VEHICLE AIR CONDITIONING
COMPACT KNOWLEDGE
FOR THE GARAGE
Thermal management means optimum engine temperature in all operating states and heating and cooling of the vehicle interior. A modern thermal management system therefore consists of engine cooling and air conditioning components.

Components of these two sub-assemblies which interact with each other often form a unit. In this booklet we describe modern air conditioning systems and their technical background. In this context, we also discuss their function, causes of failure, special features and diagnostic methods.

**What is thermal management?**

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Alternating air conditioning check and air conditioning service

Air conditioning check and air conditioning service can be compared to small and large inspection:

### Info box

Behr Hella Service recommends the following for passenger cars:
- Have the air-conditioning check carried out every 12 months and air-conditioning service every 2 years.

### What should be done when?

<table>
<thead>
<tr>
<th>What?</th>
<th>Air conditioning check</th>
</tr>
</thead>
<tbody>
<tr>
<td>When?</td>
<td>Every 12 months for passenger cars</td>
</tr>
<tr>
<td>Why?</td>
<td>The interior filter filters dust, pollen and dirt particles out of the air before it flows clean and cooled into the interior. Like with any other filter, the absorption capacity of this filter is limited. There is an evaporator in every air conditioning system. Condensation forms in its fins. With time, bacteria, fungi and micro-organisms settle here. For this reason, the evaporator must be disinfected regularly.</td>
</tr>
</tbody>
</table>
| What does it involve? | Visual inspection of all components  
Function and performance test  
Replacement of cabin filter  
If needed, disinfection of evaporator |

### What should be done when?

<table>
<thead>
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<th>What?</th>
<th>Air conditioning service</th>
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<tr>
<td>When?</td>
<td>Every 2 years for passenger cars</td>
</tr>
<tr>
<td>Why?</td>
<td>Up to 10% of the refrigerant escapes per year, even from a new air conditioning system. A normal process which does however reduce cooling capacity and threaten compressor damage. The refrigerant is freed from humidity and contaminants by the filter dryer.</td>
</tr>
</tbody>
</table>
| What does it involve? | Visual inspection of all components  
Function and performance test  
Filter dryer replacement  
If needed, disinfection of evaporator  
Refrigerant replacement  
Leak test  
Replacement of cabin filter |
Consider air conditioning and cooling as unit
Although the air conditioning system and the engine cooling system are two separate systems, they influence one another. Air conditioning system operation places additional load onto the engine cooling system and the coolant temperature rises.

The additives contained in the coolant do not only protect against frost, but also against engine overheating. The proper coolant composition increases the boiling point of the medium to above 120 °C. An enormous performance reserve.

This is particularly important in the summer, when the air conditioning system and the cooling system are heavily burdened by ambient temperatures and long trips. The best approach is to check the coolant during air conditioning service as well.
AIR CONDITIONING CIRCUIT

Refrigerant circuit with expansion valve

How the air conditioning system with expansion valve works
Refrigerant and the cooling circuit are required to control the climate inside the vehicle. A blend of cold and hot air makes it possible to create the desired climate conditions – irrespective of the conditions outside. This makes the air-conditioning system a key factor in improving safety and driving comfort.

The individual components of the refrigerant circuit are connected by tubes and/or aluminium pipes and thus form a closed system. Refrigerant and refrigerant oil circulate in the system, driven by the compressor. The circuit has two sides:

→ The section between the compressor and the expansion valve is the high pressure side (yellow/red).
→ The section between the expansion valve and the compressor is the low pressure side (blue).

The gaseous refrigerant is compressed by the compressor (thereby significantly increasing its temperature) and pressed under high pressure through the condenser. This removes heat from refrigerant – it condensates and changes its state from gas to liquid.

The filter dryer, the next unit, removes contaminants and air from the liquid refrigerant as well as humidity. This ensures system effectiveness and protects the components from damage caused by contaminants.
Compressors
The air conditioning compressor is usually driven by the engine via a belt or ribbed V-belt. The compressor compresses and transports the refrigerant in the system. There are different designs available.

The refrigerant is sucked in as a gas at low temperature from the evaporator; it is then compressed. It is then forwarded in a gaseous state at high temperature and high pressure to the condenser.

The compressor can be dimensioned depending on the size of the system. The compressor is filled with special oil to provide lubrication. Some of the oil circulates through the air conditioning system with the refrigerant.

Please observe that compressors are described in detail starting from page 20.
Condensers
The capacitor is needed in order to cool the refrigerant that is heated up by the compression in the compressor. The hot refrigerant gas flows into the condenser and transfers heat to the surroundings via the pipe and fins. As it cools down, the state of the refrigerant changes again from gaseous to liquid.

How they work
The hot refrigerant gas flows on top into the condenser and transfers heat to the surroundings via the pipe and fins. Due to cooling down the refrigerant exists the condenser at the lower connection in liquid state.

Effects of failure
A defective condenser may exhibit the following symptoms:
→ Poor cooling performance
→ Failure of the air conditioning system
→ Continuously running condenser fan

Causes for occurring faults can be:
→ Leaks at the connections or caused by damage
→ Insufficient heat exchange due to contamination

Troubleshooting
Test steps for fault elimination:
→ Check condenser for contamination
→ Check for leaks
→ Pressure test on the high and low pressure sides
Info box

The passenger car filter dryer must normally be replaced every 2 years or each time the refrigerant circuit is opened. Ageing of the filter dryer can lead to severe defects in the air-conditioning system. Filter dryers can be integrated in the condenser. Sometimes it is not possible to replace the filter dryer separately.

Filter dryer

The filter elements of the air conditioning system are either referred to as filter dryers or accumulators, depending on the type of system. The task of the filter dryer is to remove impurities from the refrigerant and to dehumidify it.

How they work

The liquid refrigerant enters the filter dryer, flows through a hygroscopic drying medium and leaves the filter dryer again as a liquid. The upper part of the filter dryer serves as a compensation chamber; at the same time, the lower part serves as refrigerant storage in order to compensate fluctuations in pressure in the system.

Depending on its design, the filter dryer can only remove a certain amount of humidity – then the drying medium is saturated and no longer in a position to absorb further humidity.

Effects of failure

A failure of the filter dryer may exhibit the following symptoms:

- Poor cooling capacity
- Failure of the air conditioning system

Causes for the failure of the filter dryer can be:

- Ageing
- Defective filter pad inside
- Leaks at the connections or caused by damage

Troubleshooting

The following steps are to be considered during troubleshooting:

- Check maintenance intervals (every 2 years for passenger cars)
- Leak test/correct fit of the connections/damage
- Pressure test of the high and low pressure sides
Expansion valve/orifice tube

The expansion valve represents the point of separation between the high pressure and low pressure sections in the refrigerant circuit. It is installed in upstream of the evaporator. To achieve optimum cooling capacity in the evaporator, the refrigerant flow is controlled by the expansion valve depending on the temperature. As a result, complete evaporation of the liquid refrigerant is ensured and gaseous refrigerant arrives at the compressor only. Expansion valves may differ in their design.

How they work

The liquid refrigerant - arriving through the filter dryer from the condenser - flows through the expansion valve and is injected into the evaporator. The evaporating refrigerant releases evaporation cold. This causes the temperature to drop. To achieve optimum cooling capacity in the evaporator, the refrigerant flow is controlled by the expansion valve depending on the temperature. At the end of the evaporator, the refrigerant is transported through the expansion valve to the compressor. If the refrigerant temperature increases at the end of the evaporator, it expands in the expansion valve. This results in an increase of the refrigerant flow (injection quantity) to the evaporator. If the refrigerant temperature lowers at the end of the evaporator, the volume in the expansion valve decreases. As a result, the expansion valve reduces the refrigerant flow to the evaporator.

Effects of failure

A defective expansion valve can manifest itself as follows:

- Poor cooling capacity
- Failure of the air conditioning system

There are a number of possible causes of failure:

- Temperature problems due to overheating or icing
- Contaminations in the system
- Leaks at the component or the connection pipes

Troubleshooting

The following test steps should be followed in the case of a malfunction:

- Visual inspection
- Acoustic test
- Check connection pipes for tight and correct fit
- Check components and connections for leak-tightness
- Temperature measurement on the line system
- Pressure measurement with the compressor switched on and the engine running

Info box

Humidity and contaminations in the air conditioning system can severely impact the functional capability of expansion valves/orifice tubes and lead to malfunctions. This means regular maintenance is important!
Temperature problems, contamination, humidity and insufficient maintenance can lead to evaporator defects. In order to avoid this, the air conditioning must be maintained and/or disinfected on a regular base.

**Evaporator**
The evaporator is used to exchange heat between the ambient air and the refrigerant in the air conditioning system.

**How they work**
The expansion valve and/or orifice tube injects the highly pressurised liquid refrigerant into the evaporator. The refrigerant expands. The resulting evaporation cold is discharged to the environment via the large surface of the evaporator and routed to the vehicle interior through the ventilation airflow.

**Effects of failure**
A defective evaporator exhibits the following symptoms:
- Poor cooling performance
- Failure of the air conditioning system
- Poor ventilation performance

Causes for failure of the evaporator can be:
- Pipes blocked in the evaporator
- Evaporator leaking (at the connection, caused by damage)
- Evaporator contaminated (air passage disturbed)

**Troubleshooting**
The following test steps should be considered during troubleshooting:
- Check evaporator for contamination
- Inspect evaporator for damage
- Check connection pipes for correct fit
- Leak test
- Pressure measurement with the compressor switched on and the engine running
- Temperature measurement on the input and output line
Pressure switches and sensors are designed to protect the air-conditioning system from damage caused by excessively high or low pressures. A distinction is made between low-pressure switches, high-pressure switches and the trinary switch. The trinary switch includes the high-pressure and low-pressure switch as well as an additional switch contact for the condenser fan.

How they work
The pressure switch (pressure monitor) is normally installed on the high pressure side of the air conditioning system. In the case that the pressure is too high (approx. 26-33 bar) it switches the power supply to the compressor clutch off. If the pressure is reduced (approx. 5 bar), its switches the power supply on again. If the pressure is too low (approx. 2 bar), the power supply is interrupted as well in order to avoid compressor damage due to insufficient lubrication. The third switch contact in the trinary switch controls the electrical condenser fan in order to ensure optimum refrigeration condensation in the condenser.

Effects of failure
A defective or failing pressure switch can manifest itself as follows:
- Insufficient cooling performance
- Air conditioning system without function
- Frequent switching on and off of the compressor clutch

Air conditioning system without function. There are a number of possible causes of failure:
- Contact fault at electrical connections
- Contaminations in the system
- Damage to the housing caused by vibrations or accidents

Troubleshooting
Test steps for fault diagnostics:
- Visual inspection
- Check connector block for correct fit
- Inspect component for damage
- Pressure measurement with the compressor switched on and the engine running
- Component test in the disassembled condition with nitrogen gas cylinder, pressure reducer and multimeter
Ventilation fan
The ventilation fan is used to ventilate the passenger car. It ensures clear visibility and a pleasant interior climate. Major pre-requisites for safe and comfortable driving.

