant, air conditioning compressor defective, defect in the electrical installation |

## Air conditioning system with fixed restrictor/orifice tube

| Low pressure | High pressure | Exit temperature at the middle nozzle | Possible causes |
|---|---|---|---|
| High | High | Higher, up to ambient temperature | Engine overheats, air conditioning condenser clogged, air conditioning condenser fan defective or incorrect direction of rotation, system overfilled |
| Normal to high | High | Higher | System overfilled, air conditioning condenser clogged |
| Normal | Normal to high | Fluctuating | Moisture in the system, fixed restrictor intermittently clogged |
| High | Normal | Higher | Fixed restrictor defective (cross section) |
| Normal | Normal | Higher | Excessive refrigerant oil in the system |
| Normal to low | Normal to low | Higher | Insufficient refrigerant |
| Low pressure and high pressure the same | Low pressure and high pressure the same | Ambient temperature | Insufficient refrigerant, air conditioning compressor defective, defect in the electrical installation |

# Overview and important information

## General

The air conditioning compressor is usually driven by the vehicle engine via a V-ribbed belt. It compresses or circulates the refrigerant in the system. There are different types of air conditioning compressors.

## Principle of operation

The compressor sucks in gaseous refrigerant from the evaporator at low temperature and pressure, compresses it, and then passes it in its gaseous form to the air conditioning condenser at high temperature and pressure.

## Impact in the event of failure

The following signs may indicate a damaged or broken air conditioning compressor:

- Leaks
- Noise
- Insufficient cooling or absence of cooling
- Error code in the climate control unit or engine/central control unit

## Failures may be due to a variety of causes:

- Bearing damage due to defective clamping device or wear and tear
- Leaks in the air conditioning compressor shaft or housing
- Mechanical damage to the air conditioning compressor
- Bonding (electrical connections)
- Electric control valve
- Insufficient refrigerant oil
- Insufficient refrigerant
- Solid matter (e.g., chips)
- Moisture (corrosion, etc.)
- Defective clamping elements, engine accessories

## Troubleshooting

Functional test and pressure measurement of the system:

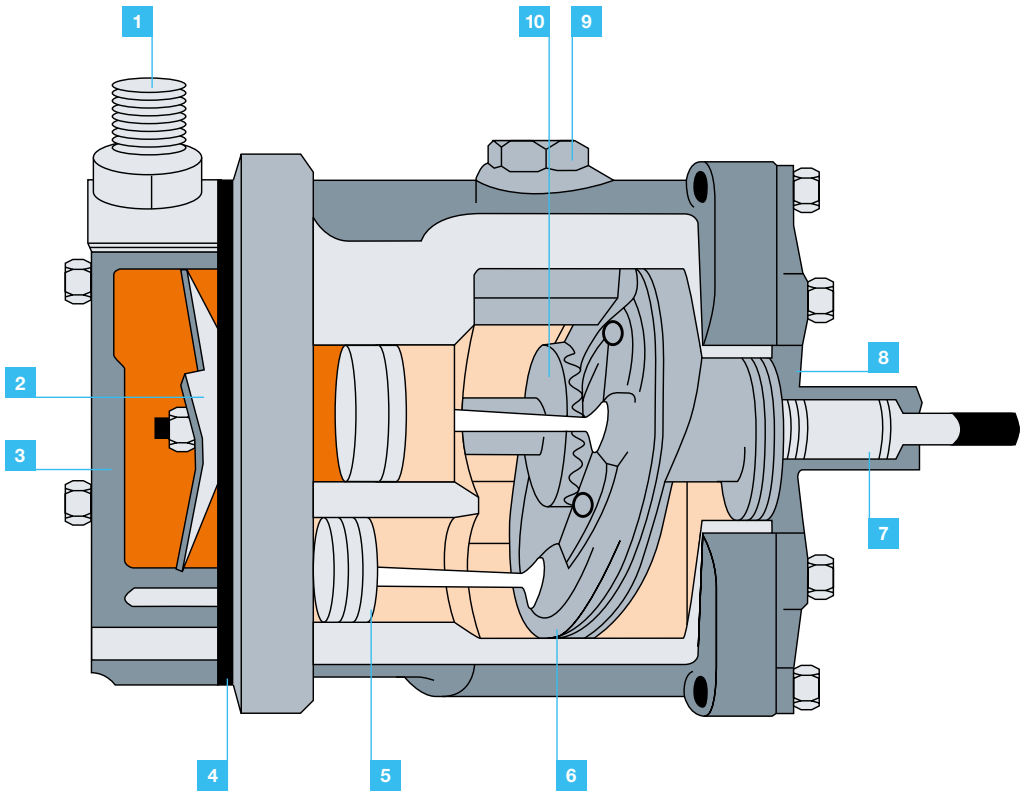
- Does the air conditioning compressor switch on, is the plug firmly connected, is voltage applied?
- Check electric control valve or actuation
- Check the drive belts for positioning, damage, and tension
- Carry out visual inspection for leaks
- Check that the refrigerant lines are properly secured
- Compare pressure on the high- and low-pressure sides
- Read out fault memory

## Fully automated testing program of cooling capacity and failure diagnostics

The MAHLE ACX 320, ACX 350, ACX 380 and ACX 420, ACX 450, ACX 480 come with a fully automated testing program. If the test result is “Not OK”, the necessary steps are indicated on the monitor of the unit.

More information is available from page 72, Workshop equipment.

# Cross section of the A/C compressor




1 Screw connections
2 Suction pressure valve
3 Cylinder head
4 Gasket
5 Piston
6 Swash plate
7 Driving shaft
8 Housing
9 Oil cap
10 Gear wheel

Example shown: piston air conditioning compressor

# Work process for failure analysis and replacement

## A/C compressor defective?

**Identify the causes:**

a) Defect in refrigerant circuit
b) Electrical fault
c) Defect in A/C compressor environment (belt drive, auxiliary aggregates)

OK

Check the A/C compressor when installed

**Practical tip:**

a) Magnetic clutch
b) Mechanical damage
c) Electric control valve
d) Leaks

Not OK

Extract refrigerant

Remove A/C compressor

Check system for contamination/solid matter/impermeability

**1 Consistent flushing:**

Important! When exchanging the A/C compressor, the entire A/C system has to be flushed and the consumables and nonflushable components have to be replaced.

Install new or repaired A/C compressor

**2 Refrigerant oils:**

Important! Before installing a new A/C compressor, always check the oil quantity and viscosity in accordance with the manufacturer specifications and top up if necessary! To do this, the A/C compressor needs to be drained and refilled with the amount recommended by the manufacturer. The O-rings should be replaced when installing the compressor.

**3 A/C compressor filter screens:**

Practical tip: Before assembly, install he filter screen in the suction line of the A/C compressor if necessary.

Replace expansion or throttle valve/ filter-drier/accumulator/O-rings

With service unit
1. Create vacuum
2. Perform leakage test
3. Fill with refrigerant

**4 Fill A/C system with refrigerant:**

It is important to follow the start-up instructions.

**Practical tip:**

Observe the manufacturer specifications:
a) Vacuum time
b) Refrigerant charge quantity

1. System pressure test
2. Leakage test
3. System check

**5 Leak detecting agent:**

Fill with leak detecting agent.

1. Attach service sticker
2. Perform test drive
3. Document work performed

## 1 Consistent flushing

Dirt particles in the air conditioning circuit can only be removed by thoroughly flushing the entire system. Depending on the contamination level, we recommend using R134a or R1234yf refrigerants, or a special flushing solution. Air conditioning compressors, filter-driers (accumulators), and expansion or throttle valves cannot be flushed. Because system contamination (abrasion particles, chips) is always assumed or cannot be ruled out when the air conditioning compressor is defective, the system must always be flushed when replacing these components.

## 2 Refrigerant oils

Note the manufacturer specifications and package insert as well as the viscosity.

### 2.1 Breakdown of oil quantities

Refrigerant oil is found in every component of the air conditioning system. The oil is removed along with the replaced component in case of a repair. It is therefore vital that the system is topped up again with the appropriate amount of oil. The chart below illustrates the average breakdown of the oil quantities within the system.

### 2.2 Note the oil quantity and specification

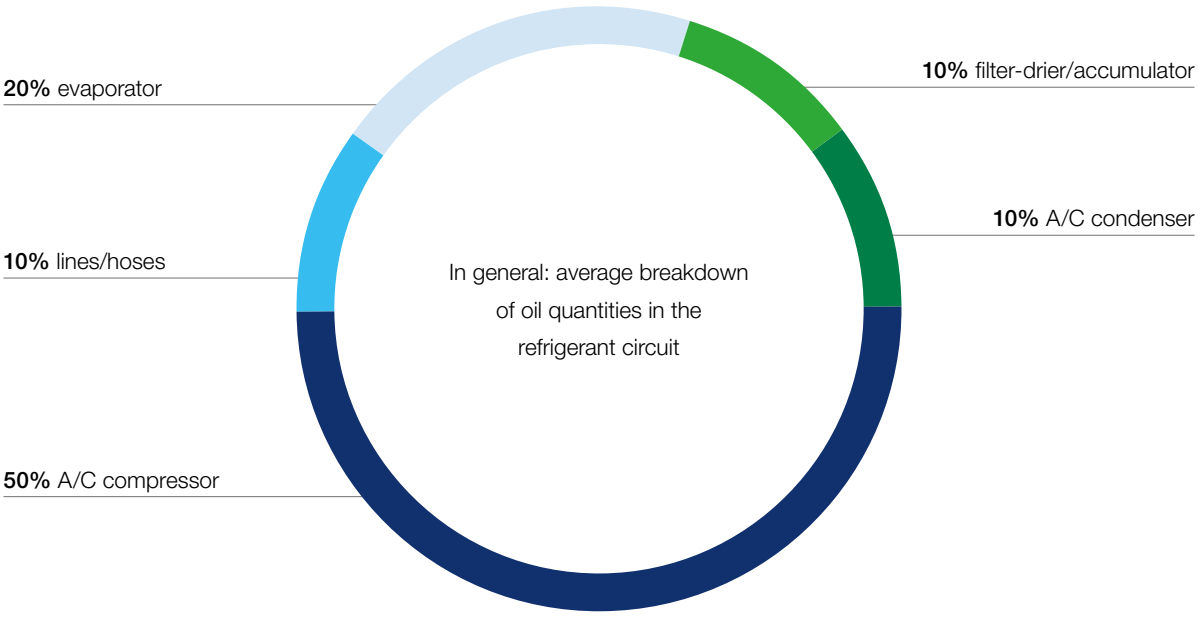
Before installing a new air conditioning compressor or topping up the system with refrigerant oil, the oil quantity and viscosity must always be checked in accordance with the vehicle manufacturer specifications.

### 2.3 System oil quantity in the air conditioning compressor

As one air conditioning compressor may be used for different vehicles or systems, it is crucial to check or adjust the oil filling quantity before installing the compressor. All oil must first be drained and collected. The air conditioning compressor must then be refilled with the total quantity of oil specified by the vehicle manufacturer (system oil volume). To ensure that the oil is distributed evenly, the air conditioning compressor must be turned ten times by hand before installation. Individual vehicle manufacturer specifications must be taken into account in each case.

## 3 Air conditioning compressor filter screens

In principle, every air conditioning system must be flushed when replacing the air conditioning compressor in order to remove contamination and foreign material from the system. If contamination remains in the circuit after flushing, the use of filter screens in the suction line can help to prevent damage.



## 4 Filling the air conditioning system with refrigerant

Start-up instructions for the air conditioning compressor:

- The refrigerant must always be filled via the air conditioning service unit using the service connection on the high-pressure side, to prevent refrigerant hammering in the air conditioning compressor.
- Only the appropriate refrigerant should be used, in the quantity/specification prescribed by the vehicle manufacturer.
- Set the air distribution to the center nozzles position and open all center nozzles.
- Set the switch for the fresh air blowers to the medium level.
- Set the temperature to maximum cooling.
- Start the engine (without running the air conditioning system) and let the engine run uninterrupted at idle-running speed for at least 2 minutes.
- Switch on the air conditioning for about 10 seconds at idle-running speed; switch off the air conditioning for around 10 seconds. Repeat this process at least five times.
- Perform a system check.

## 5 Leak detecting agent

Insufficient refrigerant can also cause damage to the air conditioning compressor. Therefore, regular air conditioning maintenance and, if necessary, addition of contrast agent to the system is recommended. There are various methods for doing this. The use of contrast agent in the vehicle should be documented. This prevents overfilling, which—in extreme cases—can cause damage to the air conditioning compressor.

Further details on the required workshop equipment from MAHLE Service Solutions can be found from page 72.

## Caution

Always renew all O-rings and coat them with refrigerant oil before installation.
Before installing a new air conditioning compressor, always check the oil quantity and viscosity in accordance with the manufacturer specifications and top up if needed!
When replacing the air conditioning compressor, it is necessary to flush the entire air conditioning system and replace the consumables and nonflushable components.


ACX 380
POE
UV
R134a
MAHLE
ArcticPRO

# A/C compressor damage

*The air conditioning system no longer functions after the repair of a leak or after the service of the air conditioning.*

## Case

It is common for the air conditioning system to stop working correctly either immediately after a normal service or the replacement of air conditioning system components, or a short time thereafter.

## What does the customer complain about?

The vehicles originally come to the workshop with a note from the customer saying “The air conditioning system doesn’t cool properly anymore” or “The air conditioning system doesn’t cool at all anymore.”

## How does the workshop respond?

In such cases, the first step is usually to check the filling quantity of the refrigerant circuit. This often shows that there is insufficient refrigerant in the system. Depending on the type of system, up to 10% of the refrigerant can diffuse out of the air conditioning system within a year. However, before the system is refilled with refrigerant, it must be established whether the lack of refrigerant is due to “natural loss” or a leak. If leaks are suspected, the system must not simply be refilled with refrigerant. A leak detection must be carried out beforehand, for example by filling the air conditioning system with forming gas and checking it with an electronic leak detector. Depending on the result, either a leaking component (Figure 1) of the refrigerant circuit or only the filter-drier element is replaced. The system is then evacuated as prescribed and filled with refrigerant and air conditioning compressor oil according to the manufacturer specifications.