Info box
Failure of the fan results in an uncomfortable interior climate, which has a negative impact on the driver’s concentration. This represents a significant reduction in safety. Lack of ventilation can also cause the windshield to mist up. Vision limited by misted up windows is a major safety risk.

Fittings and tubes
Fittings and tubes connect the single components carrying refrigerant. The fittings are pressed onto the tube end using a special tool. This tool is available in a variety of designs.

Info box
Hoses from Hella Gutmann Solutions are characterised by high flexibility, low weight and minimal refrigerant loss.

Condenser fan
The condenser fan helps to ensure the optimal liquefaction of the refrigerant no matter what operating state the vehicle is in. It is mounted upstream or downstream of the condenser and/or engine cooling system as an additional or combination fan.

Info box
Condenser fans may fail due to electrical or mechanical damage. As a result, the refrigerant is not sufficiently liquefied anymore. The air conditioning system performance is reduced.
REPAIR AND SERVICE

Safety information/handling of refrigerant

- Always wear protective goggles and gloves! Under normal atmospheric pressure and ambient temperatures, liquid refrigerant evaporates so quickly that any physical contact with the skin or eyes can cause the tissue to freeze (risk of blindness).
- If direct physical contact has been made, thoroughly rinse the affected areas with a generous supply of cold water. Do not rub. Seek the medical attention of a doctor immediately!
- The workplace must be well ventilated for working on refrigerant circuits. Breathing in high concentrations of gaseous refrigerant can cause dizziness and even suffocation. The refrigerant circuit must not be worked out from an inspection pit. As gaseous refrigerant is heavier than air, it can collect in high concentrations there.
- Do not smoke! Refrigerant can be broken down into poisonous substances if it contacts cigarette ash.
- Do not introduce an open flame or hot metal in the immediate vicinity of refrigerant. Doing so can cause lethal gases to form.
- Never allow refrigerant to leak out into the atmosphere. If the refrigerant reservoir or air-conditioning system is opened, its contents will escape under high pressure. The extent of the pressure depends on the temperature. The higher the temperature, the higher the pressure.
- Avoid any head impact on components of the air conditioning system. After paintwork, vehicles must not be heated above 75 °C (drying furnace). Otherwise, the air conditioning system must be drained first.
- When removing the service tubes from the vehicle, the connections must not be pointed towards your body. Refrigerant residues may leak.
- When cleaning the vehicle, the steam-jet cleaner must not be directly pointed onto parts of the air conditioning system.
- Never change the factory setting of the adjusting screw on the expansion valve.

Info box
Work on air-conditioning systems may only be carried out by qualified personnel (certificate of competence). The relevant EU regulations (307/2008, 517/2014, 2006/40) must be observed.
REMOVAL AND INSTALLATION NOTES

Air conditioning system

Before removing or installing a spare part, check whether the connections, mountings and other installation-relevant characteristics are identical.

When replacing components, always use new O-rings suitable for the refrigerant.

The compressor oil has a pronounced hygroscopic effect, which is why the system should remain closed as much as possible and the oil only added shortly before the refrigerant circuit is closed.

Prior to the installation, O-rings and seals are to be greased with refrigerant oil or special lubricants in order to facilitate installation. No other greases or silicone spray may be used as this results in immediate contamination of the new refrigerant.

Every time the refrigerant circuit is opened, the dryer must be replaced due to its pronounced hygroscopic effect. If the dryer or accumulator is not regularly replaced, the filter cushion may become separated and distribute silicate particles throughout the entire system, which can cause severe damage.

The connections of the system should never remain open for an extended period and instead be immediately closed, or sealed off, with caps or plugs. Not doing so will introduce the humidity of the air into the system.

In order to avoid damage to connection pipes and/or components, always use two wrenches when loosening and fastening the connections.

When routing hoses and cables, take steps to avoid causing damage by contacting vehicle edges and other moving components.

When replacing a component of the air conditioning system, the correct oil quantity in the system is to be ensured. Oil must be refilled or drained as needed.

Before refilling the system, the system must be checked to ensure that it is already leaktight. Then sufficiently evacuate the system (approx. 30 minutes) to ensure that all humidity is removed.

O-ring set  Filter dryer  Pressure gauge
After filling using the quantity of refrigerant specified by the vehicle manufacturer, check the system to ensure that it operates as intended and is leaktight (electronic leak indicator). At the same time, the high and low-pressure values must be monitored using pressure manometers and compared against the prescribed values. Compare the outlet temperature at the center nozzle with the values defined by the manufacturer.

After the service connections are fitted with protective caps, affix a service label sticker on the front crossrail to verify that the maintenance work has been carried out.

**Information regarding the installation of air conditioning system compressors**

Ensure that all contamination and foreign material has been removed from the refrigerant circuit. To this end, flush the system before installing the new compressor. Depending on the level of contamination, use refrigerant R134a or a special flushing solution to flush; compressors, driers (accumulators) and expansion or throttle valves cannot be flushed. Since system contamination (abrasion, chips) must always be assumed in the case of a compressor defect and cannot be ruled out, it is absolutely essential that the system be flushed when replacing this component. Ensure that no residual flushing solution remains in the system. Dry the refrigeration circuit using nitrogen if necessary.

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

As one and the same compressor can potentially be used for different vehicles or systems, the oil filling quantity and viscosity must be checked and/or corrected according to the manufacturer’s specifications before installing the compressor. All the oil must be siphoned off and collected. The compressor must then be newly filled with the entire oil quantity specified by the vehicle manufacturer (system oil quantity).
Oil is drained and filled using the designated “oil drain plug”. If the compressor does not have such a plug, the oil is drained via the high and low-pressure connection and filled via the low-pressure connection. To this end, the compressor shaft must be turned multiple times.

The compressor must be spun 10 x by hand before being installed to ensure the oil is distributed evenly. When installing the drive belt it must be ensured that it is aligned. Some compressors are designed for so-called “multiple applications”. This means that they can be installed in different vehicles. Except the number of grooves on the magnetic clutch, there is 100% agreement with the “old part”.

After compressor installation and new filling of the refrigerant circuit, the engine should first be started and operated for several minutes at idling speed.

Further specifications (instruction leaflets, manufacturer’s specifications, run-in specifications) are to be separately observed.
Testing the cooling capacity
In addition to test and special tools, every garage requires respective specialist knowledge, which can be acquired by training.

This applies in particular to air conditioning systems. Due to the different systems, these instructions can merely be used as guidelines.

1. Start the engine. Switch through the ventilation stages.
   Ventilation functioning?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
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<tbody>
<tr>
<td></td>
<td>2.</td>
</tr>
<tr>
<td></td>
<td>→ Check fuse</td>
</tr>
<tr>
<td></td>
<td>→ Check relays switches, wiring of all components</td>
</tr>
</tbody>
</table>

3. Temperature to maximum cooling
   Magnetic clutch activated?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
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<tbody>
<tr>
<td></td>
<td>4.</td>
</tr>
<tr>
<td></td>
<td>→ Check wiring/electrical connections, power supply (+/-)</td>
</tr>
<tr>
<td></td>
<td>→ Check temperature switch/sensor, pressure switch</td>
</tr>
<tr>
<td></td>
<td>→ Refrigerant filling level not correct</td>
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</tbody>
</table>

Proceed to 5.

5. Operate the system at maximum cooling performance and medium ventilation stage for several minutes. Air outflow temperature at the centre vent 3-8 °C.

<table>
<thead>
<tr>
<th>Yes</th>
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<td>6.</td>
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<tr>
<td></td>
<td>→ Check fuse</td>
</tr>
<tr>
<td></td>
<td>→ Check relays switches, wiring of all components</td>
</tr>
</tbody>
</table>

6. If the outflow temperature is too hot:
   → Heating switched off?
   → Interior filter OK?
   → Check temperature switch/sensor, thermostat (if available)
   → Check venting flaps, heating valves, condenser ventilation

7. Check low pressure (LD) and high pressure (HD) at 2000 - 2500 rpm: LD: 0.5 - 3.0 bar; HD: 6.0 - 25.0 bar; for power-regulated compressors: LD: approx. 2 bar, constant

<table>
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</tr>
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<td></td>
<td>→ Check fuse</td>
</tr>
<tr>
<td></td>
<td>→ Check relays switches, wiring of all components</td>
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8. Check low pressure (LD) and high pressure (HD) at 2000 - 2500 rpm: LD: 0.5 - 3.0 bar; HD: 6.0 - 25.0 bar; for power-regulated compressors: LD: approx. 2 bar, constant

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<td>→ Check fuse</td>
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</table>

Air conditioning OK

See table Troubleshooting
Correct evaluation of the pressure manometer display is particularly important. Here are some examples:

### Air conditioning systems with expansion valve

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<tr>
<th>Low pressure</th>
<th>High pressure</th>
<th>Outflow temperature at the centre vent</th>
<th>Possible causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>high</td>
<td>higher; up to ambient temperature</td>
<td>engine overheated, condenser contaminated, condenser fan defective—incorrect direction of rotation, system overfilled</td>
</tr>
<tr>
<td>normal to occasionally low</td>
<td>high, occasionally</td>
<td>higher; possibly fluctuating</td>
<td>expansion valve stuck, occasionally closed</td>
</tr>
<tr>
<td>normal</td>
<td>high</td>
<td>slightly higher</td>
<td>filter dryer aged, condenser contaminated</td>
</tr>
<tr>
<td>high</td>
<td>normal to high</td>
<td>higher depending on bottleneck</td>
<td>line from condenser to expansion valve narrowed</td>
</tr>
<tr>
<td>normal</td>
<td>normal</td>
<td>higher</td>
<td>too much refrigerant oil in the system</td>
</tr>
<tr>
<td>normal, but inconsistent</td>
<td>normal, but inconsistent</td>
<td>higher</td>
<td>humidity in the system, defective expansion valve</td>
</tr>
<tr>
<td>fluctuating</td>
<td>fluctuating</td>
<td>fluctuating</td>
<td>expansion valve or compressor defective</td>
</tr>
<tr>
<td>normal to low</td>
<td>normal to low</td>
<td>higher</td>
<td>evaporator contaminated, lack of refrigerant</td>
</tr>
<tr>
<td>high</td>
<td>low</td>
<td>higher; almost ambient temperature</td>
<td>expansion valve stuck in opened position, compressor defective</td>
</tr>
<tr>
<td>low</td>
<td>low</td>
<td>higher, up to ambient temperature</td>
<td>lack of refrigerant</td>
</tr>
<tr>
<td>low pressure and high pressure are the same</td>
<td>low pressure and high pressure are the same</td>
<td>ambient temperature</td>
<td>lack of refrigerant, compressor defective, fault in the electrical system</td>
</tr>
</tbody>
</table>

### Air conditioning system with orifice tube

<table>
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<th>High pressure</th>
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<td>high</td>
<td>higher; up to ambient temperature</td>
<td>engine overheated, condenser contaminated, condenser fan defective—incorrect direction of rotation, system overfilled</td>
</tr>
<tr>
<td>normal to high</td>
<td>high</td>
<td>higher</td>
<td>system overfilled, condenser contaminated</td>
</tr>
<tr>
<td>normal</td>
<td>normal to high</td>
<td>fluctuating</td>
<td>humidity in the system, orifice tube occasionally blocked</td>
</tr>
<tr>
<td>high</td>
<td>normal</td>
<td>higher</td>
<td>orifice tube defective (cross-section)</td>
</tr>
<tr>
<td>normal</td>
<td>normal</td>
<td>higher</td>
<td>too much refrigerant oil in the system</td>
</tr>
<tr>
<td>normal to low</td>
<td>normal to low</td>
<td>higher</td>
<td>lack of refrigerant</td>
</tr>
<tr>
<td>low pressure and high pressure are the same</td>
<td>low pressure and high pressure are the same</td>
<td>ambient temperature</td>
<td>lack of refrigerant, compressor defective, fault in the electrical system</td>
</tr>
</tbody>
</table>
REMOVAL/INSTALLATION AND TROUBLESHOOTING FOR AIR CONDITIONING COMPRESSORS

General
The air conditioning compressor is driven by the vehicle engine via a ribbed or V-ribbed belt. It compresses and transports the refrigerant in the system. There are different compressor designs available.

How they work
The refrigerant is sucked in as a gas under low pressure and low temperature from the evaporator; it is then compressed and forwarded to the condenser as a gas under high temperature and high pressure.

Example shown: Piston compressor

Effects of failure
A damaged or failed compressor can manifest itself as follows:
- Loss of sealing
- Development of noise
- Insufficient or no cooling performance
- Fault code is stored (automatic air conditioning)

Caution!
Before installing a new compressor, you must check the oil quantity and the viscosity according to the manufacturer’s instructions!
There are a number of possible causes of failure:

- Bearing damage caused by a defective tensioner or by wear
- Loss of sealing of the compressor shaft or of the housing
- Mechanical damage to the compressor housing
- Contact (electrical connections)
- Lack of refrigerant oil
- Lack of refrigerant
- Solids (e.g. swarf)
- Humidity (corrosion etc.)

Troubleshooting

Function test and pressure measurement of the system:

- Does the compressor switch on, is the connector plug securely in place, is there voltage?
- Check that the drive belt is positioned correctly, undamaged, and that there is tension
- Check visually for loss of sealing
- Check that refrigerant tubes are securely in place
- Compare the pressures on the high and low pressure sides
- Read out the fault memory

Attention must always be paid to the following:

The entire air conditioning system must be cleaned to 100 % and the consumables must be replaced when the compressor is replaced.
REPAIR AND REPLACEMENT OF AIR CONDITIONING COMPRESSORS

IDENTIFY CAUSE
a) Fault in refrigeration circuit
b) Electrical fault
c) Fault near the compressor (belt drive, ancillary units)

PRACTICAL TIP
a) Magnetic clutch
b) Mechanical damage
c) Electrical control valve
d) Loss of sealing (leak)

Not OK

Drain off refrigerant

Remove compressor

Check the system for contamination / solids / permeability

OK

Check the compressor in its installed state

IMPORTANT
Flush the system
1. Install a new or repaired compressor

2. Replace the expansion / orifice tube and filter dryer/accumulator

3. Using the service station
   a) Generate a vacuum
   b) Carry out leaktightness test
   c) Fill with refrigerant

4. 1. System pressure test
    2. Leaktightness test
    3. System test

5. 1. Attach service label
    2. Conduct test drive
    3. Document completed work

IMPORTANT
Check oil quantity before installing
→ Top up, if necessary

IMPORTANT
Filling the air conditioning system
Run-in specification

PRACTICAL TIP
If necessary, before installing, insert the filter screen in the intake line at the compressor

PRACTICAL TIP
Following the manufacturer’s instructions:
   a) Vacuum time
   b) Refrigerant filling level

PRACTICAL TIP
Add leak detection agent

See the following page
Thoroughly flush
Dirt particles in the air conditioning circuit can only be removed by flushing the entire system thoroughly. Refrigerant R134a or a special flushing solution is suitable for flushing, depending on the level of contamination. Compressors, dryers (accumulators), expansion valves and orifice tubes cannot be flushed. As it must always be assumed and cannot be ruled out that the system is contaminated (abrasion, swarf) when a compressor is defective, the system must always be flushed when this component is replaced.

Refrigerant oils
Note manufacture’s specifications and leaflet/note viscosity.

1. Distribution of the oil.
There is refrigerant oil in every component of the air conditioning system. The oil is removed with the replaced component during repairs. It is therefore essential to refill the appropriate quantity of oil. The graphic below shows the average distribution of the quantities of oil within the system.

2. Observe the quantity and specification of the oil.
Before installing a new compressor or refilling refrigerant oil, the oil quantity and the viscosity according to the vehicle manufacturer’s specifications must always be observed.

3. Correct quantity of system oil in the compressor.
As one and the same compressor can potentially be used for different vehicles or systems, the oil filling quantity must be checked and corrected before installing the compressor. For this purpose, all the oil must be siphoned off and collected. The compressor must then be refilled with the entire oil quantity specified by the vehicle manufacturer (system oil quantity).
Oil is drained and filled using the designated “oil drain plug”. If the compressor does not have such a plug, the oil is drained via the high and low-pressure connection and filled via the low-pressure connection. To this end, the compressor shaft must be turned multiple times. To ensure that the oil is distributed equally, the compressor must be turned 10x by hand before installing. This also corresponds with the specifications of compressor manufacturer Sanden, whereby vehicle manufacturer specifications must likewise be observed.

Info box
Oil cannot be drained from Denso 5SE/5SL and Visteon VS16 compressors due to their design. These are profiled with the required system oil fill quantity. Observe the special/separate product and installation notes.
Compressor filter screen

Every air conditioning system must be flushed when the compressor is replaced in order to remove contamination and foreign substances from the system. If there is still contamination in the circuit despite flushing, damage can be prevented by the use of filter screens in the suction line.

Fill the air-conditioning system with refrigerant

Run-in specification for the compressor:

→ Only fill the refrigerant using the air conditioning service station via the high pressure side service connection to prevent pressure surges of refrigerant in the compressor.
→ Only the correct refrigerant in the quantity / specification defined by the vehicle manufacturer may be used.
→ Set the air distribution to “centre vents” and open all centre vents.
→ Set the switch for the fresh air fan to medium.
→ Set the temperature to maximum cooling.
→ Start the engine (without running the air conditioning) and run the engine for at least 2 minutes without interruption at idle speed.
→ While at idle speed, turn on the air conditioning for approx. 10 seconds, then turn off the air conditioning for approx. 10 seconds. Repeat this procedure at least 5 times.
→ Carry out a system check.

Leak detection agent

Compressor damage is caused by lack of refrigerant. It is therefore recommended that air conditioning maintenance is carried out regularly and that dye is added to the system, if necessary.

Important!

Replace all O-rings and wet with refrigerant oil before installation.
COMPRESSOR DAMAGE

After correction of a leak or air conditioning service the air conditioning system does not function anymore.

Case:
After the replacement of air conditioning components as well as after normal air conditioning service it happens from time to time that the air conditioning system does not function properly anymore - either immediately or shortly after the work conducted.

What is the customer complaining about?
The customer originally brings the vehicle into the garage claiming that “the air conditioning system does not cool properly anymore or "the air conditioning system does not cool at all anymore".

What does the garage do?
In such cases, the filling level of the refrigerant circuit is usually checked first. It is often found that the refrigerant amount in the system is insufficient. Depending on the system type, up to 10 % of refrigerant can diffuse from the air conditioning system within one year. However, before the system can be newly filled with refrigerant, it must be determined, whether the lack of refrigerant is caused by “natural loss” or a leak. If a leak is suspected, the system may not simply be filled with refrigerant again. First, a search for leaks must be performed, where the air conditioning system is e.g. filled with forming gas and tested using an electronic leak indicator. Depending on the result, either the leaking component (figure 1) of the refrigerant circuit is replaced, or the filter dryer element only. Next, the system is properly evacuated and filled with refrigerant and oil according to manufacturer’s specifications.

When the air conditioning system is started up again, it may occur that the compressor output is gone. If the pressure values are compared at the service station it can be observed that the values on the high pressure and low pressure side are almost identical (figure 2). It can be suspected that either the flow in the refrigerant circuit is insufficient (e.g. at the expansion valve) or that the compressor is defective. Strangely enough, there are cases, where the high pressure and low pressure values during the initial air conditioning system inspection are within the normal range, and merely the refrigerant filling level is too low; and where problems only occur after proper new filling of the air conditioning system. Evacuating and new filling can loosen dirt particles or metal abrasion, which can then deposit in the control valve (figure 3) of the compressor or in the expansion valve/orifice tube (figure 4) and cause malfunctions. This can particularly occur if the filter dryer was aged or the system was "under-filled".

Fig. 1

Fig. 2
What needs to be done?
In the case of problems the compressor should be removed and the oil should be drained. If a “greyish discolouration” (grey-green or grey-yellow if dye is used) of the oil can be detected, where fine metal particles (figure 5) are present as well, the refrigerant circuit must be properly flushed due to the foreign particles, the expansion valve and the filter dryer must be replaced, and the refrigerant circuit must be evacuated according to the specifications and newly filled with refrigerant and oil. After that, the system should function again without problems.

Is the customer sufficiently informed?
As the garage provided the customer merely with an estimate for the search for leaks and possibly for replacing the leaking component or the air conditioning service only, they may face arguments with the customer. The customer is often not ready to pay for the significant additional costs for e.g. replacing the compressor or flushing the system. For this reason, a detailed discussion with the customer, where the technical issue and risks are presented, is especially important.

What is the cause for the compressor failure?
The compressor contains the only moving components of the refrigerant circuit, and must respectively be sufficiently supplied with oil. Another task of oil in the refrigerant circuit is compressor cooling in order to avoid overheating. If a compressor is operated with an insufficient amount of refrigerant for an extended period of time (e.g. due to a leak), this results in insufficient heat dissipation and lubrication of the compressor components, as the oil must be transported together with the refrigerant through the air conditioning system. Due to the excessive operating stress on the compressor components, metal abrasion is generated on the components, which may cause partial or complete blockage of the control valve located on the inside. The control valve blockage results in the compressor not properly working anymore. This damage can only be corrected by professional replacement of the compressor, which also includes flushing of the system. By the way, insufficient lubrication results in damage in all compressor designs. However, power-controlled compressors react particularly sensitively to insufficient refrigerant and/or oil.