At times, the air conditioning compressor may no longer deliver any power when the air conditioning system is put back into operation. The pressure values shown on the service unit for the high- and low-pressure sides will be almost identical (Figure 2). This suggests that either the refrigerant circuit has insufficient flow (e.g., at the expansion valve) or that the air conditioning compressor is defective. Strangely enough, there are also cases where the high- and low-pressure values are within the normal range when the air conditioning system is initially tested, with the only issue being that the refrigerant quantity is too low; problems do not arise until the air conditioner has been refilled in accordance with regulations. Evacuating and refilling the system can loosen dirt particles or metal abrasion and deposit them in the control valve (Figure 3) of the air conditioning compressor or in the expansion/throttle valve (Figure 4), which leads to malfunctions, especially if the filter-drier was excessively old or the system was “underfilled.”

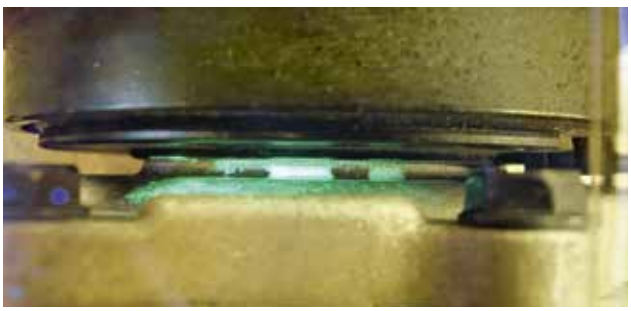


**Figure 1**


**Figure 2**

## What should be done?

If problems occur, remove the air conditioning compressor and drain the oil. If a grayish (grayish-green or grayish-yellow if contrast medium is used) discoloration of the oil can be detected and fine metal particles are also found in the oil (Figure 5), the refrigerant circuit must be properly flushed due to the foreign particles. The expansion valve and filter-drier must then be replaced and the refrigerant circuit evacuated once again according to the instructions and refilled with refrigerant and oil. The system should then function properly.

## Has the customer been sufficiently informed?

Since the workshop has previously only provided the customer with a cost estimate for leak detection and, if necessary, replacement of the leaking component, a difficult discussion arises. The customer is often not prepared to pay the considerable additional costs, such as for the replacement of the air conditioning compressor and flushing. That is why a detailed discussion with the customer, in which the technical facts and the risks are clearly set out, is so important.

## What is the cause of failure of the air conditioning compressor?

The air conditioning compressor contains the only moving components in the refrigerant circuit and must therefore be supplied with sufficient oil. The oil in the refrigerant circuit has the additional task of cooling the air conditioning compressor to prevent it from overheating. If an air conditioning compressor is operated with too little refrigerant over an extended time frame (e.g., due to a leak), heat transfer and lubrication of the air conditioning compressor components will be insufficient. This is because the oil is transported through the air conditioning system with the refrigerant. Overloading of the air conditioning compressor components leads to metallic abrasion at the components, which may partially or completely clog the control valve inside. The blockage of the control valve causes the air conditioning compressor to stop working properly. The damage can only be rectified through the professional replacement of the air conditioning compressor and flushing of the system. Inadequate lubrication causes damage to all types of air conditioning compressors. However, output-controlled air conditioning compressors are particularly sensitive to insufficient refrigerant or oil.

## Note for the workshop and repair contractor

If a customer brings a vehicle in for repair due to inadequate cooling performance, it should be mentioned that the air conditioning compressor may need to be replaced. This is because insufficient refrigerant and the associated lack of lubrication may already have caused damage. If in doubt, remove the air conditioning compressor and, if the oil is contaminated, flush the system before replacing the air conditioning compressor. If the customer wishes to proceed differently, it is a good idea for the workshop to make a note of this on the invoice or to have the customer confirm it in writing.

Figure 3

Figure 4

Figure 5

# Noise

## Notes on troubleshooting noises and replacing the air conditioning compressor

**When troubleshooting noise sources and before replacing the air conditioning compressor, the following instructions should be followed:**

- Check all retaining clips and fastening points for fractures or cracks and any missing bolts or nuts. Any vibration caused by these issues can lead to excessive air conditioning compressor noise. Pay attention to whether the noises change when you apply force to the retaining clips or fastening points, for example, with a fitting lever (Figure 1). If it does, the noises are probably not caused by the air conditioning compressor.
- Check the hoses and lines to see if vibrations from the engine or pulsating refrigerant are being transmitted to the vehicle cabin. To do this, hold them in your hand and listen for any changes (Figure 2).
- Check the V-belt, clamping device, tension rollers, generator freewheel, and pulleys for ease of movement, play, and alignment. Excessive tolerances due to worn parts can lead to noise.
- Excessive high pressure (Figure 3) can cause unusual compressor noises. If the high-pressure service connection is behind a blockage in the system, the high pressure may actually be higher than indicated by the pressure gauge. To diagnose such a problem, it is helpful to measure the temperatures at the air conditioning condenser.
- If there is too much refrigerant or it is contaminated, this may cause excessive high pressure, which may in turn lead to air conditioning compressor noise. The same applies to refrigerants with too high a proportion of noncondensable gases (air).

Figure 1

Figure 2

- The air conditioning condenser can also be a source of unusual noises. If not enough air is fed through the air conditioning condenser, the refrigerant cannot condense sufficiently and the high pressure rises excessively. This may result in unusual noise development. Therefore, check whether the fans are propelling enough air through the air conditioning condenser. Also check the air conditioning condenser and cooler fins for any contamination (Figure 4).
- Noises can also be caused by clogged expansion (Figure 5) or throttle valves. This may be the result of contaminants such as metal abrasion particles. These reduce the refrigerant flow, leading to excessive high pressure. “Defective” expansion valves can, for example, produce various buzzing, whistling, or booming noises that are also clearly audible in the vehicle cabin.


Figure 3

Figure 4

Figure 5

# A/C compressors without magnetic clutch

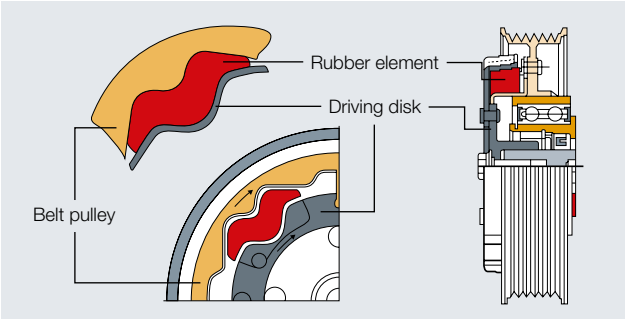
## General

Externally controlled, variable air conditioning compressors without a clutch—so-called “clutchless” air conditioning compressors—have been in use for some years now. All major manufacturers of air conditioning compressors use a range of different types. The most common models on the market include: Denso with types 6SEU & 7SEU; Sanden with types PxE 13 & PxE 16. MAHLE is also represented by the CVC7 range, which is very similar in construction to the V5 air conditioning compressor. This generation of air conditioning compressors is used by almost all vehicle manufacturers. The term “externally controlled” means that the displacement of the air conditioning compressor is controlled by the climate control unit on the basis of a wide range of system parameters—such as outside/desired temperature, high/low pressure, engine speed, and engine load—via a built-in control valve. Clutchless means that the air conditioning compressor no longer has an electromagnetic clutch. The air conditioning compressor is thus permanently driven via the pulley and operates even if the air conditioning system is switched off. However, the power output is turned down to a few percent in that case.

## Function

The pulley unit of the air conditioning compressor includes, for example, a driver pulley and the actual pulley (drawing). The driving disk consists of a rubber element and forms the connection between the belt pulley and the shaft of the air conditioning compressor. It serves firstly as a vibration damper and also protects the air conditioning compressor or the other driven units from overload and damage. If the air conditioning compressor should block, for example, the transmission forces between the belt pulley and the driving disk increase considerably near the rubber element.

Depending on the air conditioning compressor manufacturer or model, the connection is interrupted by the deformation of the rubber element or the tripping of the “overload protection.” The belt pulley then merely idles. This prevents damage to the belt and other units driven by it.




Functional example

Figure 1

Figure 2

The control valve (Figure 1) is located within the air conditioning compressor and receives a pulse-width-modulated (PWM) signal from the climate control unit. The current that is fed from the control unit to the control valve, and which ultimately determines the output of the air conditioning compressor, can be displayed as a block of measured values with the aid of a diagnostic tool. Clutchless air conditioning compressors also have a safety valve (Figure 2) to protect the air conditioning compressor and the other components of the air conditioning system from excessive pressure. The valve usually trips at between 35 and 45 bar (depending on the manufacturer of the air conditioning compressor). It remains open only until the overpressure has been reduced. It then closes again to prevent the refrigerant from being released into the atmosphere. If the valve film is damaged, it can be assumed that the valve has tripped.

## Diagnostics

The belt pulley and its rubber elements, which act as an overload protection device, differ depending on the air conditioning compressor type. The procedure for determining whether the overload protection has tripped varies depending on the model:

1. Rubber wear particles are visible on the inside of the belt pulley (Figure 3). The shaft of the air conditioning compressor is no longer driven. Belt pulley/rubber element can be replaced if the air conditioning compressor turns easily.

2. The overload protection has tripped the driving disk (Figure 4). Driving disk/rubber element can be replaced individually. Prerequisite: air conditioning compressor can be turned easily.

3. A tripped torque limiter is hard to detect visually. To check whether the limiter has tripped, hold the air conditioning compressor shaft with a suitable tool (Figure 5) while turning the pulley to the left. If the belt pulley can be turned to the left, the limiter has tripped and the air conditioning compressor must be replaced. For the Sanden air conditioning compressor models PxE 13 and PxE 16, it is not possible to replace the torque limiter.

Figure 3

Figure 4

Figure 5

For the Audi A3, for example, the maximum current fed from the control unit to the control valve is approx. 0.65 A at the lowest temperature setting. This is also when the air conditioning compressor reaches its maximum output. During normal operation, the average current flow is 0.3 A. The problem with newer vehicles is that diagnostics outside the engine management area are not yet possible with many test devices. The use of an oscilloscope is ideal here. Using suitable test prods, the PWM signal can be recorded at the plug-type connection of the air conditioning compressor. The oscilloscope should be set to 5 V/Div and 0.5 ms/Div. The individual modes of operation can now be seen on the monitor of the oscilloscope with the engine running. At the lowest temperature setting (“Low”), a square wave signal with a duty cycle of approx. 75% is displayed (Figure 7). The duty cycle results from the ratio of the pulse width -B- and the distance between signals -C- (in this case 75% on-period, 25% off-period).

The level of the on-board voltage (approx. 13.5 V) can be determined at the same time using the volt divisions (A = 5 V). The voltage value displayed as a number (9.8 V) is only a mean value. The pulse width depends on the desired cooling performance and the on-board voltage. The current to the control valve is “regulated” by the control unit via the section of the range -B-. Depending on the setting of the control unit and the environmental influences (e.g., outside temperature), the pulse width of the square wave signal is changed or the control valve is controlled in such a way that the air conditioning compressor provides the necessary power output to reach the desired temperature. Figure 8 shows how the air conditioning compressor is turned down when the temperature is set to “High”. Figure 9 was taken in “Econ” mode (air conditioning compressor off) and displays no signal. This method can be used to determine the extent to which the control unit will change the signal. If there is a plausible change to the signals, but no change in the discharge temperature or reduction in the cabin temperature, there is probably a defect in the air conditioning compressor.

There are also diagnostic tools on the market that allow a PWM signal to be generated with different pulse times. In this way, it can be determined whether activating the air conditioning compressor leads to a change in the refrigerant pressure. This in turn makes it possible to establish whether the air conditioning compressor is working correctly.

A functional test using a PWM signal can also be carried out with a function generator (Figure 10). For this purpose, however, it is essential to connect a load corresponding to that of an electronic control valve to the control unit side of the air conditioning system. Otherwise, the control unit detects a defect in the system and stores it in the fault memory, which can lead to malfunctions or the failure of the system. The fault memory must then be read out and cleared using a diagnostic tool.

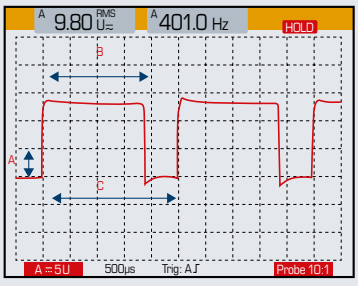



Figure 7

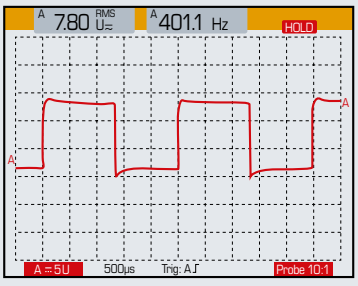



Figure 8

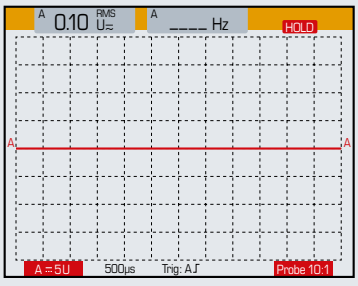



Figure 9

Figure 10

Air conditioning compressors are often prematurely returned with complaints relating to noise and other problems in the air conditioning system. It often turns out that the air conditioning compressor is fine or that the cause of the defect lies elsewhere. Therefore, troubleshooting should always include all system components. Possible sources of noise include not only the air conditioning compressor itself, but also its mounting, drive, expansion valve, or lines. A wrong amount of refrigerant can also be responsible for various noises.