Information for garages and parties accepting repairs
If the customer brings a vehicle for repair due to insufficient cooling capacity, he should be informed about the possibility of a replacement compressor being required. The reason for that is that a possibly insufficient refrigerant quantity and the related lack of lubrication can cause pre-existing damage. In the case of doubt, the compressor must always be removed. If the oil is contaminated, the system must be flushed prior to replacing the compressor. If the customer requests a deviating approach, the garage should record this on the bill and/or have the customer confirm his request in writing.

This Technical Information was prepared in collaboration with compressor manufacturer Sanden and is applicable to all compressor manufacturers and compressor types currently known in the market.
DEVELOPMENT OF NOISE

Troubleshooting information in the case of noise and for compressor replacement.

The following information should always be taken into consideration when troubleshooting noise sources and prior to every compressor replacement:

- Check all retaining clamps and attachment points for breakage or cracks and possibly missing bolts or nuts. Any vibration caused may be the cause of excessive compressor noise. Observe, whether the noise changes, if you e.g. apply force onto the retaining brackets or attachment points using the assembly lever (figure 1). If a change occurs, the noises are most likely not caused by the compressor.

- Check tubes and pipes to determine, whether vibrations from the engine or pulsing refrigerant enter into the vehicle interior. For this purpose, hold them with one hand and observe possible changes in the noise (figure 2).

- Check V-belts, tensioners, tension pulleys, freewheel clutch (alternator) and belt pulleys for smooth running, play and alignment. Excessive tolerances caused by worn parts can cause noise.

- Excessive high pressure (figure 3) can cause abnormal compressor noise. If the high pressure service connection is additionally located behind a blockage in the system, the high pressure may even be higher than indicated on the manometer. In order to diagnose such a problem it is useful to measure the temperatures at the compressor.

- Excess or contaminated refrigerant causes excessive high pressure, which may cause compressor noise. The same applies to refrigerant, where the content of non-condensable gases (air) is too high.

- The condenser can also be considered as cause of unusual noise. If insufficient air is routed through the condenser, the refrigerant cannot sufficiently condensate and the high pressure increases excessively. This can result in abnormal noise development. Check as well, whether the fan(s) transport(s) sufficient air through the condenser. Check the condenser and radiator fins for possible contaminations as well (figure 4).
Often noise can be caused by contaminated expansion valves (figure 5) or orifice tubes. This can e.g. be caused by contaminations in the form of metal abrasion. This causes a reduction of the refrigerant flow and excessive high pressure occurs. “Defective” expansion valves can e.g. generate diverse “buzzing, whistling or droning noise”, which can be well perceived in the vehicle interior.
COMPRESSORS WITHOUT MAGNETIC CLUTCH

General
Since a few years so-called "clutch-free", externally controllable, variable compressors have been used. All major compressor manufacturers use different basic types. Here the types most commonly used in the market are listed: Denso with types 6SEU and 7SEU; Sanden, with types PXE 13 and PXE 16. Delphi/Harrison offers a model with the CVC7 series, which is very similar to the V5 compressor design. This generation of compressors is used by almost all vehicle manufacturers (Audi, BMW, Citroen, Seat, VW, Opel, ...). Externally controlled means that the displacement volume of the compressor is determined using an integrated control valve controlled by the air conditioning control unit depending on different system parameters, such as exterior temperature, requested temperature, high pressure, low pressure, RPM speed and engine load. "Clutch-free" means that the compressor is not equipped with an electromagnetic clutch. This means that the compressor is permanently driven via a belt pulley and that it also operates, when the air conditioning system is switched off. However, its output is reduced to a small percentage value.

Function
The belt pulley unit of the compressor consists e.g. of a driven plate and the actual belt pulley (drawing). The driven plate consists of a rubber element and establishes the connection between belt pulley and compressor shaft. This acts as a vibration damper and protects the compressor and/or other driven aggregates against overload and/or damage. If the compressor should e.g. block, the transmitted forces between belt pulley and driven plate significantly increase in the area of the rubber element.

Depending on compressor manufacturer and/or compressor type, the connection is interrupted due to deformation of the rubber element or by triggering the "overload protection". In this case the belt pulley just moves along without function. As a result, damage to the belt and/or other aggregates driven by the belt is prevented.

Function example

Fig. 1

Fig. 2
The control valve (figure 1) is arranged in the compressor and receives its PWM signals from the air conditioning control unit. The current, which is relayed from the control unit to the control valve and which determines the compressor output, can be displayed as measured value block using a diagnostic device. Compressors without clutch are equipped with a safety valve (figure 2), which should protect the compressor and all other components of the air conditioning system against too high pressure. The valve mostly triggers between 35 and 45 bar (depending on the compressor manufacturer). The valve opens only, until the overpressure is released. Next, it closes again in order to not release the entire refrigerant quantity into the atmosphere. If the foil of the valve is damaged, it can be assumed that the valve did “trigger”.

**Diagnostics**

The belt pulleys and their rubber elements designed as ‘overload protection’ are designed differently depending on the compressor type. Depending on the type, there are different ways to detect, whether the ‘overload protection’ was triggered:

1. Rubber abrasion is visible on the inside of the belt pulley (figure 3). The compressor shaft is not driven anymore. If the compressor can be easily turned, belt pulley and/or rubber element can be replaced.
2. The overload protection triggered the driven plate (figure 4). Driven plate and/or rubber element can be replaced individually. Prerequisite: The compressor can be easily rotated.
3. A triggered speed limiter can visually not necessarily be detected. In order to check, whether the limiter triggered, the compressor shaft must be secured using a suitable tool (figure 5) and the belt pulley must be turned counterclockwise at the same time. If the belt pulley can be turned counterclockwise, the limiter triggered and the compressor must be replaced. In the case of Sanden PXE 13 and PXE 16 compressor types, the speed limiter cannot be replaced.
In the case of the Audi A3 and the lowest temperature setting, the maximum current relayed by the control unit to the control valve amounts to approx. 0.65 A. In this case the compressor reaches its maximum output. In closed-loop operation a mean current of 0.3 A flows. However, the problem in the case of newer vehicles is that diagnostics outside the engine management range is not possible yet using many test devices. Ideally, an oscilloscope should be used. Using suitable probe tips, the PWM signal at the plug connector of the compressor can be recorded. The oscilloscope should be adjusted to 5 V/Div and 0.5 ms/Div. Now, the different operating modes can be illustrated on the oscilloscope’s screen, while the engine is running. At the lowest temperature setting (“Lo”), a square-wave signal with a duty cycle of approx. 75 % can be seen (figure 7). The duty cycle results from the ratio between pulse width \( B \) and signal distance \( C \) (in this case, 75 % on-period and 25 % off-period).

At the same time, the amount of the onboard electrical system voltage (approx. 13.5 V) can be read out based on the Volt divisions (A=5 V). The voltage value shown (9.8 V) is merely a mean value. The pulse width depends on the requested cooling capacity and the onboard electrical system voltage. The current from the control unit to the control valve is “regulated” across the distance of the \( B \) range. Depending on the settings of the operating unit and environmental influences (e.g. exterior temperature), the pulse width of the square-wave signal is changed such and/or the control valve actuated that the compressor output necessary to achieve the requested temperature is obtained. Figure 8 shows, how the compressor is regulated down for temperature setting “High”. Figure 9 was recorded during “Econ” operation (compressor off) and shows no signal. Based on this method it can be determined, to what extent the signal is changed by the control unit. If the signal change is plausible, however the outlet air temperature and/or the interior temperature does not change, a compressor defect is likely.

Furthermore, diagnostic devices are available in the market, using which a PWM signal with different pulse duration can be generated. This way it can be determined, whether an actuation of the compressor results in a change in the refrigerant pressure. Based on this it can be determined, whether the compressor still functions without problems.

A function test using PWM signal can also be performed using a function (waveform) generator (figure 10). However, for this purpose it is imperatively necessary to connect a “load” to the control unit side of the air conditioning system, which corresponds to the load of an electronic control valve. Otherwise, the control unit detects a fault in the system and stores it in the fault memory. This can lead to malfunctions and/or a system failure. In this case the fault memory must be read out and cleared using a diagnostic device.

In connection with noise and other problems of the air conditioning system, defective compressors are time and again prematurely claimed. In many cases it turns out that the compressor is OK or that the defect is not caused by the compressor. For this reason, all components of the system should always be considered during troubleshooting.
Noise cannot only be caused by the compressor, but also by its fixing, the drive, the expansion valve or by the pipes. An incorrect refrigerant quantity can cause diverse noises as well.

**Beyond that, the oil provides important information regarding possible damage:**
- If the oil in the compressor or in the systems assumes a red colour, this might be caused by too much humidity.
- Black oil indicates a defective compressor.
- Silver-grey oil should be tested for metal filings. The greyish discoloration indicates metal abrasion.

As the system oil quantities are becoming smaller (partly 80 ml only), monitoring of and compliance with the oil quantity (e.g. during air conditioning service and component replacement) is of highest importance.

A compressor without clutch is only possible to a limited extent. In any case, a repair must be conducted using suitable tools and repair information.

The evaluation of system pressures is of special importance during diagnostics. In this context, the target values of the vehicle manufacturer should be considered. This also applies to the outlet air temperature.

Guidelines for the evaluation of system pressures can be obtained from the table below:

<table>
<thead>
<tr>
<th>System pressure evaluation</th>
<th>High pressure</th>
<th>Low pressure</th>
<th>Symptoms</th>
<th>Possible cause</th>
<th>Possible remedies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Out-flowing air is not cold</td>
<td>Too much oil in the air conditioning system, Air or humidity in the in the air conditioning system</td>
<td>Exhaust and flush the air conditioning system and refill with oil and refrigerant, Exhaust air conditioning system, replace dryer and refill</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low pressure line colder than evaporator, High pressure decreases, if the condenser is cooled with water, High pressure and low pressure equalise as soon as the compressor is switched off and pulse as soon as the compressor is switched on</td>
<td>Expansion valve opened too far, Too much refrigerant in the system, Condenser contaminated/ blocked, Fan problems, Problem with compressor (exhaust valve/sealing)</td>
<td>Replace expansion valve, Exhaust and refill the air conditioning system, Check the condenser, clean/ replace, Check the fan, Check the compressor, replace as needed</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Out-flowing air is not cold, Suction line is colder than the evaporator</td>
<td>Not enough refrigerant in the system, Blockage on the suction side</td>
<td>Exhaust and refill the air conditioning system, Check pipes and connections, replace as needed</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Ice generation on the liquid line, Ice generation on the dryer</td>
<td>Line/dryer blocked</td>
<td>Check dryer/line, replace as needed</td>
</tr>
</tbody>
</table>
All air conditioning compressors work the same way: Gaseous refrigerant is drawn in and compressed.