## The oil provides important information about possible damage:

- If the oil in the air conditioning compressor or in the system has turned red, this may be a sign of excess moisture.
- Black oil indicates a defective air conditioning compressor.
- Silver-gray oil should be examined for metal swarf. The grayish discoloration points to metal abrasion.

Since the system oil quantities are getting smaller all the time (in some cases as little as 80 ml), monitoring and maintaining the right oil quantity (e.g., during the air conditioning service and when components are replaced) is of utmost importance.

The options for repairing clutchless air conditioning compressors are limited. In any event, the appropriate tools must be used and repair instructions followed.

Of course, the evaluation of system pressures is of particular significance when performing diagnostics. The vehicle manufacturer's default values should be used. The same applies for the discharge temperature.

> Noises associated with air conditioning compressors often do not originate from the air conditioning compressor itself. Therefore, troubleshooting should always include its drive, fastenings, and all system components.

*The following table provides a guide for assessing the system pressures:*

**Evaluation of system pressures**

| High pressure | Low pressure | Symptoms | Possible cause | Possible solution |
|---|---|---|---|---|
| Normal | Normal | ▪ Outflowing air is not cold | ▪ Too much oil in the A/C system<br>▪ Air or moisture in the A/C system | ▪ Empty A/C system, flush and refill with oil and refrigerant<br>▪ Empty A/C system, replace filter-drier and refill |
| High | High | ▪ Low-pressure line colder than evaporator<br>▪ High pressure drops when the A/C condenser is cooled with water<br>▪ High and low pressure even out as soon as the A/C compressor is switched off and pulsate as soon as it is switched on | ▪ Expansion valve opened too wide<br>▪ Too much refrigerant in system<br>▪ A/C condenser clogged/blocked<br>▪ Fan problems<br>▪ Problem with A/C compressor (exhaust valve/seal) | ▪ Replace expansion valve<br>▪ Empty A/C system and refill<br>▪ Check A/C condenser, clean/replace<br>▪ Check fan<br>▪ Check A/C compressor, replace if necessary |
| Low | Low | ▪ Outflowing air is not cold<br>▪ Suction line colder than the evaporator | ▪ Too little refrigerant in system<br>▪ Blockage on the suction side | ▪ Empty A/C system and refill<br>▪ Check line and connections, replace if necessary |
| High | Low | ▪ Ice formation on fluid line<br>▪ Ice formation on filter-drier | ▪ Line/filter-drier blocked | ▪ Check filter-drier/line, replace if necessary |

# Types of A/C compressors

*The principle of operation of air conditioning compressors is always the same: gaseous refrigerant is drawn in and compressed. There are, however, different designs, and their exterior often indicates the respective type:*

**Piston air conditioning compressors** are very common and often have an elongated design. The number of pistons may vary depending on the type.

**Scroll air conditioning compressors** are relatively compact and can be recognized by their bulbous shape.

**Vane air conditioning compressors** have a very small design.

**Electric air conditioning compressors** can be immediately identified because they have no belt pulley.

## Controlling the air conditioning compressor performance

The air conditioning compressor or refrigerant pressure can be controlled in a number of ways. The classic method is by switching on and off the magnetic clutch and an internal, mechanical control valve. Modern designs have no magnetic clutch, but are permanently driven. Control is enabled by an electric control valve (Figure 1), which is actuated externally by pulse width modulation. There are also compressor variants that have a magnetic clutch and an electric control valve. Electrically driven air conditioning compressors are controlled only by the compressor speed.

## Safety valve

Most air conditioning compressors have an overpressure safety valve that releases refrigerant at approx. 35 bar, thereby protecting the system from further damage. The pressure-relief valves may include a sealant or membrane (Figure 2). In the event of damage, this provides an indication that refrigerant has been discharged due to a defect in the air conditioning system. There are also versions of the safety valve without a “seal” (Figure 3). If residues of oil or contrast agent are visible, it can be assumed that refrigerant has been released via the valve. The valve should thus be inspected in the event of a system defect.

**Figure 1**

**Figure 2**

**Figure 3**

# Filling A/C compressors with oil

*The following questions come up frequently regarding air conditioning compressor replacement:*

*a) Are new air conditioning compressors filled with oil?*

*b) How much oil do new air conditioning compressors contain?*

*c) How do I check the oil level in air conditioning compressors?*

*d) How do I fill new air conditioning compressors with oil?*

MAHLE air conditioning compressors come filled with a standard quantity of oil. Irrespective of the delivery condition of the air conditioning compressors, the oil filling quantity of each compressor must always be checked before installation and, if necessary, adjusted in accordance with the manufacturer specifications and the accompanying documentation. This is because many air conditioning compressors can be used in a wide range of vehicles and vehicle variants. The oil filling quantity must therefore be adjusted to the vehicle.

The oil quantity of the new air conditioning compressor is drained via the opening of the previously removed drain or fill plug (Figure 1). To do this, the shaft of the air conditioning compressor must be turned several times. The air conditioning compressor is then refilled using the total system oil filling quantity specified by the vehicle manufacturer. At the same time, the oil viscosity must be checked. The air conditioning compressor shaft is then turned several times to ensure that the oil is evenly distributed. Finally, the drain/fill connection on the air conditioning compressor is closed. The relevant specifications in the documentation supplied with the air conditioning compressor must be observed separately.

## Note

For air conditioning compressors without a drain/fill plug, the oil is drained via the high- and low-pressure connections (Figure 2) on the air conditioning compressor and filled via the low-pressure connection (Figure 3). Once again, the shaft of the air conditioning compressor is turned. If it is not possible to fill the entire oil quantity into the air conditioning compressor, the remaining quantity can be added to the refrigerant circuit via the air conditioning service unit.


# Characteristic features

**There is one anomaly for the following air conditioning compressor types:**

- Denso 5SL12C/5SEL12C/5SE12C
- Denso 5SA09C/5SE09/5SER09C
- Hanon VS16

Due to their design, the oil cannot be drained from these air conditioning compressors. They do not have an oil drain/fill plug, and it is not possible to drain the oil via the high-/low-pressure connections.

These air conditioning compressors are prefilled with the required system oil quantity. It is therefore essential to flush the air conditioning system before installing the new air conditioning compressor to remove any oil.

Electric air conditioning compressors are also filled with the correct system oil quantity. For these, too, the system must be flushed before installation.

Figure 1

Figure 2

Figure 3


Further details on the required workshop equipment from MAHLE Service Solutions can be found from page 72.

# Flushing the A/C system

## Flushing is obligatory!

Flushing the air conditioning system to remove contamination and harmful substances from the air conditioning circuit is one of the most important tasks performed during repair work or when an air conditioning compressor is damaged. Flushing is necessary to carry out repairs properly and avoid expensive follow-up work. It also preserves supplier warranty rights and ensures customer satisfaction. However, air conditioning compressors, expansion valves, throttle valves, and filter-driers cannot be flushed and must be bypassed by adapters during the flushing process. Once the flushing process has been completed, valves and filters must be replaced.

### Why flush?

1. If the air conditioning compressor is damaged, the contamination caused by metal abrasion must be removed.
2. Any remaining acid caused by the ingress of moisture must be eliminated.
3. Blockages caused by elastomer particles must be flushed out.
4. All traces of contaminated refrigerant or refrigerant oil must be removed.

### General information on flushing

- Carefully read through the relevant operating instructions, package inserts, information from the vehicle manufacturer, material safety data sheets, etc.
- Before and during implementation, follow the relevant safety regulations, including the technical information “Handling refrigerants” and “Instructions for removal and installation.”
- Air conditioning compressors, filter-driers/accumulators, and expansion and throttle valves may not be flushed and must be bypassed by adapters during the flushing process.
- Verify that all dirt particles and fragments of damaged components are removed from the refrigerant circuit.
- Ensure that no residues of flushing solution remain in the system by drying the components with nitrogen (do not use compressed air).
- Fill the air conditioning compressor with the correct amount and specification of oil (PAO 68 oil from MAHLE is particularly suitable). Allow for the flushed components when calculating the oil quantity.
- Before commissioning, turn the air conditioning compressor 10 times by hand.
- Replace the filter-drier or accumulator and the expansion or throttle valve.
- If necessary, fit a filter screen in the intake line of the air conditioning compressor.
- After evacuating the refrigerant circuit according to the specifications, fill with the prescribed quantity of refrigerant.
- Start the engine. Wait until the idling speed stabilizes.
- Over a period of 10 seconds, switch the air conditioning system on and off several times.
- Carry out a system pressure, performance, and leakage test.

# Flushing the air conditioning system and its components

Flushing the air conditioning system removes contaminants and harmful substances from the refrigerant circuit. The following information serves to introduce the operator to the subject of air conditioning flushing by providing answers to important questions such as:

- Why air conditioning systems need flushing
- What the term flushing means in the context of automotive air conditioning
- Which types of contamination can be removed by flushing and what effect these contaminants can have
- What flushing methods there are and how they are applied

Ageing filter-drier

## Why do vehicle air conditioning systems require flushing?

Defective system components—such as ageing filter-driers (as shown in the illustration), damage to the air conditioning compressor, etc.—can spread dirt particles that are carried with the refrigerant and distributed throughout the entire air conditioning system. If the response to air conditioning compressor damage is simply to replace the air conditioning compressor, dirt particles may quickly accumulate in the new air conditioning compressor. This can destroy not only the newly installed system component, but also the expansion/throttle valve or multiflow components, and result in an expensive follow-up repair. To avoid this, the system must always be flushed after component damage that could result in contamination of the refrigerant circuit by metal swarf, rubber abrasion, etc. Flushing is now required by many vehicle and air conditioning compressor manufacturers.

## What does the term flushing mean in the context of automotive air conditioning?

Flushing is the removal of contaminants or harmful substances from the refrigerant circuit. It is necessary to ensure proper repairs, avoid expensive follow-up work, preserve supplier warranty rights, and keep customers satisfied.

### What types of contamination can be removed by flushing and what effects can they have if not eliminated?

- Abrasion particles from compressor damage:
  The material particles clog expansion valves, throttle valves (orifice tubes), or multiflow components (air conditioning condenser, evaporator).
- Moisture:
  Expansion valves and orifice tubes can freeze. Chemical reactions between refrigerants or refrigerant oils and moisture can lead to the formation of acids that cause hose lines and O-rings to become porous. System components are damaged by corrosion.
- Elastomers (rubber):
  Elastomer particles clog expansion valves, orifice tubes, and multiflow components.
- Contaminated refrigerant oil or refrigerant:
  Contaminated refrigerant or mixing of different refrigerant oils can also result in the formation of acids. These can cause hose lines and O-rings to become porous. Other system components may be damaged by corrosion.

## 1. Chemical substance (flushing agent)

The connection lines or systems components must be flushed individually. They are flushed with a chemical substance (flushing agent) using a universal adapter on a flushing gun. Following the flushing process, the remaining flushing agent must be eliminated from the refrigerant circuit using nitrogen and the refrigerant circuit dried. A good result can be achieved by the use of both flushing agent and nitrogen. The flushing agent is used first (in combination with compressed air) to remove stuck particles and hardened deposits. Nitrogen is then blown through the system to dry the refrigerant circuit or components. It is important to ensure that the maximum pressure does not exceed 12 bar when blowing out the system.

### Disadvantage

The cost of the chemical cleaning agent and its proper disposal, as well as the additional assembly cost for installing and removing the lines and components. In addition, this flushing method is not approved by vehicle manufacturers.

Abrasion compressor damage

Contaminated oil

# 2. Refrigerant

Air conditioning service units with an integrated flushing function allow fast, low-cost flushing of the air conditioning system with the refrigerants R134a or R1234yf. An external flushing unit and parts from a flushing kit will be required—both are available separately. After starting the function on the unit, the vehicle air conditioning system is flushed with liquid refrigerant under high pressure and then evacuated. This cycle should be completed three times in order to achieve an optimal cleaning result.

## Disadvantage

The service unit cannot be used for other vehicles during the application. The filter element of the flushing unit must be replaced regularly.

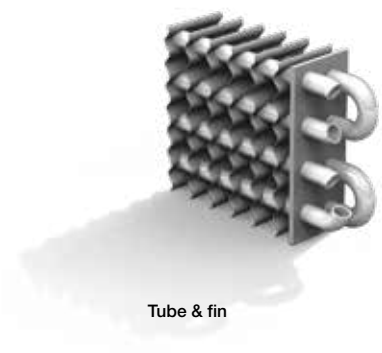
## Note

While tube & fin and serpentine components are usually easy to clean, it is often not possible to clean multiflow (parallel flow) components. If there is any doubt about the cleaning success for such components, it is best to replace them. Once the refrigerant circuit has been flushed, it must always be refilled with the right amount of new oil.

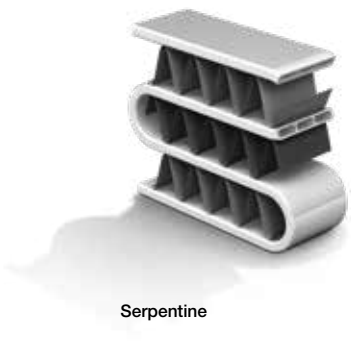
**The following values (% of total quantity of oil) serve as a guide:**

- Air conditioning condenser: 10%
- Filter-drier/accumulator: 10%
- Evaporator: 20%
- Hoses/pipework: 10%
- Failure to comply with the above points may void the warranty

Further details on the required workshop equipment from MAHLE Service Solutions can be found from page 72.



Tube & fin



Serpentine

Multiflow

# Advantages and disadvantages of the two flushing methods

## Flushing agent

### Flushing method

Using an additional flushing device and a chemical solution, the system components are flushed against the direction of the refrigerant flow. Nitrogen must be used to remove the remaining flushing agent and dry the system.

### Advantage

- Removes loose and stuck particles and oil

### Disadvantages

- Cost of the flushing agent
- Disposal cost for the flushing agent
- Not approved by vehicle manufacturers

## Refrigerant

### Flushing method

Using the air conditioning service unit and an additional flushing device with filters and adapters, the system components are flushed against the direction of the refrigerant flow (both available separately).

### Advantages

- No cost for a separate flushing agent, as the existing refrigerant is used as the flushing agent
- No disposal cost for the flushing agent
- Removes loose dirt particles and oil
- Method is approved by various vehicle manufacturers

### Disadvantages

- Filter element of the flushing unit must be replaced regularly
- Air conditioning service unit cannot be used for other purposes during application

# Leak detection techniques

*Leaks in the refrigerant circuit are one of the most common causes of air conditioning malfunctions. They cause the filling quantity to drop without being noticed, resulting in performance losses up to total failure. The refrigerant R134a in particular is known to diffuse from rubber pipes and connections. Since it is not immediately obvious to the air conditioning technician whether there is a leak or the system is simply losing refrigerant based on the number of operating hours, thorough leak detection is essential.*

## The following are tested:

- All connections and lines
- Air conditioning compressor
- Air conditioning condenser and evaporator
- Filter-drier
- Pressure switch
- Service connections
- Expansion valve

## Three leak detection methods are recommended:

1. Contrast agent and UV lamp
2. Electronic leak detection
3. Leak detection using forming gas

## 1 Leak detection using contrast agent

### Contrast agent

There are various ways of adding the contrast agent to the refrigerant (e.g., spotgun contrast agent, dye cartridges).

### Spotgun/Pro-Shot

The Spotgun cartridge applicator or the Pro-Shot system is used to inject the exact amount of contrast agent required. Additional advantage: the contrast agent can be applied when the system is full.

### Leak detection lamp

The leaked contrast agent is made visible with the UV lamp.

Further details on the required workshop equipment from MAHLE Service Solutions can be found from page 72.

## 2 Leak detection with electronic tester/with nitrogen/by foaming

### Electronic leak detection

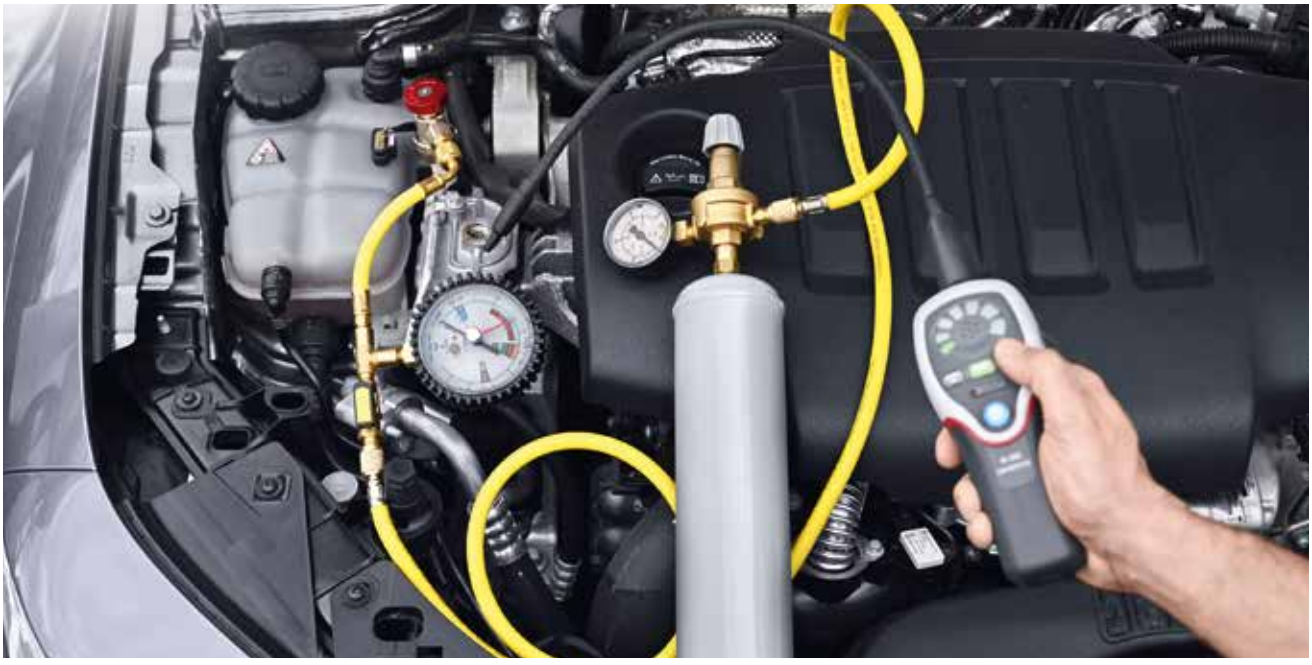
Leaks are indicated by an acoustic signal. Halogen gases are identified and even extremely small leaks in hard-to-reach areas (e.g., evaporator leaks) are detected.

### Leak detection with nitrogen set

In addition to drying the system, this tool can also be used for leakage testing. For this application, a filling adapter is needed for the service connection as well as a hose adapter. The emptied air conditioning system is filled with nitrogen (max. 12 bar). It is then monitored over an extended time period (e.g., 5–10 min.) to see whether the pressure remains constant. Leaks can be detected by listening for a hissing noise. Otherwise, it makes sense to identify a leak using leak detecting agent. The leak detecting agent is sprayed on from the outside. Foam forms at the site of the leak. Only major leaks in easily accessible places can be detected using this method.

## 3 Leak detection with forming gas set

To trace leaks, the empty air conditioning system is filled with forming gas—a mixture of 95% nitrogen and 5% hydrogen. The components are checked for leaks using a special electronic leak detector. Since hydrogen is lighter than air, the sensor must be guided slowly above the suspected leak (line connections/components). After leak detection has been completed, the forming gas can be discharged to the environment. This leak detection method complies with Art. 6, Section 3 of EU Directive 2006/40/EC.



# Repair of pipework and hoses

## LOKRING pipe connection technology

LOKRING is a fast and very cost-effective repair method. Defective pipework can be fixed on the spot, saving the expense and waiting time associated with ordering a complete new pipework system. Often, the work can even be done with the pipes still installed. The LOKRING principle has proven itself in air conditioning and refrigeration.

## It offers nine processing advantages:

- Quick and simple assembly
- Nondetachable, hermetically sealed metal–metal seals
- Secure connection of pipes made of different materials
- No particular pipe preparation necessary
- Handy assembly tools
- Large dimensional tolerances permitted
- No notch effect in assembly area
- No welding, soldering, or thread cutting
- Environmentally friendly and safe connection technology

LOKRING is so leaktight that there is no pressure drop and no reduction in throughput speed. As an additional safeguard, the surfaces of the pipe ends are wetted with the LOKPREP sealing liquid. The system is permanently leaktight at the LOKRING points. The pipe connections are designed for a maximum nominal pressure of 50 bar and a test pressure of 200 bar. They can be used within a temperature range of –50°C to +150°C.

Metal with metal: **LOKRING fitting**

## Press tools for refrigerant fittings

The crimping tool allows hoses and fittings to be affixed quickly and securely and is the ideal press system for stationary and mobile use. The supplied hydraulic hand pump builds up the pressure. You can build up an enormous compressive force in just a few hand movements, and the tool has a long adjustment range. Therefore, hose repairs can often be performed with the hoses still fitted. Similar to LOKRING, the crimping system reduces repair and waiting times and cuts costs for replacement parts.

Hose with hose: **crimp fitting**

# Refrigerants R12, R134a, R1234yf

There are still vehicles on the market with air conditioning systems that were originally designed for the R12 refrigerant. R12 was officially withdrawn from use in vehicle air conditioning systems in 2001. As of this date, R12 systems had to be converted during maintenance or repair work. Since then, R134a has been used as a replacement refrigerant, in addition to a few “drop-in” refrigerants (refrigerant mixes).

Even today, the conversion of R12 to R134a is still a topic for vintage and modern classic cars as well as in some countries outside the EU.

The system must be checked for leaktightness during conversion and leaks must be eliminated in advance. All components should be checked for proper function and damage. The filter-drier must be replaced. Sealing rings should be changed. In addition, the mineral oil of the R12 system has to be replaced by PAG or PAO oil. During this process, it is also advisable to flush the air conditioning system.

R134a has a high GWP (Global Warming Potential) of 1,430. EC Directive 2006/40/EC states that in future only refrigerants with a GWP lower than 150 may be used.

Air conditioning systems in category M1 vehicles (passenger cars with up to 8 seats) and category N1 vehicles (commercial vehicles with a permissible total weight of up to 3.5 t), for which a type approval was issued from January 1, 2011, will no longer be filled with R134a. Since January 1, 2017, vehicles filled with R134a can no longer be registered for the first time. However, the use of R134a is still permitted for service and maintenance work on existing R134a systems. The most common new refrigerant being used is R1234yf with a GWP of 4. But other refrigerants can also be used, as long as the GWP value is below 150.

This, of course, has an impact on workshops and their service staff. The purchase of new service units seems unavoidable. Separate measures for storage and handling also apply for the new refrigerants.

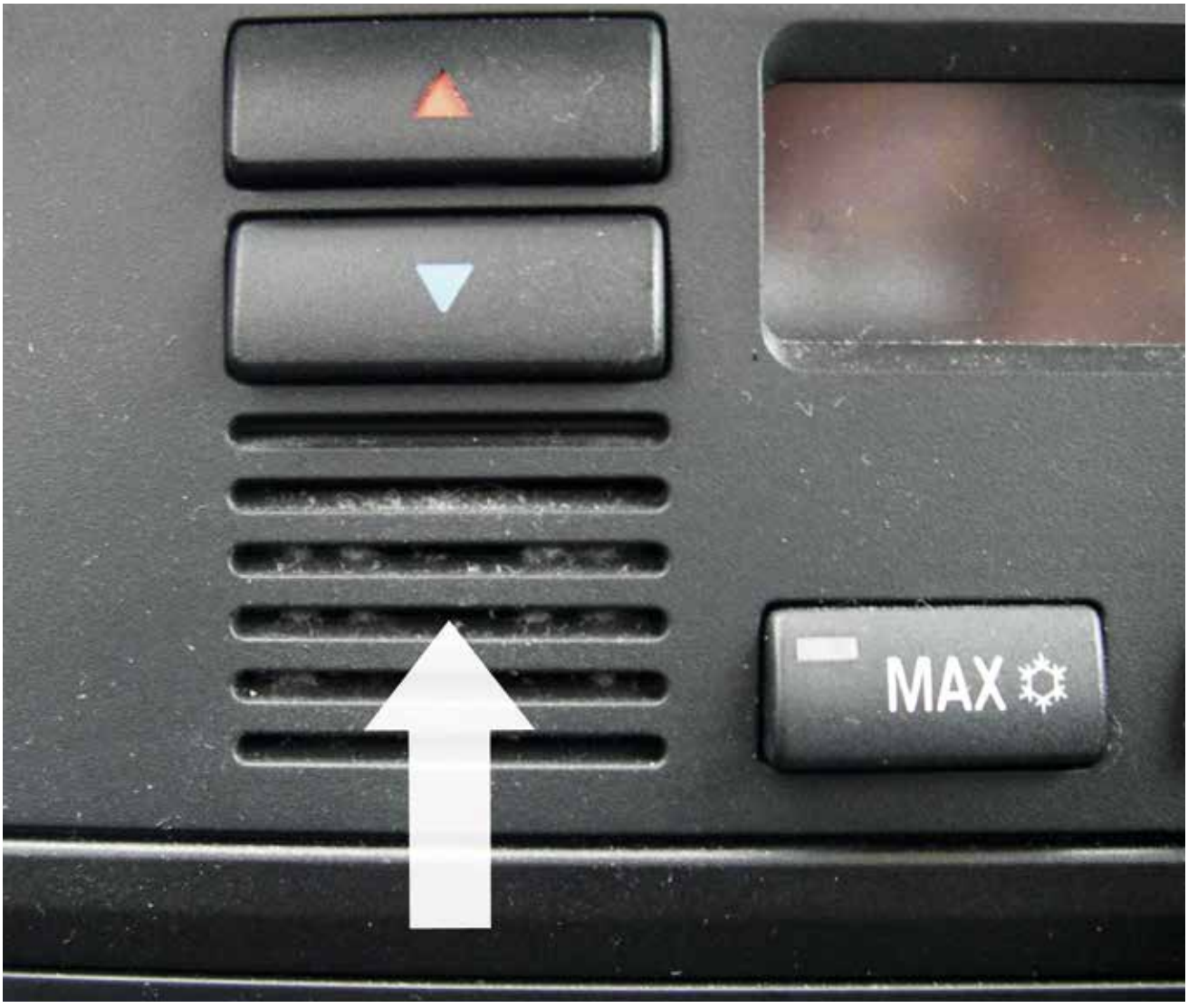
Further details on the required workshop equipment from MAHLE Service Solutions can be found from page 72.

# Cabin temperature sensors

## Inadequate temperature regulation due to contaminated sensors

The cabin temperature sensor is located in the airflow of a miniature fan (usually in the control unit). It transmits the temperature of the cabin air to the control unit in the form of a resistance value. The measured value is compared with the setpoint value.

Nicotine, dust, etc. can severely clog the sensor (see figure). If not enough of the airflow that is drawn in finds its way to the sensor, incorrect measurements and malfunctions may result. The correct functioning of the air conditioning/heating control system is then no longer guaranteed. This manifests itself in a continuous up-and-down adjustment of the temperature—very cold one moment and very hot the next. The sensor can be cleaned using special cleaning agents (e.g., acetone). Deposits of dust can be removed beforehand with a minimal amount of compressed air. In most cases, the temperature control is back to normal once the sensor has been cleaned.



# Sealants

Air conditioning system sealants are made up of a mixture of chemicals. They are added to the air conditioning system to seal minor leaks in components and O-rings.

Sealants escape along with the refrigerant at the site of the leak. They react with the oxygen in the air and moisture, cures, and seals the leak.