There are different designs, however, whose appearance frequently is enough to determine the respective type:

**Piston compressors** are very common and often have an elongated shape. The number of pistons can vary, depending on the construction.

**Scroll compressors**, for example, are relatively compact and can be identified by their bulbous shape.

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

The **electric compressor** can be immediately detected because it does not have a pulley.
Regulation of compressor output

The compressor or refrigerant pressure can be regulated in many different ways. Typically, regulation occurs by activating/deactivating the magnetic clutch and an internal, mechanical control valve. More modern designs, however, no longer have a magnetic clutch. Rather, they are permanently driven. The regulation process is assumed by an electric control valve (Figure 1) that is externally actuated in pulse width modulated fashion. There are also compressor variants that have a magnetic clutch and an electric control valve. The regulation process for electrically driven compressors takes place exclusively by way of the compressor’s operating speed.

Safety valve

Most compressors have an overpressure safety valve that bleeds off refrigerant at approx. 35 bar to protect the system from further damage. Pressure relief valves can have a foil or sealing wax (Figure 2). If this foil or wax is damaged, this is an indication that refrigerant was drained due to a fault in the air-conditioning system. There are also safety valves in circulation that do not have a “seal” (Figure 3). Here, if any residue of oil or contrast agent can be seen, one can assume that refrigerant was drained via the valve. In the event of a system fault, the valve itself should also be inspected.
The following questions continually arise in conjunction with replacing a compressor:

a) Are new compressors filled with oil?

b) How much oil is contained in new compressors?

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

d) How do I fill the new compressor with oil?

e) Which oil do I need to use?

Behr Hella Service compressors are filled with a minimum quantity of oil. Irrespective of the delivery state of the compressors, the oil filling level must be checked for every compressor before installation in the vehicle and, if necessary, corrected according to the manufacturer’s specifications and enclosed documentation. The reason for this is that it is not only possible to use many types of compressors in just the one vehicle but also in a wide range of different vehicles and vehicle models. The appropriate oil quantity must then be accordingly adapted.

The oil in the new compressor is to be emptied via the opening of the previously removed drain or filling screw (Figure 1). To this end, the compressor shaft must be turned multiple times. The compressor is then refilled with the complete oil filling amount for the system as specified by the vehicle manufacturer. At the same time, care is to be taken to select the correct oil viscosity. The compressor shaft should be turned several times to ensure even distribution of the oil. Finally the drain/filling connection on the compressor is be closed again. The individual specifications of the documentation accompanying the compressor are to be observed separately.

FILLING OIL INTO COMPRESSORS

Note:

In the case of compressors without a drain/filling screw, the oil must be drained using the high and low pressure connection (Figure 2) on the compressor and filled using the low pressure connection (Figure 3). Here, too, the compressor shaft has to be turned. Should it not be possible to add the entire oil quantity into the compressor, the differential quantity can be administered into the refrigerant circuit using the air conditioning service unit.
Special considerations

One special consideration must be taken into account for the following compressor types, however:

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

By design, oil cannot be drained from these compressors. An oil drain/filling screw is not provided and it is also not possible to drain the oil via the high-pressure and low-pressure connections.

The compressors are already filled with the entire system oil quantity. It is therefore vital that you flush the air-conditioning system before installing the new compressor to ensure that all oil has been removed.

Electric compressors are also filled with the correct system oil fill quantity. Here, too, the system must also be flushed prior to installing.

Further information on this topic can be found online at ‘Hella Tech World’: www.hella.com/hella-tech-world-de-de/
MAINTENANCE AND REPAIRS
FLUSHING THE AIR CONDITIONING SYSTEM

Flushing is mandatory!
The flushing of air conditioning systems is one of the most important tasks in the event of repairs or compressor damage, since it removes contaminations and damaging substances from the air conditioning circuit. Flushing is required for repairs to be performed properly and so as to avoid expensive subsequent repairs. In addition, flushing ensures warranty claims can be made against suppliers – and guarantees customer satisfaction. Compressors, expansion valves, orifice tubes and filter dryers cannot be flushed, however, and have to be bypassed by adapters during the flushing process. Valves and filters have to be replaced after the flushing process has been completed.

Why is flushing necessary?
1. In the case of compressor damage, contamination caused by metal abrasion must be removed.
2. Acid residue caused by humidity penetration must be removed.
3. Blockages caused by elastomer particles must be flushed out.
4. Contaminated refrigerant or refrigerant oil must be removed without residue.

General information regarding flushing
→ Always read the respective operating manuals, instruction leaflets, vehicle manufacturer’s specifications, safety data sheets etc. carefully.
→ Before and during work, always observe the respective safety regulations, including the Technical Information ‘Handling refrigerants’ and ‘Removal and installation instructions’.
→ Compressors, dryers/accumulators, expansion valves and orifice tubes cannot be flushed.
→ Please make sure that all dirt or damaged components have been removed from the refrigerant circuit.
→ Make sure that there is no residual flushing agent residue in the system by blowing the system components sufficiently dry with nitrogen (do not use compressed air).
→ Fill the compressor with the correct quantity/specification of oil (PAO Oil 68 available from Behr Hella Service is particularly suitable). Make sure you fill the correct quantities for the components flushed.

→ Before starting operation, spin the compressor 10 times by hand first.
→ Replace the filter dryer or accumulator and the expansion valve or orifice tube.
→ Insert a filter screen into the suction line of the compressor.
→ Following correct evacuation, fill the refrigerant circuit with the prescribed quantity of refrigerant.
→ Start the engine. Wait for idle stabilisation.
→ Switch the air conditioning system several times on and off for 10 seconds each.
→ Carry out system pressure, function and leak tests.
Flushing the air conditioning system and the components

Air conditioning systems are flushed to remove impurities and damaging substances from the refrigerant circuit. The following information has been compiled to provide support for users new to the subject of "flushing air conditioning systems" by answering important points such as:

→ Why air conditioning systems need flushing at all.
→ What the term "flushing" means in connection with vehicle air conditioning.
→ What types of impurities are eliminated by "flushing" or what effects these kinds of impurities have.
→ Which methods of flushing exist and how they are used.

Why should a vehicle air conditioning system be flushed at all?

Defective system components (old filter dryers (see figure), compressor damage etc.) can lead to dirt particles that are swept along by the refrigerant being distributed in the whole air conditioning system. If, for example, only the compressor is replaced following compressor damage, dirt particles can collect in the new compressor in no time and lead to the destruction of the newly installed system components as well as the expansion valve/orifice tube or multi-flow component – with expensive follow-on repairs the logical consequence. To avoid this, the system must always be flushed out following component damage that could lead to contamination of the refrigerant circuit through metal filings, rubber abrasion etc.!

In the meantime, the process of flushing is also required by many vehicle or compressor manufacturers.

What does the term "flushing" mean in connection with vehicle air conditioning?

The term "flushing" is used to describe the process of removing impurities or damaging substances from the refrigerant circuit. Flushing is necessary for professional repairs to be carried out, expensive follow-on repairs to be avoided, guarantee claims against suppliers to be upheld and customer satisfaction to be ensured.
What types of impurities are eliminated by "flushing" or what effects do these kinds of impurities have?

- Abrasion when the compressor is damaged:
  The material particles block expansion valves, orifice tubes or multi-flow components (condenser and evaporator).

- Humidity:
  Expansion valve and orifice tubes can freeze up.
  Acids that make tubes and O-rings porous can form as the result of chemical reactions between refrigerants / refrigerant oils and humidity. System components are damaged by corrosion.

- Elastomers (rubber):
  The elastomer particles block expansion valves, orifice tubes or multi-flow components.

- Contaminated refrigerant oil or refrigerant:
  Contaminated refrigerant or a mixture of different refrigerant oils can cause acids to form as well. The acids can make tubes and O-rings porous. Further system components can be damaged by corrosion.

1. Chemical agent (flushing liquid)

The connection pipes or system components must be flushed individually. They are flushed using a chemical agent (flushing liquid) with the aid of a universal adapter on a flushing gun.

Following the flushing process, nitrogen must be used to remove the flushing medium residue from the refrigerant circuit and to dry the refrigerant circuit.

**Recommendation**

Maximum efficiency is achieved by combining the use of flushing liquid and nitrogen. First, even stubborn particles and hardened deposits are eliminated by flushing with flushing liquid. The subsequent blowing out with nitrogen dries the refrigerant circuit and the components again.

**Disadvantage**

Costs for the chemical cleaning agent and its professional disposal, as well as additional installation costs for removing and replacing pipes and components.
2. Refrigerant
When flushing with refrigerant (R134a), the existing air-conditioning service station is outfitted with adapters and filter elements to flush the refrigerant as a liquid through the refrigerant circuit.

Disadvantage
Only loose dirt particles and oil can be removed from the system. In addition, adaptation panels are required for flushing to be carried out properly. These adaptation panels increase the costs of this method due to the additional installation and removal work involved. The service station is not available for other vehicles during the application.

Note
Whereas tube & fin and serpentine components are usually easy to clean, it is often not possible to clean components using 'multi-flow' technology at all. If there is any doubt about the cleaning success where these components are involved, the components must be replaced. After the refrigerant circuit has been flushed, care must always be taken that a sufficient quantity of new oil is filled into the system.

The following quantities (% of the total oil content) serve as a reference:
- Condenser: 10 %
- Dryer/accumulator: 10 %
- Evaporator: 20 %
- Tubes/pipes: 10 %

If the above-mentioned points are not complied with, warranty may be voided.
Advantages and disadvantages of the different flushing methods

<table>
<thead>
<tr>
<th>Flushing medium</th>
<th>Refrigerant</th>
<th>Flushing liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flushing method</td>
<td>System components are flushed with the aid of the air conditioning service unit and an additional flushing unit with filters and adapters (both available separately).</td>
<td>System components are flushed using an additional flushing unit and a chemical solution. Flushing liquid residue needs to be removed with nitrogen and the system needs to be dried with nitrogen.</td>
</tr>
</tbody>
</table>
| Advantages      | + No costs for the flushing agent  
+ No disposal costs for the flushing agent  
+ Removes oil and loose dirt particles  
+ Method released by various vehicle manufacturers | + Removes oil and loose and persistent particles  
+ Excellent cleaning results |
| Disadvantages   | – Less than optimal cleaning effect in the case of adhering contaminations  
– Filter insert of the flushing unit has to be replaced at regular intervals  
- The air conditioning service unit is not available during the procedure | - Costs for the flushing agent  
- Disposal costs for the flushing agent |

Air conditioning products
Leak detection technologies
One of the most frequent causes of functional problems in the air conditioning system are leaks in the refrigerant circuit. These lead to an unnoticed drop in filling level and thus to a reduction in performance or even complete failure. As far as refrigerant R134a is concerned in particular, it is well known that it diffuses out of rubber pipes and connections. Since air conditioning experts cannot be sure whether there is a leak or whether the refrigerant loss is the normal loss over time, careful leak detection is a must.