The use of sealants is problematic for a number of reasons. According to EU regulations and directives, a leaking air conditioning system may not be put back into operation or filled with refrigerant without first eliminating the leak. There are penalties for noncompliance with this principle.

If sealants are used, refrigerant will continue to escape from the leaking air conditioning system until the sealant takes effect (assuming that it really does completely stop the leak). EU law and national regulations are thus violated and refrigerants are released unnecessarily. The only possible use for sealants would be to add them to intact systems as a preventative measure.

If the components already show signs of damage or weakness (e.g., corrosion), it is a matter of time before another leak occurs somewhere else.

When extracting refrigerant from vehicles that have previously been filled with sealant, there is a risk that the sealant inside the air conditioning service unit will react and cause blockages or damage. For many vehicle, equipment, and component manufacturers, the use of sealants will void warranty claims.

Ultimately, the use of sealants in a leaky air conditioning system is not a legitimate and permanent method of repair.

# Innovative thermal and cabin comfort management

## Where is the trend and development of air conditioning systems and cabin comfort heading?

Multizone air conditioning systems are increasingly becoming the standard. In the premium class, air conditioning systems with “humidity management” are already being installed, counteracting excessively dry air.

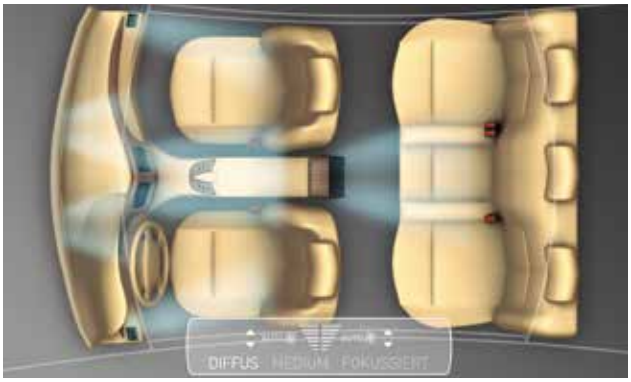
In the future, “cabin climate management” will be part of air conditioning and ventilation systems. This means that air quality sensors are used to create the best possible climate inside the vehicle in conjunction with air treatment systems.

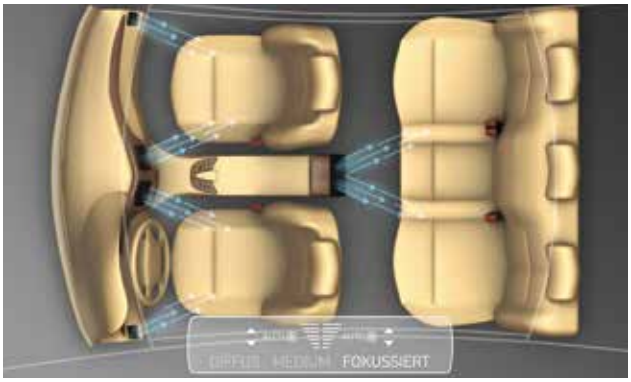
Electronically controlled air conditioning compressors will become standard in all vehicle classes. They allow individual performance matching and thus reduce fuel consumption. Optimized components, lines, and seals will minimize refrigerant loss rates.

## Perfect climate for everyone, no matter the seat

### A perfect climate means:

- Individual thermal comfort for every seat in the vehicle
- Draft-free, comfortable ventilation
- High air quality
- Acoustic comfort, minimal perception of noise
- Simple, clear operation




**To achieve this, systems such as PHYSIO-CONTROL® from MAHLE and BHTC have been developed:**

PHYSIO-CONTROL® takes multizone climate control a step further. The system is able to selectively detect and control the main variables for comfort in the vehicle cabin (solar load, air humidity, air volume, and air temperature) at defined locations. Subsystems are precisely coordinated to work together.

The technical complexity is immense. For example, an intelligent sun sensor uses hardware and software to measure the exact solid angle and intensity of the solar load in relation to the vehicle. A calculation model determines the radiation intensity on the body parts exposed to the sun by recording the contours of the vehicle.

Optimal climate in the vehicle cabin also means keeping the windows clear at all times. To prevent the windows from fogging up, the humidity is measured continuously near the front windshield. If necessary, the air is dried by switching the air conditioning system on. Humidity management is another intervention of which the vehicle passengers are unaware. This involves keeping the air humidity in the cabin constant by controlling the air conditioning compressor and the fresh air flap.

A subsystem made up of so-called comfort ventilation nozzles is used for this purpose. These are designed in such a way that the individual diffuser nozzles can be precisely swiveled and continuously varied from direct to diffuse air discharge. The nozzles supply exactly the air volume and type that is perceived as comfortable to the desired areas of the passenger. This can be in the form of a concentrated air blast (spot) for cooling on a hot summer's day, or a draft-free, diffuse air flow.

The desired air distribution profile is defined by operating the air volume control. It adjusts the volume and thus the velocity of the air emitted by the individual vent nozzles. This is made possible by the development of simulation software for the entire air conditioning and air intake system. The air volume control detects a one-sided increase or decrease in air volume, for example, due to the mechanical closing of the air vent. Control algorithms stored in the software prevent the air conditions on the other side of the vehicle from changing. The air volume and air distribution can thus be adjusted individually without unduly affecting other areas and passengers in the vehicle.

Another innovation is the selection of various climate styles. Passengers preselect the spot, moderate, or diffuse settings, depending on comfort type. The "fresh, sporty" type is directly supplied with cool air, whereas the "more sensitive" soul receives fresh air without being exposed to drafts.


## Air quality

In modern air conditioning systems, supplying the vehicle cabin with good air quality is a multistage process. This is known as a “comfort staircase.” It begins by filtering the fresh and recirculated air with the help of a nitrogen oxide sensor. An $NO_x$ or air quality sensor determines the proportion of pollutants in the fresh air supply and this information is used to automatically control the fresh air/recirculated air. Filtering with activated carbon is becoming increasingly important in this context.

The surface of the evaporator should be such that microorganisms do not give rise to odors. To avoid this from happening, MAHLE has developed a special coating: BehrOxal®. It is an environmentally friendly coating technology that provides a corrosion-resistant and hydrophilic aluminum surface without toxic and aggressive chemicals. This ensures very good condensation drainage and rapid drying of the evaporator surface.

The above-mentioned measures neutralize contamination and odors. To further increase the level of comfort, an oxygen ionizer can be added to remove bacteria and germs from the air and make it feel fresh. A fragrance system can also be used to fill the cabin air with a variety of aromas.

## Ergonomics

It has been found that adjusting the air conditioning system can distract the driver from what is happening on the road and that air conditioning systems are not always operated correctly.

### The addition of more functions can make the air conditioning system more difficult to operate. Here are some examples:

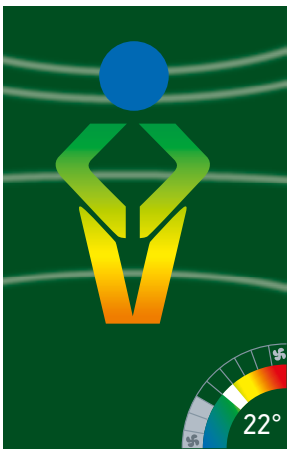
- Lack of a clear, logical arrangement of control elements and displays
- Complicated and at times overwhelming operation
- Confusing labeling of control elements
- Lack of clear status messages

### Studies have shown that the following criteria should be taken into account when designing air conditioning control units:

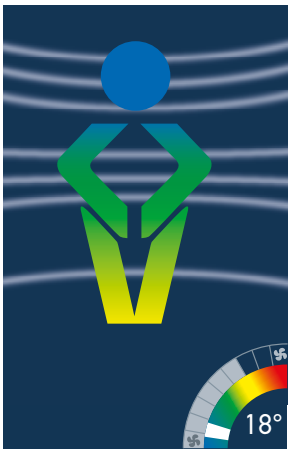
- Display, control elements, and symbols should be large enough
- Graphics or text images should be used instead of text only
- Control elements with related functions should be grouped together
- Primary functions should not be paired with other functions and/or hidden in secondary functions
- Control unit and display should be in close proximity

Control units developed according to the above criteria minimize distraction, allowing the driver to focus on the actual driving. The symbols used are either familiar or their meaning is intuitively obvious. The main control elements can also be located by touch without diverting the focus from the road. Menu navigation has been kept simple and a comfort preselection is possible. The user interface concepts developed by BHTC, for example, make it easy to select the desired climate settings automatically based on various climate styles. The visualization design aims to make the settings quickly recognizable and self-explanatory. This is achieved through high-resolution display technologies that allow the display to adapt to the situation.

In recent years, there has been a great deal of innovation in the field of air conditioning and passenger comfort. This trend is set to continue. The challenge for the workshops is keeping pace with these developments. Only in this way can such complex systems be maintained, tested, and repaired.




**Neutral/auto**




**Fresh**

# Thermal management in electric and hybrid vehicles

*Electric and hybrid technology also introduces significant changes to thermal management in both the coolant and refrigerant circuits. The areas and components of thermal management that are affected are described below, along with how this changes the principles of operation and what it means for your work.*

## Interior air conditioning

In conventional drive concepts with combustion engines, the interior air conditioning is directly dependent on the engine operation due to the mechanically driven air conditioning compressor. Air conditioning compressors with belt drives are also used in vehicles that are referred to by specialists as micro hybrids and only have a stop-start function. The problem is that when the vehicle is at a standstill and the engine is switched off, the temperature at the evaporator outlet of the air conditioning system starts to increase after just two seconds. The associated slow rise in the discharge temperature of the ventilation and the increase in humidity can be annoying for passengers.

To counter this problem, cooling batteries—known as storage evaporators—can be used.

The storage evaporator comprises two cores: an evaporator core and an accumulator core. Refrigerant flows through both cores in the start-up phase or when the engine is running. In the meantime, a latent medium in the evaporator is cooled to the extent that it freezes, which makes it a cooling battery.

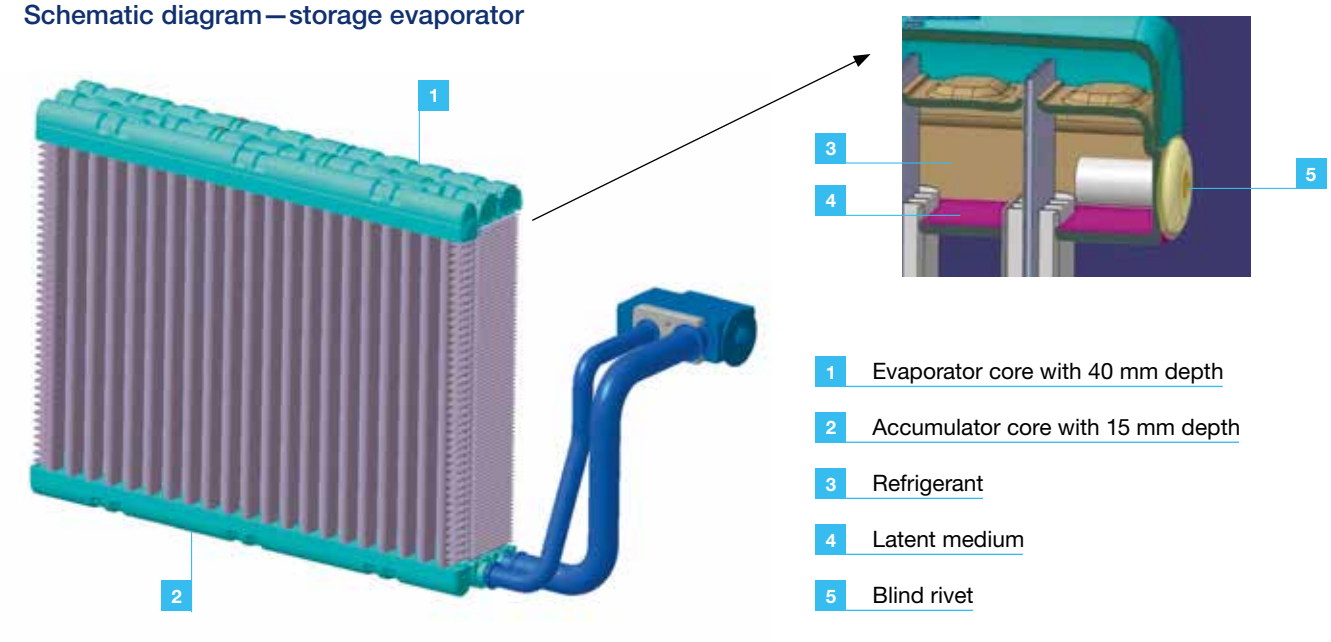
**Storage evaporator**

## Important!

Never work on live high-voltage components. Always take note of the warning labels on components and elements.

**Example: warning labels on modules and components**

## Schematic diagram—storage evaporator




In the stop phase, the engine is switched off and the air conditioning compressor is no longer driven. The warm air flowing past the evaporator cools down and a heat exchange takes place. This exchange continues until the latent medium has completely melted. Once the journey is resumed, the process restarts. After just one minute, the storage evaporator starts cooling the air again.