The following are tested:
- All connections and pipes
- Compressor
- Condenser and evaporator
- Filter dryer
- Pressure switches
- Service connections
- Expansion valve

Three leak detection methods are recommended:
1. Dye and UV lamp
2. Electronic leak detection
3. Leak detection with forming gas

Leak detection using dye

Dye
Different methods are used to add dye to the refrigerant (e.g. Spotgun dye, dye cartridges ...).

Spotgun/Pro-Shot
The exact amount of dye required is injected using the Spotgun cartridge gun or the Pro-Shot system. Further advantage: Dye can be added when the system is full.

Leak detection lamps
Escaping dye is made visible by the UV light.
Leak detection with electronic tester/with nitrogen/ through foam generation

Electronic leak detection using a leak detector
Indicates leaks through an acoustic signal. It detects halogen gases and even detects the tiniest of leaks at points that are difficult to reach (e.g. evaporator leaks).

Leak detection using a nitrogen set
This tool can be used for leak tests – in addition to its function for drying the system. For leak tests, a filling adapter is required for the service connection as well as a tube adapter. The emptied air conditioning system is filled with nitrogen (maximum 12 bar). It is then observed over an extended period of time (e.g. 5-10 min), whether the pressure remains constant. Leaks are detected via a "hissing" sound. Otherwise, it may be sensible to make the leaky spot visible using leak detection agent. The leak detection agent is sprayed on from the outside. It forms foam at the point of the leak. Using this method, larger leaks at well accessible locations can be detected only.

Leak detection using a forming gas leak indicator
To detect leaks, the empty air conditioning system is filled with forming gas, a mixture of 95 % nitrogen and 5 % hydrogen. Using a special electronic leak indicator, the components are checked for leaks. Due to the fact that hydrogen is lighter than air, the sensor needs to be moved slowly above the suspected leak (electrical connections/components). After the end of the leak search, the forming gas can be released into the atmosphere. This leak detection method complies with Article 6, § 3 of the EU Directive 2006/40/EC.
LOKRING pipe connection technology
LOKRING is a fast and extremely profitable repair method. Instead of having to order expensive complete pipe systems and wait for deliveries when pipes are defective, the problem can be solved on the spot – often without having to dismantle anything. The LOKRING principle has proved its worth thousands of times over in air conditioning and climate technology.

It stands out thanks to nine processing advantages:
- Simple and quick fitting
- Hermetically sealed metal/metal seals that cannot be detached
- Safe connection of pipes made of various materials
- No special preparation necessary for the pipes
- Handy fitting tools
- Large dimensional tolerances allowed
- No burring effect in the installation area
- No welding, soldering or thread cutting
- Eco-friendly and harmless connection technology

LOKRING is so airtight that there is no notable drop in pressure and no reduction in flow speed. As a backup, the surfaces of the pipe ends are wetted with LOKPREP sealing fluid. The system is permanently airtight at the LOKRING spots. The pipe connections have been designed for a maximum rated pressure of 50 bar and a testing pressure of 200 bar. They can be used in a temperature range of -50 °C to +150 °C.

Pressing tools for refrigerant fittings
The crimping tool enables the fast and secure connection of tubes and fittings. An ideal pressing system for stationary and mobile use. The hydraulic hand-pump included builds up the pressing effect. A few hand movements are all that are needed to create an immensely strong pressure with a high adjusting range. It often allows tube repairs to be carried out without the tubes having to be removed first. Similar to the LOKRING, the crimp system saves repair-/waiting times and spare part costs. An investment that quickly pays off.
There are still numerous vehicles in the market with air conditioning systems originally designed for refrigerant R12. 2001 was the official final end for R12 in vehicle air conditionings systems. Starting from that date, R12 system had to be converted during maintenance or repair work. R134a was and is used as replacement refrigerant besides several "drop-in" refrigerants (refrigerant mixtures).

Even today, the conversion from R12 to R134a is still a topic in the area of classic ("Oldtimer") and modern classic ("Youngtimer") cars as well as in several non-EU countries.

In the course of conversion, the system must be checked for leak-tightness. Leaks are to be corrected upfront. All components should be checked for function and damage. The filter dryer is to be replaced. Sealing rings should be replaced. In addition, the mineral oil if the R12 system is to be replaced with PAG or PAO oil. In the course of this replacement it is recommended to flush the air conditioning system. A detailed description can be found as Technical Information in "Hella Tech World".

R134a has a high GWP (global warming potential) of 1430. With the current EC Directive 2006/40/EC it was decided to only use refrigerants with a GWP of less than 150 in the future.

Air-conditioning systems in class M1 vehicles (passenger cars, vehicles with up to 8 passenger seats) and in class N1 vehicles (commercial vehicles with a permissible total weight of up to 3.5 tons) for which a type approval was issued within the EU as of January 1, 2011 can therefore no longer be filled with R134a. As of January 1, 2017, vehicles filled with R134a are no longer entitled to receive initial registration approval.

R134a can, however, continue to be used to carry out service and maintenance work on existing R134a systems. One of the predominant new refrigerants being used is R1234yf, which has a GWP of 4. Other refrigerants can also be used, however, provided their GWP value is below 150. Only in time will it become apparent if all vehicle manufacturers agree on a single refrigerant, or whether different refrigerants will be used.

This, of course, also impacts garages and their service personnel. As such, it appears that purchasing new service units is something that cannot be avoided. Special measures must also be observed when it comes to storing and using the new refrigerants.
INTERIOR TEMPERATURE SENSORS

Insufficient temperature control due to contaminated sensors
The interior temperature sensor is located in the air flow of a miniature fan (mostly in the operating unit). It provides the temperature of the interior air as resistance value to the control unit. The measured value is compared with the target value.

Nicotine, dust and the like can heavily contaminate the sensor (see Figure). If the intake air flow to the sensor is no longer sufficient, this can result in faulty measurements and malfunctions. The balanced regulation of the air conditioning and heater systems is then no longer ensured. This becomes apparent when the temperature is continually regulated up and down and becomes very cold and then very warm. The sensor can be cleaned using special cleaning agents (e.g. acetone). Accumulated dust can be removed by applying a gently stream of compressed air. In most cases, the regulation mechanism returns to normal operation after the sensor is cleaned.
Sealants for air conditioning systems consist of chemical components, which are entered into the air conditioning system in order to seal against smaller leaks on components and O-rings.

Not only refrigerant, but the sealant escapes through the leak as well.

This sealant normally reacts with atmospheric oxygen and humidity, hardens and closes the leak.

The use of sealants is problematic from a different point of view.

According to EC Regulations and Directives, a leaking air conditioning system may not be operated or filled with refrigerant again, without correcting the leak first. An infringement may result in substantial fines.

If components are pre-damaged or weakened (e.g. due to corrosion), it is just a matter of time until a leak occurs at a different location.

When draining refrigerant from vehicles, which were previously filled with sealant, there is a risk that the sealant reacts inside the air conditioning service unit and thus, causes blockage/damage. For many vehicle, device and component manufacturers the use of sealants puts a warranty claim at risk.

Finally, the use of sealants for a leaking air conditioning system does not represent a legal conformity and permanent repair method.

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What are the trends and development directions with respect to air conditioning systems and interior comfort?

“Multi-zone air conditioning systems” are increasingly becoming the standard. In luxury-class models, air conditioning systems with “humidity management” are already being used, which counteract the production of extremely dry air.

In future, “interior climate management” shall be a part of air conditioning and ventilation systems. This means that with the help of air quality sensors the best possible interior climate is created in connection with air treatment systems.

Electronically controlled compressors shall be the standard in all vehicle classes. These make individual adaptation of power and thus lower fuel consumption possible. Optimised components, pipes and seals will ensure “refrigerant loss rates” as low as possible in future.

Customised air conditioning for everybody on every seat:

Customised air conditioning means:

- Individual air conditioning comfort for every seat in the vehicle
- Draught-free, pleasant ventilation
- High air quality
- Acoustic comfort, with as low as possible noise perception
- Simple, clear operation
In order to realise these goals, systems such as Physio-Control® made by Behr and BHTC were developed: Physio-Control® is a further development of multi-zone air conditioning. The system can selectively record and control the variables (solar irradiation, air humidity, air volume and air temperature) responsible for the comfort in the vehicle interior at defined locations. For this purpose, perfectly aligned subsystems work together.

The technical effort required is enormous. For example, an intelligent sun sensor measures the exact solid angle and solar irradiation intensity relative to the vehicle with the help of hardware and software. Based on that and the recorded vehicle contour, a computation model determines the intensity of radiation on body parts exposed to solar irradiation.

Optimum climate in the vehicle interior also means to continuously keep the windows clear. In order to prevent the windows misting up, the humidity is continuously measured in the area of the windshield. The air is dried via air conditioning system actuation as needed. Another intervention not obvious to vehicle occupants is the so-called humidity management. Here, the air humidity in the interior is kept at a constant level by actuating the air conditioning compressor and the fresh air flap.

Comfort ventilation outlets are used as subsystem. These are designed such that the individual outlet vents can be swivelled in a defined manner and continuously adjusted from direct to diffuse air outflow. Using the vents, the exact amount of air volume and type of air is provided to the occupants' bodies, which is perceived as pleasant. For example, this can be a concentrated air flow ("spot") during the cool-down process during the summer or a draught-free, diffuse air flow.

In order to determine the requested air distribution profile, the "Air Volume Control" is used. Here, the air volume exiting from the individual air vents and thus the air velocity is determined. Technically, this is enabled by a simulation software of the entire air conditioning and air routing system. The Air Volume Control detects for example one-sided air increase or decrease caused e.g. by mechanical closing of the air vent. The control algorithms stored in the software avoid changes in the air conditions on the other side of the vehicle. As a result, air volume and air distribution can be individually adjusted without unnecessary impact on other areas and persons in the vehicle.

Another innovation is the selection of different air conditioning styles. Hereby, the occupants choose between a spot, moderate or diffuse pre-selection depending on their "comfort type". Thus, cool air is directly blown onto the "sporty fresh" type, while the more "sensitive" type prefers a draught-free environment.
Air quality

In the meantime, the air quality in the vehicle interior is treated in several steps in the case of modern air conditioning systems. This is also referred to as “comfort steps”. It starts with filtering of fresh and recirculated air. This is realised by means of a nitrogen oxide sensor system. A NOx or air quality sensor determines the share of pollutants on the sucked in fresh air, which is considered in an automatic fresh air/ recirculated air control. In this context, filtering using activated carbon is increasingly gaining on importance.

The evaporator surface should be structured such that no odour generation caused by microorganisms can occur. For this purpose,Behr developed a special coating: Behr-Oxal®. This is an environmental coating technology, which generates a corrosion-resistant and hydrophilic aluminium surface without toxic or aggressive chemicals. As a result, the condensate is very well drained and the evaporator surface dries very quickly.