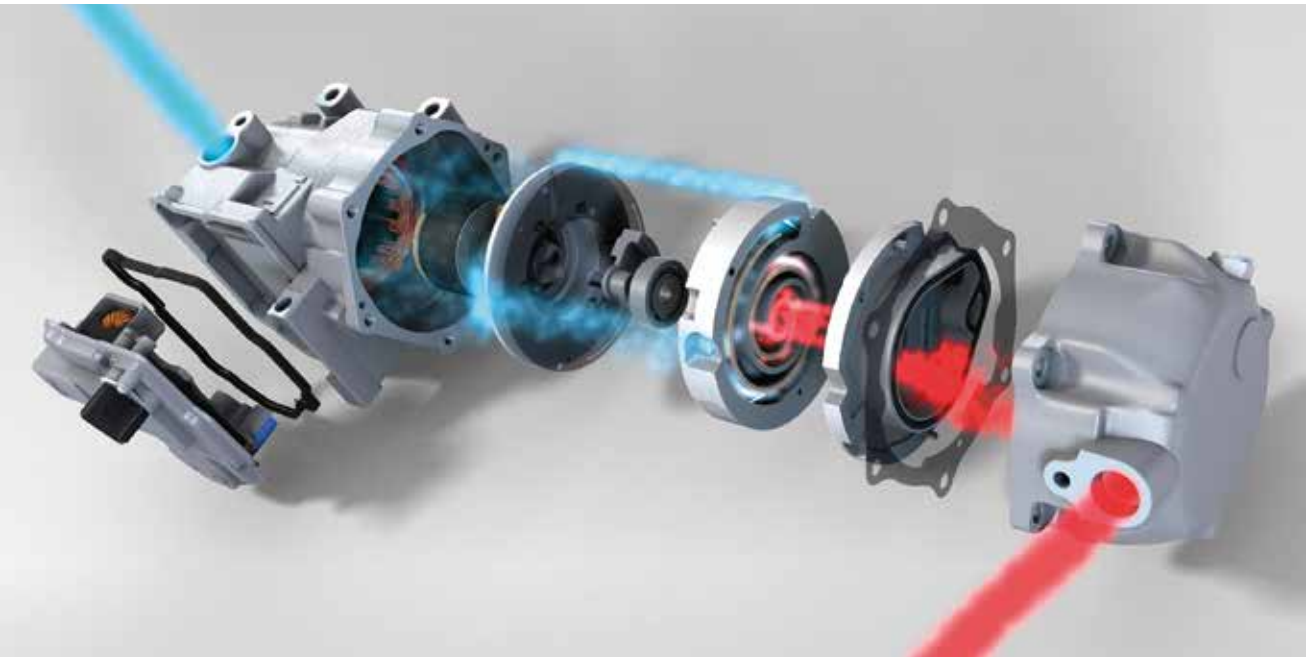
On vehicles that do not have a storage evaporator, the engine has to be restarted after a short standstill period in very warm weather. This is the only way to maintain interior cooling.

Interior air conditioning also includes heating the passenger compartment, if required. In full hybrid vehicles, the combustion engine is switched off in electric driving mode. The residual heat in the water circuit is only sufficient to heat the cabin for a short period of time. Electric PTC heating elements are then switched on to take over the heating function. The operation is similar to that of a hair dryer: the air that is drawn in by the interior fan is heated up as it flows past the heating elements and then passes into the cabin.

# High-voltage A/C compressors

## Function

*Vehicles with full hybrid technology use high-voltage electric air conditioning compressors that do not depend on the operation of the combustion engine. This innovative drive concept clears the way for automotive air conditioning functions that further increase comfort for passengers.*



It is possible to precool the heated cabin to the desired temperature before starting the journey. This can be activated via remote control.

Cooling while stationary is only possible if there is enough charge in the battery. The air conditioning compressor is turned down to the lowest power output possible while still providing the required level of air conditioning.

In the high-voltage air conditioning compressors used today, the power is regulated by adjusting the speed in steps of 50 rpm. It is therefore not necessary to have an internal power control.

In contrast to the swash plate principle, which is used mainly in belt-driven compressors, high-voltage air conditioning compressors use the scroll principle to compress the refrigerant. This results in weight savings of 20% and a reduction in displacement of the same amount without compromising output.

A DC voltage of over 200 volts is used to generate the right amount of torque to drive the electric air conditioning compressor—a very high voltage in this vehicle sector. The inverter fitted into the electric motor unit converts this DC voltage into the three-phase AC voltage required by the brushless electric motor. The return flow of refrigerant to the suction side facilitates the necessary heat transfer from the inverter and the motor windings.

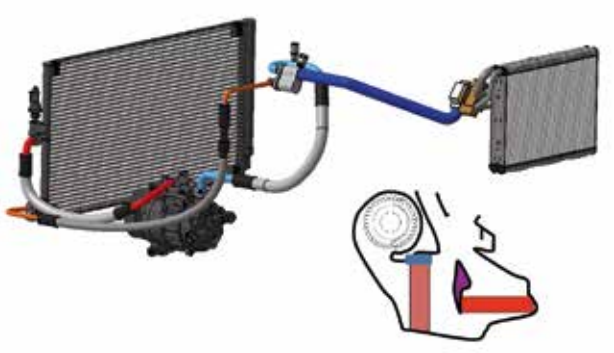
# Temperature management of the battery

## Comparison

The battery is essential for the operation of an electric and hybrid vehicle. It has to provide the large amount of energy required for the drive both quickly and reliably. Lithium-ion and nickel-metal hybrid high-voltage batteries are the most common types. This further reduces the size and weight of hybrid vehicle batteries.

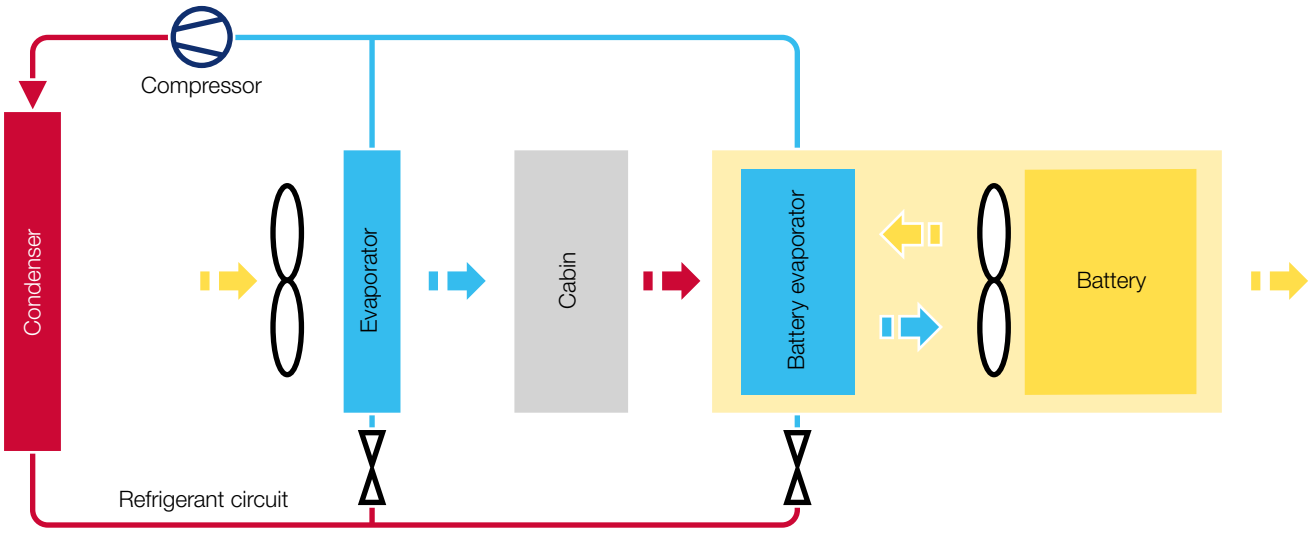
It is essential that the batteries used are operated within a defined temperature window. Service life decreases at operating temperatures of +40°C or higher, while efficiency drops and output is lower at temperatures below 0°C. Furthermore, the temperature difference between the individual cells must not exceed a particular value.

Brief peak loads in connection with high current flows, such as from recuperation and boosting, lead to a significant increase in the temperature of the cells. High outside temperatures in the summer months can also contribute to the temperature quickly



reaching the critical 40°C level. The consequences of exceeding this temperature level are faster aging and the associated premature failure of the battery. Vehicle manufacturers strive to ensure that the calculated battery service life is one car life (around 8–10 years). Therefore, the aging process can only be countered with an appropriate temperature management system. So far, three different temperature management options have been used:

### Option 1



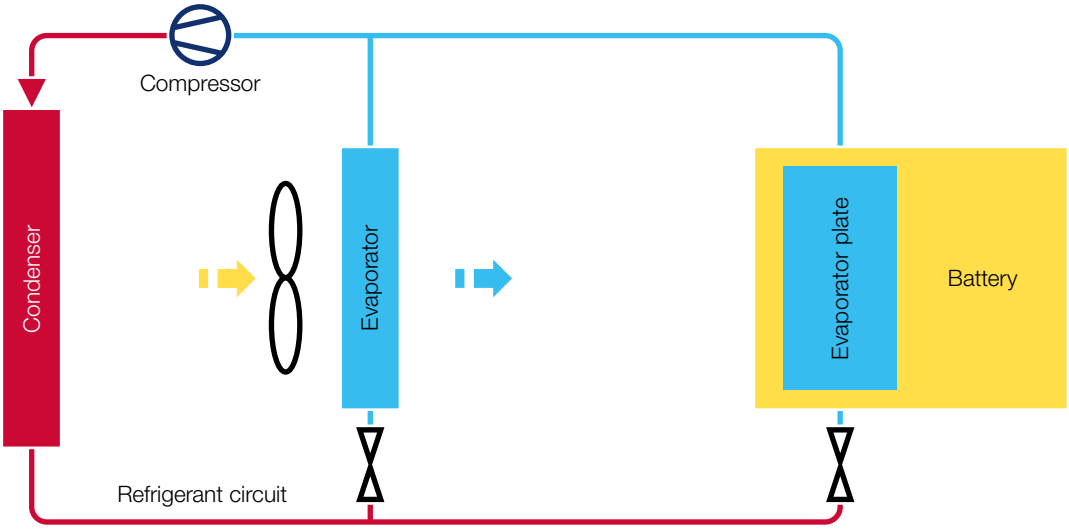

Air is drawn in from the air-conditioned vehicle cabin and used to cool the battery. The cool air drawn in from the cabin has a temperature of less than 40°C. This air circulates around the accessible surfaces of the battery pack.

### This has the following disadvantages:

- Low cooling effect
- Air drawn in from the cabin cannot be used to reduce the temperature evenly
- Considerable effort required to guide the air
- Possible annoying noises in the cabin from the blower
- There is a direct connection between the passenger cabin and the battery via the air ducts. This is problematic for safety reasons (e.g., outgassing of the battery).
- Another factor that should not be underestimated is the risk of dirt entering the battery pack, because the air from the vehicle cabin also contains dust. The dust is deposited between the cells, where it combines with condensed humidity to form a conductive layer. This layer allows leak currents to arise within the battery.

To avoid this risk, the intake air is filtered. Alternatively, air cooling can also be provided by a separate small air conditioning unit similar to the separate rear air conditioning systems in premium-class vehicles.

### Option 2




A special evaporator plate inside the battery cell is connected to the air conditioning system in the vehicle. This is achieved with the so-called splitting process on the high-pressure and low-pressure side via pipelines and an expansion valve. The interior evaporator and the evaporator plate of the battery, which works like a conventional evaporator, are thus connected to the same circuit.

The different tasks for the two evaporators result in correspondingly different requirements for refrigerant flow. While the interior cooling system aims to satisfy the comfort demand of the passengers, the high-voltage battery must be cooled to varying degrees of intensity depending on the driving situation and the ambient temperature.

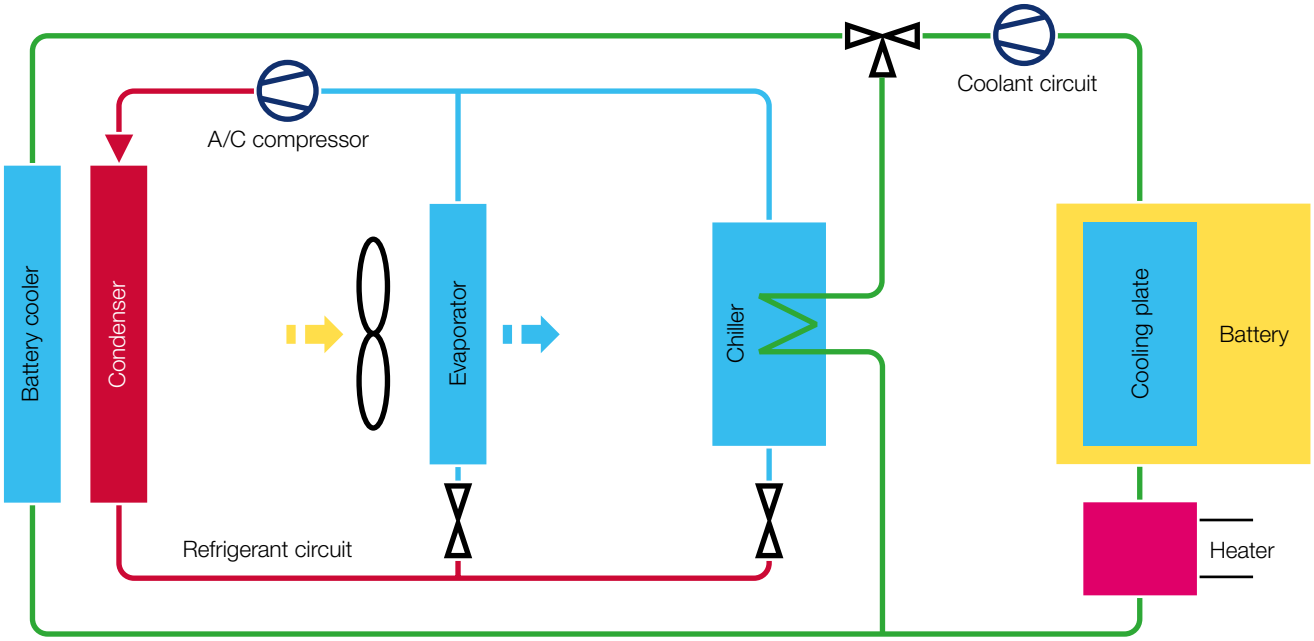
These requirements are the defining factors for the complex control of the quantity of evaporated refrigerant. The special design of the evaporator plate and its resulting integration into the battery offer a large contact surface for the heat transfer. This means it is possible to guarantee that the critical maximum temperature of 40°C is not exceeded.

When outside temperatures are very low, an increase in the temperature of the battery to bring it to its ideal temperature of least 15°C may be required. However, the evaporator plate cannot help in this situation. A cold battery is less powerful than one at the right temperature. It is also difficult to charge the battery when temperatures are significantly below freezing. In a mild hybrid, this can be tolerated: in extreme cases, the hybrid function is only available in a limited capacity. It is, however, still possible to drive with the combustion engine. In a battery electric vehicle, on the other hand, a battery heater needs to be fitted so that the vehicle can be started and driven in any situation in winter.

## Note

Evaporator plates integrated directly into the battery cannot be individually replaced. Therefore, the whole battery needs to be replaced in the event of damage.

### Option 3




The correct temperature plays a key role for batteries with higher capacities. Therefore, at very low temperatures, additional heating of the battery is required to bring it within the ideal temperature range. This is the only way to achieve a satisfactory cruising range when in electric driving mode.

To provide this additional heating, the battery is integrated into a secondary circuit. This circuit ensures that the ideal operating temperature of 15–30°C is maintained at all times. Coolant made of water and glycol (green circuit) flows through a cooling plate integrated into the battery core. At lower temperatures, the coolant can be quickly heated by a heater to reach the ideal temperature. The heater is switched off if the temperature in the battery rises when the hybrid functions are being used. Benefiting from the headwind, the coolant can then be cooled via a battery cooler or a low-temperature radiator located in the front of the vehicle.

If the cooling provided by the battery cooler is not sufficient at high outside temperatures, the coolant flows through a chiller. This is where the refrigerant from the vehicle air conditioning system is evaporated. Moreover, heat can be transferred from the secondary circuit to the evaporating refrigerant in a very compact space and with a high power density. An additional recooling of the coolant takes place. Thanks to the use of the special heat exchanger, the battery can be operated within the most efficient temperature window.

## Further training for the repair of electric and hybrid vehicles

Ongoing training is required to maintain and repair the complex systems, especially those for thermal management in electric and hybrid vehicles. In Germany, for example, employees working on such high-voltage systems require an additional two-day training course to become “experts for work on high-voltage (HV) intrinsically safe vehicles.”

This course teaches the participants to recognize the risks when working on systems of this kind as well as how to switch off all current to the system for the duration of the work. People who have not received appropriate training are prohibited from working on high-voltage systems and their components. The repair or replacement of live high-voltage components (batteries) requires special qualification.

# Thermal management training from MAHLE:

Whether trainees, qualified technicians, master technicians, or engineers: MAHLE Aftermarket offers the right training course for everyone.

In addition to covering theory, MAHLE Aftermarket offers special practical training on damage prevention for passenger cars and trucks as well as for agricultural and construction machinery.

At MAHLE Aftermarket, we are flexible: you select the topic, tell us when and where the training should take place—and we take care of the rest. Simply speak to your MAHLE Aftermarket trading partner or contact us directly at: **ma.training@mahle.com**

MAHLE Aftermarket’s technical experts look forward to organizing interesting and exciting events for you.

- T-AC Air conditioning in the vehicle: air conditioning system design, function, and common causes of failure
- C-SK Expertise in vehicle air conditioning

## Maintenance of hybrid vehicles

A special situation also arises when performing routine inspections and repair work (e.g., on exhaust systems, tires, shock absorbers, oil change, tire change).

This work may only be performed by employees who have been trained by an “expert for work on HV intrinsically safe vehicles” on the dangers of these high-voltage systems and instructed accordingly.

It is also essential to use tools that comply with the specifications of the vehicle manufacturer.

Tools for working on high-voltage systems

Workshops are required to instruct all employees involved in the operation, maintenance, and repair of electric and hybrid vehicles. Please take into account the respective country-specific conditions.

During the air conditioning check and service, it is important to ensure that the electric air conditioning compressors are not lubricated with the usual PAG oils. These do not have the necessary insulating properties. POE oil is generally used, as it does possess these properties. MAHLE PAO 68 AA1 Clear Version oil (without leak detecting agent) can also be used.

Air conditioning service units with an internal flushing function and a separate fresh oil reservoir are therefore recommended for the air conditioning check and service on electric and hybrid vehicles. In this way, fresh oil mixtures of different oil types can be ruled out.

# PAG and PAO oils

Oil plays an important role in air conditioning systems.

## There are many types of oil. Which one is recommended?

*Whether you are changing the air conditioning compressor oil or topping it up during an air conditioning service: oil in the air conditioning system performs vital functions—just like the blood in the human body.*

That is why using a high-grade air conditioning compressor oil is crucial for ensuring that the system can be used safely and for a long time. Just like in an engine, the use of low-grade or incorrect oils results in increased wear, premature failure of the air conditioning compressor, and loss of the warranty or guarantee.

The wrong choice can lead to damage. Vehicle- or manufacturer-specific instructions must be followed carefully.

# PAG oil

## Performance for a good atmosphere

### Product features

- PAG oils are fully synthetic, hygroscopic oils based on polyalkylene glycol.
- Used in production by many vehicle and air conditioning compressor manufacturers in air conditioning systems with refrigerant R134a, available at various viscosities.
- Special new PAG oils 46 YF and 100 YF suitable for both R1234yf and R134a refrigerants.

### Advantages and effect

- PAG oils are highly miscible with R134a (PAG oils 46 YF and 100 YF can also be mixed with R1234yf) and are suitable for lubricating the air conditioning systems of most passenger cars and commercial vehicles.
- It is important to choose the right viscosity class when using PAG oils (PAG 46, PAG 100, PAG 150). The vehicle manufacturer specifications and approved products should be taken into account.

### Additional details

The disadvantage of PAG oils is that they are hygroscopic, which means that they absorb and bind moisture from the ambient air.

If the moisture content in the air conditioning system is too high, this can contribute to the formation of acids and corrosion, resulting in damage to components and leaks.

For this reason, any oil container that has been opened must be resealed immediately, and the residual oil will only have a limited shelf life. This applies particularly to fresh oil containers in air conditioning service units.


## New to the range

New PAG SP-A2 oil from Sanden for special, electric Sanden air conditioning compressors
Part number ACPL 9 000P/8FX 351 213-141

# PAO 68 oil and PAO 68 Plus UV oil

## Product features

- Nonhygroscopic: in contrast to other oils, these do not absorb any moisture from the ambient air.
- Can be used as an alternative to a range of PAG oils (see application overview): stock one oil instead of three.
- Successfully used in practice for more than 20 years.
- Helps increase the performance of the air conditioning system.
- No adverse effects on components in the air conditioning circuit (also applies to use in air conditioning service units/ confirmed by manufacturers on the basis of sealed tube tests in accordance with the ASHRAE 97 standard).
- Available with (PAO 68 Plus UV oil) or without (PAO 68 oil) the addition of a contrast agent.

## Advantages and effect

### PAO 68 oil

- Being nonhygroscopic, PAO oil is easy to use in workshops. The required amount of oil can also be taken from large containers (e.g., 5 liters).
- A low degree of refrigerant solubility in the oil means that the PAO oil is not diluted and retains its full viscosity in the air conditioning compressor.
- The oil film inside the components creates a better seal and decreases friction between the air conditioning compressor's moving parts.
- Reduction of operating temperature and wear.
- Results in increased operational safety and reduces noise, running time, and energy consumption by the air conditioning compressor.


### PAO 68 Plus UV oil

- Same positive characteristics as PAO 68 oil.
- Additional admixture of a fluorescent contrast agent for UV leak detection.
- Low volume percent concentration of the contrast agent with the following advantages: preserves the oil's positive characteristics and avoids negative effects on system components or service equipment.

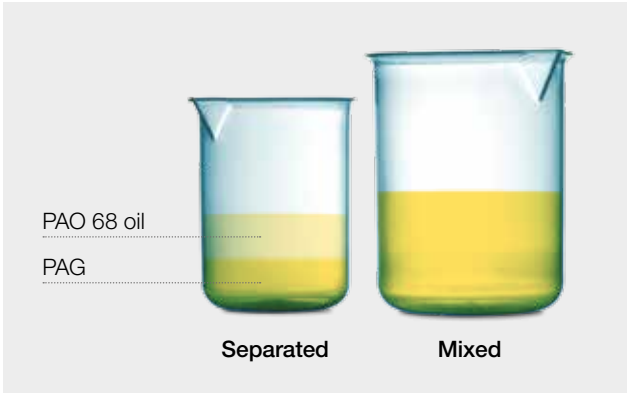
## Additional details

### Is PAO 68 oil compatible with other oils?

- PAO 68 oil does not damage fluoroelastomer materials, such as hoses and seals.
- Since PAO 68 oil is compatible with many other lubricants and refrigerants, it can be used both when topping up and when changing the entire system oil quantity. Due to its molecular structure and density, PAO 68 oil can be mixed to a certain extent with other oils, but separates from them again when it settles and does not form a permanent bond.
- This guarantees that the necessary viscosity of the oils is maintained and there is no change in the overall viscosity (see figure on the following page).

### How was PAO 68 Plus UV oil tested?

- PAO 68 Plus UV oil has been tested by the manufacturer and by independent institutes. For example, its chemical stability was established using the sealed tube test in compliance with the ASHRAE 97 standard. This test evaluates the interaction between the refrigerant, the refrigerant oil, the various O-ring materials, and the metals used in air conditioning systems.
- All the tests produced positive results, confirming that negative effects on components in the vehicle air conditioning system or the air conditioning service station can be excluded. PAO 68 Plus UV oil can thus be added directly to a component, such as an air conditioning compressor, or introduced into the refrigerant circuit via the air conditioning service unit.




### Can PAO 68 oil be used in case of moisture problems?

- PAO 68 oil is not hygroscopic—i.e., unlike other oils, it does not absorb any moisture from the ambient air. This means that moisture-related problems, such as the icing up of components or the formation of acids, can be combated by using only PAO 68 oil. The range of possible uses and the storage stability of PAO 68 oil are significantly greater than for conventional oils.

## Characteristic features and properties

- No risk of oil collecting in the evaporator and the associated deterioration in cooling performance
- Oil film in the components improves the seal
- Reduction in friction between the components
- Lower energy consumption by the air conditioning compressor
- Unique combination of highly refined, synthetic oil and special performance-enhancing additives
- Very wide operating range (–68°C to +315°C)
- Low volume percent concentration of the highly active contrast agent in PAO 68 Plus UV oil, which means the system components and service units are protected and subject to reduced wear

The AA1 Clear Version of PAO 68 oil (without leak detecting agent) is also approved for use with R1234yf and in electric air conditioning compressors in hybrid and electric vehicles.

# Comparison of A/C compressor oils

| Type of oil | Application | Comments |
|---|---|---|
| **PAG oils**<br>For refrigerant R134a | There are various PAG oils with different flow characteristics (viscosities) for use with refrigerant R134a.<br><br>PAG oils are hygroscopic. This means that cans do not have a long shelf life once opened. | Standard PAG oils are not suitable for refrigerant R1234yf or for electrically driven A/C compressors. |
| **PAG YF oil**<br>For refrigerants R1234yf and R134a | Various PAG oils with different flow characteristics (viscosities) for use with refrigerant R1234yf are also available.<br><br>What makes these PAG oils from MAHLE special is that they are not only suitable for use with the refrigerant R1234yf, but can also be used with the refrigerant R134a.<br><br>PAG oils are hygroscopic. This means that cans do not have a long shelf life once opened. | PAG YF oil is suitable for both R1234yf and R134a refrigerants. |
| **PAG SP-A2 oil**<br>For refrigerants R1234yf and R134a | For use in electric A/C compressors, such as those manufactured by Sanden and Hanon. | |
| **PAO 68 oil**<br>For refrigerant R134a, and in some cases for refrigerant R1234yf and others | Can be used as an alternative to the various PAG oils that are offered for R134a (has the advantage of not being hygroscopic—i.e., in contrast to other oils, it does not absorb any moisture from the ambient air).<br><br>The two different PAO oils offered by MAHLE (AA1 and AA3) can be used in conjunction with many different refrigerants (see product overview). | **PAO 68 AA1 Clear Version oil (without leak detecting agent) can also be used with the new refrigerant R1234yf as well as in electrically driven A/C compressors in hybrid and electric vehicles.** |