The measures mentioned above ensure neutralisation of contaminations and odours. For further comfort increase, an oxygen ioniser can be used, which cleans bacteria and germs from the air and maintains a freshness effect. In addition, a perfume atomiser can be used, which adds certain scents to the air in the vehicle interior.

Ergonomics

It has been shown that operating an air conditioning system still distracts the driver too long from traffic events and that the air conditioning system is partly incorrectly operated.

With increasing functionality, ease of use of the air conditioning system is partly made more difficult. This is expressed via:

→ No clear, logic arrangement of operating elements and displays
→ Complicated, partly too difficult operation
→ Unclear marking of operating elements
→ Unclear or missing status feedback

The investigations show that the following criteria should be considered for the air conditioning operating units to be used:

→ Sufficient dimensioning of displays, operating elements and symbols
→ Use of graphics and/or textual graphics instead of text only
→ Operating elements spatially arranged by similar functions
→ No coupling of main functions with other functions and/or hiding in sub-functions
→ Arrange operating unit and display closely together
Operating units developed according to the criteria above, relieve the driver from activities unrelated to driving the vehicle. The symbols used are known and their meaning can be intuitively understood. Main operating elements can also be felt, e.g. without looking at them. Menu navigation is simple and a comfort pre-selection is possible. The operating concepts e.g. developed by BHTC simplify individual adjustments of the requested automatic air conditioning control using different air conditioning styles. The graphical visualisation design focuses on quick, self-explanatory recognisability of the settings. For this purpose, high-resolution display technologies are used, allowing a situation-specific representation.

In the last years many innovations have been introduced in the area of air conditioning and/or interior comfort management. This shall be continued in the future as well. The challenge for the garage is to keep up with these developments. This is necessary to ensure maintenance, inspection and repair of such complicated systems in the future.
THERMAL MANAGEMENT IN HYBRID VEHICLES

Do not work on live high-voltage components! Always observe the warning signs on the components and elements!

The hybrid technology involves many significant changes for the thermal management system, both in the coolant and refrigerant circuits. Below, we describe what areas and components of the thermal management system are affected, how the working principles change and what this means for your work.

**Interior air conditioning**

In standard drive concepts with internal combustion engines, the air conditioning inside the vehicle directly depends on the engine operation due to the mechanically driven compressor. Compressors with belt drives are also used in vehicles, referred to as micro hybrids by experts, that only have a start stop function. The problem here 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 2 seconds. The associated slow rise in the temperature of the air blown in by the ventilation, and the increase in humidity is found to be annoying by the passengers.

To solve this problem in the future, newly developed cold accumulators will be used, so-called accumulator evaporators.
The accumulator evaporator comprises two blocks: an evaporator and an accumulator block. Refrigerant flows through both blocks in the start-up phase or when the engine is running.

In the stop phase, the motor is switched off and as a result the compressor is not driven. The warm air flowing past the evaporator cools down and the heat exchange process takes place. This exchange process goes on until the latent medium has completely melted off. After the journey is resumed, the process starts again so that the accumulator evaporator can start cooling the air again after just one minute.

In the case of vehicles without an accumulator evaporator, it is necessary to start the engine again after a short standstill period in very warm weather. This is the only way to maintain the interior cooling.

A latent medium in the evaporator is cooled during this time until it freezes. It therefore becomes a cold accumulator.

Air conditioning inside the vehicle also includes heating the passenger compartment if required. In full hybrid vehicles, the internal combustion engine is switched off during the electric driving. The prevailing residual heat in the water circuit is sufficient to heat the interior only for a short period of time. Electrical PTC heating elements are then activated, which assume the heating function. The operation is similar to that of a hair dryer: the air that is taken from the interior fan is heated up as it flows past the heating elements and then passes into the interior.
The high-voltage compressor

Vehicles with full-hybrid technology use electric high-voltage compressors that do not depend on the internal combustion engine running. This innovative drive concept allows functions to be carried out which further increase the comfort of the air conditioning system in the vehicle:

It is possible to pre-cool the heated interior of the vehicle to the required temperature before driving. It can be controlled via a remote control.

This parking cooling can only be realised depending on the amount of battery capacity available. The compressor is controlled with the lowest possible output taking into account the necessary air conditioning requirements.

In the high-volt 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 primarily used in the belt-driven compressor field, the high-volt compressors use the scroll principle to compress the refrigerant. The benefits are that the weight is reduced by approx. 20% and there is a reduction in the cylinder capacity of the same amount whilst the output remains identical.

To generate the right amount of torque for the drive of the electric compressor, a DC voltage of over 200 Volt is used – 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 necessary heat dissipation from the inverter and the motor windings is facilitated by the return flow of refrigerant to the suction side.

High voltage compressor
Temperature management of the battery

The battery is essential for operating a hybrid vehicle. It must quickly and reliably provide the high amount of required energy for the drive. Usually these batteries are nickel metal hybrid high-voltage batteries, however more and more often lithium-ion high-voltage batteries are being used. This further reduces the size and weight of the hybrid vehicle batteries.

It is imperative that the batteries that are used are operated within a defined temperature window. Starting from an operating temperature of +40 °C, the service life is reduced, whilst at temperatures below -10 °C, the efficiency drops and the output is lower. Also, the temperature difference between the individual cells may not exceed 5 °-10 ° Kelvin.

Brief peak loads in connection with high current flows, such as recuperation and boosting, lead to a significant increase in the temperature of the cells. Also, high exterior temperatures in the summer months can mean that the temperature quickly reaches the critical 40 °C level.

When the temperature is exceeded, the result is faster aging and the associated premature failure of the battery. Vehicle manufacturers strive to ensure that the calculated battery life span is 1 car life (approx. 8-10 years). Therefore, the aging process can only be countered with a corresponding temperature management system.

Until now, three temperature management options have been used.

Scroll compressor
High-voltage motor
Possibility 1
Air is drawn in from the air conditioned vehicle interior and is used to cool the battery. The cool air drawn in from the vehicle interior has a temperature of less than 40 °C. This air is used to flow around the accessible surfaces of the battery pack.

Disadvantages of this are:
- Low cooling effectiveness.
- The air drawn in from the vehicle interior cannot be used to evenly reduce the temperature.
- Considerable effort required to guide the air.
- Possibly annoying noises inside the vehicle interior caused by the fan.
- There is a direct connection between the passenger compartment and the battery via the air ducts. For safety reasons (e.g. outgassing of the battery) this is to be classified as problematic.
- Another factor that should not be underestimated is the risk of dirt entering the battery pack, as the air from the vehicle interior also contains dust. The dust is deposited between the cells and, in conjunction with condensed humidity, forms a conductive layer. This layer facilitates the creation of leak currents in the battery.

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

Possibility 2
A special evaporator plate inside the battery cell is connected to the air conditioning system in the vehicle. This is effected in the so-called splitting process on the high pressure and low pressure side via pipes and an expansion valve. This means that the evaporator inside the vehicle and the evaporator plate in the battery, which works like a normal evaporator, are connected to the same circuit.

The various requirements on the refrigerant flow are respectively defined by the different tasks of the two evaporators. Whilst the interior cooling system aims to satisfy the comfort requirements 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 exchange. As a result it can be ensured that the critical upper maximum temperature of 40 °C is not exceeded.

Note
Evaporator plates that are directly integrated into the battery cannot be individually replaced. Therefore, the whole battery needs to be exchanged in the event of any problems.
When the exterior temperatures are very low, a temperature increase to the ideal temperature of the battery of at least 15 °C would be necessary. However, the evaporator plate cannot contribute to this in this situation. A cold battery is less powerful than one that has the right temperature and it is difficult to charge when the temperatures are clearly below freezing. In the mild hybrid this can be tolerated: in extreme cases, the hybrid function is only available in a limited form. It is however still possible to drive with the internal combustion engine. On the other hand, a battery heater must be installed in pure electrical vehicles so that the vehicle can be started and driven whatever the situation in the winter.

Possibility 3
For large-capacity batteries, the correct temperature control plays a central role. Therefore, at low temperatures it is necessary to provide additional heating for the battery in order to reach the ideal temperature range. It is only in this area that a sufficient range can be achieved in the “Electric Driving” mode.

To enable this additional heating, the battery is integrated into a secondary circuit. This circuit ensures that the ideal operating temperature of 15 °C - 30 °C is maintained at all times.

In the battery block, coolant (water and glycol) flows through an integrated cooling plate (green circuit). At lower temperatures, the coolant can be quickly heated by a heater in order to reach the ideal temperature. If the temperature in the battery rises during the use of the hybrid functions, the heating is switched off. The coolant can be cooled by the air flow through the battery cooler located at the front of the vehicle.
If the cooling by the battery cooler is not sufficient at high ambient temperatures, the coolant flows through a special heat exchanger. In it, refrigerant from the vehicle air conditioning system is evaporated. In addition, heat can be transferred in a compact fashion and with high power density from the secondary circuit to the evaporating refrigerant. An additional re-cooling of the coolant is performed. By using the special heat exchanger, the battery can be operated within a temperature range offering optimal efficiency.

Further information about hybrid vehicles is available at www.hella.com/techworld or in our Know-How tool.
**Required further training for repairing hybrid vehicles**

Continuous ongoing education is required to maintain and repair the complex thermal management systems found in hybrid vehicles. Employees who carry out work on such high-voltage systems in Germany, for example, must attend an additional 2-day education workshop to become a certified "electrical technician for high-voltage systems".

**Maintenance of hybrid vehicles**

The situation is also special when performing routine inspections and repair work (such as e.g. on exhaust systems, tyres, shock absorbers, oil change, tyre change, etc.).

These tasks may only be carried out by employees who have attended the “Electrician for high-voltage systems” course to learn about the risks associated with these high-voltage systems.

Also, it is imperative that tools are used that comply with the specifications provided by the manufacturer of the hybrid vehicle.

When performing an air-conditioning check and service, note that electrical air conditioning compressors are not lubricated with traditional PAG oils. These oils do not offer the insulation properties required. POE oil is therefore typically used, which has these properties. Behr Hella Service PAO oil 68 AA1 Clearversion (without leak detector) can also be used.

As a result, air conditioning service units with an internal flushing function and a separate fresh oil reservoir are recommended for the air conditioning check and service in hybrid vehicles. This way mixing of fresh oils of different oil types can be excluded.
PAG, PAO AND POE
AIR CONDITIONING
COMPRESSOR OILS

There are many oils available, but which ones can be recommended?

Oil plays an important role in the air-conditioning system:
No matter whether it’s required when the compressor is replaced or for refilling during the air-conditioning service. Like blood in the human body, the oil fulfills vital tasks in the air-conditioning system.