# From oil type to A/C compressor type

| MAHLE part number/former Behr Hella Service part number | Product | Viscosity class | Contents | Can be used for refrigerant | Can be used for | Can be used for A/C compressor type |
|---|---|---|---|---|---|---|
| **PAG oil** | | | | | | |
| ACPL 1 000P<br>8FX 351 213-031 | PAG oil | ISO 46 | 240 ml | R134a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery) | All compressor types except for electrically driven compressors |
| ACPL 2 000P<br>8FX 351 213-041 | PAG oil | ISO 150 | 240 ml | R134a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery) | All compressor types except for electrically driven compressors |
| ACPL 3 000P<br>8FX 351 213-051 | PAG oil | ISO 100 | 240 ml | R134a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery) | All compressor types except for electrically driven compressors |
| **PAG YF oil** | | | | | | |
| ACPL 7 000P<br>8FX 351 213-121 | PAG YF oil | ISO 46 | 240 ml | R1234yf, R134a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery) | All compressor types except for electrically driven compressors |
| ACPL 8 000P<br>8FX 351 213-131 | PAG YF oil | ISO 100 | 240 ml | R1234yf, R134a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery) | All compressor types except for electrically driven compressors |
| **PAG SP-A2 oil** | | | | | | |
| ACPL 9 000P<br>8FX 351 213-141 | PAG SP-A2 oil | ISO 46 | 250 ml | R1234yf, R134a | A/C systems in hybrid and electric vehicles | Electrically driven compressors, e.g., those manufactured by Sanden and Hanon |

| MAHLE part number/former Behr Hella Service part number | Product | Viscosity class | Contents | Can be used for refrigerant | Can be used for | Can be used for A/C compressor type |
|---|---|---|---|---|---|---|
| **PAO 68 AA1 – Clear Version (without leak detecting agent)** | | | | | | |
| ACPL 10 000P<br>8FX 351 214-021 | PAO AA1<br>Clear<br>Version | ISO 68 | 1.0 L | R1234yf<br>R134a<br>R413a<br>R22<br>R12<br>R507a<br>R500<br>R502<br>R513a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery)<br><br>A/C systems in hybrid and electric vehicles<br><br>A/C systems in refrigerated trucks | All compressor types (including electrically driven compressors) except for vane compressors |
| ACPL 11 000P<br>8FX 351 214-031 | PAO AA1<br>Clear<br>Version | ISO 68 | 500 ml | | | |
| ACPL 14 000P<br>8FX 351 214-101 | PAO AA1<br>Clear<br>Version | ISO 68 | 5.0 L | | | |
| **PAO 68 AA1 – Plus UV** | | | | | | |
| ACPL 15 000P<br>8FX 351 214-201 | PAO AA1<br>Plus UV | ISO 68 | 500 ml | R134a<br>R413a<br>R22<br>R12<br>R507a<br>R500<br>R502 | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery)<br><br>A/C systems in refrigerated trucks | All compressor types except for vane compressors |
| ACPL 16 000P<br>8FX 351 214-211 | PAO AA1<br>Plus UV | ISO 68 | 1.0 L | | | |
| ACPL 17 000P<br>8FX 351 214-221 | PAO AA1<br>Plus UV | ISO 68 | 5.0 L | | | |
| **PAO 68 AA3 – Clear Version (without leak detecting agent)** | | | | | | |
| ACPL 13 000P<br>8FX 351 214-081 | PAO AA3<br>Clear<br>Version | ISO 100 | 1.0 L | R1234y<br>R134a<br>R413a<br>R513a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery) | Specifically for vane compressors |
| **PAO 68 AA3 – Plus UV** | | | | | | |
| ACPL 18 000P<br>8FX 351 214-281 | PAO AA3<br>Plus UV | ISO 100 | 1.0 L | R134a<br>R413a | A/C systems in vehicles with conventional gasoline or diesel engines (passenger cars, commercial vehicles, agricultural and construction machinery) | Specifically for vane compressors |

# Product overview

| Product | Application | A/C compressor type | Refrigerant | Viscosity class | Contents | MAHLE part number/former Behr Hella Service part number |
|---|---|---|---|---|---|---|
| **PAG oil** | Vehicle A/C systems* | All types** | R134a | PAG I (ISO 46) | 240 ml | ACPL 1 000P<br>8FX 351 213-031 |
| | Vehicle A/C systems* | All types** | R134a | PAG II (ISO 100) | 240 ml | ACPL 3 000P<br>8FX 351 213-051 |
| | Vehicle A/C systems* | All types** | R134a | PAG III (ISO 150) | 240 ml | ACPL 2 000P<br>8FX 351 213-041 |
| **PAG YF oil** | Vehicle A/C systems* | All types** | R1234yf<br>R134a | PAG I (ISO 46) | 240 ml | ACPL 7 000P<br>8FX 351 213-121 |
| | Vehicle A/C systems* | All types** | R1234yf<br>R134a | PAG II (ISO 100) | 240 ml | ACPL 8 000P<br>8FX 351 213-131 |
| **PAG SP-A2 oil** | A/C systems in hybrid and electric vehicles | Electric compressors | R1234yf<br>R134a | PAG (ISO 46) | 250 ml | ACPL 9 000P<br>8FX 351 213-141 |
| **PAO 68 oil** | Vehicle A/C systems* | All types (except vane compressors) | R1234yf<br>R134a<br>R413a<br>R22<br>R513a | AA1 (ISO 68) | 500 ml | ACPL 11 000P<br>8FX 351 214-031 |
| | A/C systems in hybrid and electric vehicles | Electric compressors | R1234yf<br>R134a<br>R513a | AA1 (ISO 68) | 1.0 L | ACPL 10 000P<br>8FX 351 214-021 |
| | Refrigerated trucks (fresh produce delivery vehicles) | Reciprocating compressors** | R1234yf<br>R134a<br>R507a<br>R500<br>R513a | AA1 (ISO 68) | 5.0 L | ACPL 14 000P<br>8FX 351 214-101 |
| | Refrigerated trucks (freezer vans) | Reciprocating compressors** | R507a<br>R502<br>R513a<br>R22 | | | |
| | Vehicle A/C systems* | Vane compressors** | R134a<br>R413a<br>R513a | AA3 (ISO 100) | 1.0 L | ACPL 13 000P<br>8FX 351 214-081 |
| **PAO 68 Plus UV oil** | Vehicle A/C systems* | All types** (except vane compressors) | R134a<br>R413a<br>R22 | AA1 (ISO 68) | 500 ml | ACPL 15 000P<br>8FX 351 214-201 |
| | Refrigerated trucks (fresh produce delivery vehicles) | Reciprocating compressors** | R134a<br>R507a<br>R500 | AA1 (ISO 68) | 1.0 L | ACPL 16 000P<br>8FX 351 214-211 |
| | Refrigerated trucks (freezer vans) | Reciprocating compressors** | R507a<br>R502<br>R22 | AA1 (ISO 68) | 5.0 L | ACPL 17 000P<br>8FX 351 214-221 |
| | Vehicle A/C systems* | Vane compressors** | R134a<br>R413a | AA3 (ISO 100) | 1.0 L | ACPL 18 000P<br>8FX 351 214-281 |

* Passenger cars, commercial vehicles, agricultural and construction machinery ** Except for electric air conditioning compressors


ACX 380
R134a
MAHLE
ArcticPRO

# Workshop equipment from MAHLE Service Solutions

*With MAHLE Service Solutions in addition to MAHLE Aftermarket, you have another strong partner by your side when it comes to automotive air conditioning.*

On the following pages, you will find a selection of equipment and accessories for work on air conditioning systems.

# ArcticPRO® ACX HFC R134a

## ACX 310

| Description | Item no. |
|---|---|
| A/C service unit ACX 310 | 1010350478XX |


## ACX 320

| Description | Item no. |
|---|---|
| New-generation A/C service units for R134a systems, convertible to R1234yf or R513a systems, Wi-Fi connection, one-touch unit opening system, ASA network connection | 1010350379XX |

# ArcticPRO® ACX HFC R134a

## ACX 350

| Description | Item no. |
|---|---|
| New-generation A/C service units for R134a systems, convertible to R1234yf or R513a systems, Wi-Fi connection, one-touch unit opening system, ASA network connection, diagnostics connection (optional) | 1010350381XX |


## ACX 380

| Description | Item no. |
|---|---|
| New-generation A/C service units for R134a systems, convertible to R1234yf or R513a systems, Wi-Fi connection, one-touch unit opening system, ASA network connection, diagnostics connection (optional), remote control app | 1010350383XX |


# ArcticPRO® ACX HFO R1234yf

## ACX 410

| Description | Item no. |
|---|---|
| A/C service unit ACX 410 | 1010350479XX |

# ArcticPRO® ACX HFO R1234y

## ACX 420

| Description | Item no. |
|---|---|
| New-generation A/C service units for R1234yf systems, Wi-Fi connection, one-touch unit opening system, ASA network connection | 1010350380XX |


## ACX 450

| Description | Item no. |
|---|---|
| New-generation A/C service units for R1234yf systems, Wi-Fi connection, one-touch unit opening system, ASA network connection, diagnostics connection (optional) | 1010350382XX |


## ACX 480

| Description | Item no. |
|---|---|
| New-generation A/C service units for R1234yf systems, Wi-Fi connection, one-touch unit opening system, ASA network connection, diagnostics connection (optional), remote control app | 1010350384XX |

# ArcticPRO® ACX accessories

## Refrigerant analysis for A/C service units manufactured from 2018

| Description | Item no. |
|---|---|
| R134a/R1234yf refrigerant analysis unit | 1010350393XX |

## Refrigerant analysis for A/C service units manufactured in 2017

| Description | Item no. |
|---|---|
| R134a/R1234yf refrigerant analysis for ACX products | 1010350394XX |

## ROU—refrigerant extraction unit R134a/R1234yf

| Description | Item no. |
|---|---|
| Patented system for the safe removal of contaminated refrigerant; only works in combination with MAHLE A/C service units | 1010350326XX |

## R134a-to-R1234yf conversion kit for A/C service units manufactured from 2018

| Description | Item no. |
|---|---|
| R134a-to-R1234yf conversion kit | 1010350397XX |

## R134a-to-R513a conversion kit for A/C service units manufactured from 2018

| Description | Item no. |
|---|---|
| R134a-to-R513a conversion kit | 1010350398XX |

## Cover for A/C service units manufactured from 2018

| Description | Item no. |
|---|---|
| ACX cover | 1010350400XX |

## Printer upgrade for A/C service units manufactured from 2018

| Description | Item no. |
|---|---|
| Printer kit for ACX products | 1010350396XX |

## Printer upgrade for A/C service units manufactured in 2017

| Description | Item no. |
|---|---|
| Printer kit for ACX products manufactured up to 2017 | 1010350299XX |

## Hose extension

| Description | Item no. |
|---|---|
| Filling hose extension kit, 3 m including adapter | 1010350303XX |

## ACX service kit

| Description | Item no. |
|---|---|
| Service kit for maintaining and calibrating A/C service units (including case) | 1010350298XX |

## Stylus for touch screen of A/C service units

| Description | Item no. |
|---|---|
| Stylus for touch screen of A/C service units, etc. | 1010350403XX |

# ArcticPRO® ACX accessories

## Contrast agent – 250 ml

| Description | Item no. |
|---|---|
| 250 ml dispensing packaging unit, 1 item | 1010350041XX |

## Contrast agent for hybrids – 250 ml

| Description | Item no. |
|---|---|
| 250 ml dispensing packaging unit, 1 item | 1010350281XX |

## R134a contrast agent with dispenser – 7.5 ml + hose

| Description | Item no. |
|---|---|
| Minimum quantity per order: 6 items<br>Fluorescent dye for hybrids + hose | 1010350285XX |

## Contrast agent for HFO R1234yf – 250 ml

| Description | Item no. |
|---|---|
| Minimum quantity per order: 1 bottle<br>Fluorescent dye for HFO R1234yf | 1010350282XX |

# ArcticPRO® ACX accessories

## R1234yf contrast agent with dispenser – 7.5 ml + hose

| Description | Item no. |
|---|---|
| Minimum quantity per order: 6 items<br>Fluorescent dye for R1234yf systems + hose | 1010350286XX |

## Contrast agent remover – 250 ml

| Description | Item no. |
|---|---|
| Minimum quantity per order: 1 bottle<br>Universal degreaser | 1010350287XX |

## Valve inserts kit

| Description | Item no. |
|---|---|
| Valve inserts kit | 1010350280XX |

## Disinfectant spray for A/C systems – 400 ml

| Description | Item no. |
|---|---|
| Minimum quantity per order: 4 items<br>Sanitizer spray for vehicle A/C systems | 1010350046XX |

# ArcticPRO® ACX accessories

## Disinfectant spray for vehicle cabins – 200 ml

| Description | Item no. |
|---|---|
| Minimum quantity per order: 6 items<br>Sanitizer spray for vehicle cabins | 1010350047XX |

## Condenser cleaner – 400 ml

| Description | Item no. |
|---|---|
| Minimum quantity per order: 4 items<br>Special degreasing cleaner for condensers | 1010350048XX |

## Expert kit

| Description | Item no. |
|---|---|
| 2 × PAG ISO 46, 2 × PAG ISO 100, 1 × PAG ISO 150<br>1 × contrast agent, 2 × cabin cleaner,<br>1 × hybrid POE ISO 80, 1 × PAG ISO 46 HFO 1234yf,<br>6 × hybrid contrast agent in 7.5 ml tube,<br>6 × HFO 1234yf contrast agent in 7.5 ml tube,<br>1 × valve kit, 1 × contrast agent remover | 1010350289XX |

## Nitrogen leak detection kit

| Description | Item no. |
|---|---|
| Convertible to R1234yf<br>Basic equipment for use of leak detection kit | 1010350130XX |

# ArcticPRO® ACX accessories

| UV kit | |
|---|---|
| **Description** | **Item no.** |
| UV kit for A/C systems | 1010350033XX |

| Nitrogen/hydrogen leak detection kit | |
|---|---|
| **Description** | **Item no.** |
| Note: Can only be used in combination with nitrogen kit (31144AI) | 1010350288XX |

| Nitrogen/hydrogen leak detection kit | |
|---|---|
| **Description** | **Item no.** |
| Note: Can be used by itself | 1010350309XX |

| Nitrogen/hydrogen refill cartridge | |
|---|---|
| **Description** | **Item no.** |
| 6 bottles | 1010350296XX |

# ArcticPRO® ACX accessories

## Conversion kit for nitrogen/hydrogen leak detection kit

| Description | Item no. |
|---|---|
| R134a-to-R1234y conversion kit | 1010350262XX |

## R134a/R1234yf M series flushing kit

| Description | Item no. |
|---|---|
| For refrigerant R134a | 1010350053XX |

## Hybrid kit

| Description | Item no. |
|---|---|
| For R134a and R1234yf, includes adapter | 1010350401XX |

## ACX hybrid kit (PAG > POE)

| Description | Item no. |
|---|---|
| Hybrid kit for R134a/R1234yf | 1010350302XX |

# ArcticPRO® ACX accessories

| Vacuum pump oil – 500 ml | |
|---|---|
| **Description** | **Item no.** |
| Available in packs of 2 only | 1010350037XX |

| Filter flushing kit for A/C service units manufactured in 2018 | |
|---|---|
| **Description** | **Item no.** |
| Filter flushing kit | 1010350402XX |

| Filter-drier for A/C service units manufactured up to 2017 | |
|---|---|
| **Description** | **Item no.** |
| Filter-drier | 1010350420XX |

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