The use of high-grade compressor oil is therefore critical for the reliable and continuous operation of the system. The use of low-quality or even the wrong oil – just like with the engine – leads to increased wear, premature compressor failure and loss of warranty/guarantee.

PAG compressor oils for the vehicle air conditioning system

Product characteristics
→ Fully synthetic, hygroscopic oils based on polyalkylene glycol
→ Used by many vehicle and compressor manufacturers for air-conditioning systems intended for the R134a refrigerant, with different viscosities
→ New special PAG oils 46 YF and 100 YF, both suitable for refrigerants R1234yf and 134a

Usage/effect
→ PAG oils are highly miscible with R134a (PAG oils 46 YF and 100 YF also with R1234yf) and are suitable for lubricating the air-conditioning systems of most passenger and commercial vehicles.
→ When using PAG oils, ensure that you select the correct viscosity classification (PAG 46, PAG 100, PAG 150). Observe the specifications and approvals of the vehicle manufacturers.

Additional details
The disadvantage of PAG oils is that they are hygroscopic, i.e. they absorb and bind moisture from the ambient air. For this reason, opened oil containers must be resealed immediately and once opened, the remaining oil cannot be stored indefinitely. This is particularly important for the fresh oil containers at the air-conditioning service unit.

Note:
Using the wrong oil can cause damage. Vehicle and manufacturer-specific information must therefore be observed accordingly.
PAO Oil 68 and PAO Oil 68 Plus UV

Product characteristics
- Not hygroscopic: Unlike other oils, they do not absorb moisture from the air
- Can also replace the different PAG oils currently used (observe usage overview!): You now only need to stockpile one oil instead of three
- Has already been successfully used for 15 years
- Contributes to an increase in air conditioning performance
- No adverse effects on components of the air-conditioning circuit (also applies to use in air-conditioning service stations/confirmed by manufacturer using the sealed tube test compliant with the ASHRAE 97 standard)
- This oil is available with (PAO oil 68 Plus UV) or without (PAO oil 68) an added contrast agent
- Using PAO oil 68 and PAO oil 68 Plus in compressors from Behr Hella Service maintains your full warranty entitlement

Usage/effect
PAO Oil 68
- Only a little oil circulates in the system because it combines only slightly with the refrigerant
- As much as possible remains in the compressor – where the oil is needed
- The oil film inside the components makes for a better seal and reduces friction between the moving parts of the compressor
- Lower operating temperature and wear
- This increases operational reliability and reduces noise, cycle times and the compressor’s energy consumption

PAO Oil 68 Plus UV
- The same positive characteristics as PAO oil 68
- In addition, it incorporates a highly effective contrast agent for UV leak detection
- Low percentage volume concentration of the contrast agent with the following advantages: Preserves the oil’s positive properties and avoids negative effects on system components or servicing equipment
- Suitable for use as the sole oil for filling the entire system, with no negative effects
Additional details

Is PAO oil 68 compatible with other oils?
→ PAO Oil 68 doesn’t have any harmful effects on fluoroelastomer materials such as hoses or seals.
→ Since PAO oil 68 is compatible with many other lubricants and refrigerants, PAO oil 68 can be used both for refilling and replacing the entire system oil quantity. Due to the molecular structure and density, PAO Oil 68 mixes to a certain extent with other oils but separates from them again when it “comes to rest” and does not form a permanent compound.
→ This guarantees that the necessary viscosity of the oils is maintained and there is no change in the overall viscosity (see Figs. 1 and 2).

Can PAO Oil 68 be used in the case of humidity problems?
→ PAO-Oil 68 is not hygroscopic, i.e. unlike other oils it does not absorb moisture from the ambient air. This means that humidity-related problems, e.g. icing on components or the formation of acids, can be combated simply by using PAO oil 68. The range of possible applications and the storage stability of PAO oil 68 are both much greater than for conventional oils.

Special features and properties
→ No risk of oil collecting in the evaporator and the associated deterioration in cooling performance
→ An oil film in the components improves the seal
→ Reduction of the friction between the components
→ Reduced energy consumption of the compressor
→ Unique combination of highly refined, synthetic oil and special performance-enhancing additives
→ Very high operating range (−68 to 315 °C)
→ Low volume % of the highly active contrast agent in PAO Oil 68 Plus UV, which means protection and reduced wear of the system components and service units

Note:
The clear version of PAO oil 68 (without leak detecting agent) is also suitable for use with R1234yf and approved for use in electrical compressors in hybrid vehicles.
POE oil for electric compressors in hybrid vehicles

Product characteristics
Electric air-conditioning compressors in hybrid vehicles are powered by an internal electric motor that operates in the high voltage range. The compressor oil in these compressors comes into contact with the electric motor coil, amongst other things. As such, it has to satisfy particular requirements:

→ It must not have any negative impact on the materials used in the compressor
→ It must have a specific electrical short-circuit resistance

The POE Oil offered by Behr Hella Service satisfies these requirements.

Usage/effect
→ Can be used on all hybrid vehicles with an electrical compressor that are filled with POE oil at the factory
→ Bottled in "Spotgun" cartridges, which gives it maximum protection against moisture (problem: POE oil is hygroscopic).

Additional details
→ Using the spotgun (cartridge press), it can either be filled directly into the system (with the aid of an adapter hose with low-pressure connection) or into the oil tank on the air-conditioning service unit
→ Spotgun cartridge 120 ml
→ Each individual cartridge is sealed in an aluminum bag
→ The aluminum bag also contains a smaller bag with desiccant (drying pellets) to optimally protect the oil against moisture
### COMPARISON OF COMPRESSOR OILS

<table>
<thead>
<tr>
<th>Type of oil</th>
<th>Application</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAG oils</td>
<td>Different grades of PAG Oil with different flow properties (viscosities) are available for use with refrigerant R134a.</td>
<td>Standard PAG oils are not suitable for R1234yf refrigerant and electrically driven air conditioning compressors</td>
</tr>
<tr>
<td></td>
<td>PAG oils are hygroscopic. As a result, any cans that have been opened cannot be stored for prolonged periods.</td>
<td>PAG oil YF is suitable for the R1234yf and R134a refrigerants</td>
</tr>
<tr>
<td>PAG-OIL YF</td>
<td>Different PAG oils are also available with different flow properties (viscosities) for use with the R1234yf refrigerant.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What makes these PAG oils from Behr Hella Service so special is that they are not only suitable for use with refrigerant R1234yf, but can also be used with the refrigerant R134a.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PAG oils are hygroscopic. As a result, any cans that have been opened cannot be stored for prolonged periods.</td>
<td></td>
</tr>
<tr>
<td>PAO oil</td>
<td>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. unlike other oils, it does not absorb moisture from the ambient air). The 3 different grades of PAO oil offered by Behr Hella Service (AA1, AA2 und AA3) can be used in conjunction with numerous different refrigerants (see product overview).</td>
<td>PAO oil AA1 Clearversion (without leak detection agent) can also be used with the new refrigerant R1234yf and also in electrically-driven compressors in hybrid vehicles.</td>
</tr>
<tr>
<td>PAO oil</td>
<td>Can be used on all hybrid vehicles with an electric compressor that are filled with POE oil at the factory (there are also electrically driven compressors for hybrid vehicles that are filled with a special PAG oil at the factory).</td>
<td></td>
</tr>
<tr>
<td>POE oil</td>
<td></td>
<td>Not suitable for refrigerant R1234yf</td>
</tr>
</tbody>
</table>
Finding the right oil quickly while on the go

Find out more about our oils and which oil goes with which compressor in our compressor app.

Simply download the app from iTunes or the Google Play Store!
<table>
<thead>
<tr>
<th>Part number</th>
<th>Product</th>
<th>Viscosity classification</th>
<th>Content</th>
<th>Can be used for refrigerants</th>
<th>Can be used for compressor types</th>
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</thead>
<tbody>
<tr>
<td>8FX 351 213-031</td>
<td>PAG oil</td>
<td>ISO 46</td>
<td>240 ml</td>
<td>R134a</td>
<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
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<tr>
<td>8FX 351 213-041</td>
<td>PAG oil</td>
<td>ISO 150</td>
<td>240 ml</td>
<td>R134a</td>
<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
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<tr>
<td>8FX 351 213-051</td>
<td>PAG oil</td>
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<td>240 ml</td>
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<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
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<td>All compressor types except electrically driven compressors</td>
</tr>
<tr>
<td>8FX 351 213-061</td>
<td>PAG oil Spotgun</td>
<td>ISO 46</td>
<td>240 ml</td>
<td>R134a</td>
<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
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<td>8FX 351 213-071</td>
<td>PAG oil Spotgun</td>
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<td>240 ml</td>
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<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
</tr>
<tr>
<td>8FX 351 213-081</td>
<td>PAG oil Spotgun</td>
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<td>240 ml</td>
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<td>All compressor types except electrically driven compressors</td>
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<td>8FX 351 213-111</td>
<td>POE oil Spotgun</td>
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<td>120 ml</td>
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<td>Air conditioning systems in hybrid vehicles</td>
</tr>
<tr>
<td>8FX 351 213-121</td>
<td>PAG OIL YF</td>
<td>ISO 46</td>
<td>240 ml</td>
<td>R1234yf; R134a</td>
<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
</tr>
<tr>
<td>8FX 351 213-131</td>
<td>PAG OIL YF</td>
<td>ISO 100</td>
<td>240 ml</td>
<td>R1234yf; R134a</td>
<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
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<td>Electrically driven compressors</td>
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<td>8FX 351 214-021</td>
<td>PAO AA1 clear version</td>
<td>ISO 68</td>
<td>1,000 ml</td>
<td>R1234yf; R134a; R413a; R22; R12; R507a; R500; R502</td>
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<td>8FX 351 214-031</td>
<td>PAO AA1 clear version</td>
<td>ISO 68</td>
<td>500 ml</td>
<td>R134a</td>
<td>Air conditioning systems in hybrid vehicles</td>
</tr>
<tr>
<td>8FX 351 214-101</td>
<td>PAO AA1 clear version</td>
<td>ISO 68</td>
<td>5,000 ml</td>
<td>R134a</td>
<td>Air conditioning systems in hybrid vehicles</td>
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<td>Air conditioning systems in refrigerated trucks</td>
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<tr>
<td>8FX 351 214-201</td>
<td>PAO AA1 PLUS UV</td>
<td>ISO 68</td>
<td>500 ml</td>
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<td>Air conditioning systems in vehicles with conventional gasoline or diesel engines (passenger cars, trucks, agricultural and construction vehicles)</td>
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<td>8FX 351 214-211</td>
<td>PAO AA1 PLUS UV</td>
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<td>1,000 ml</td>
<td>R134a</td>
<td>Air conditioning systems in refrigerated trucks</td>
</tr>
<tr>
<td>8FX 351 214-221</td>
<td>PAO AA1 PLUS UV</td>
<td>ISO 68</td>
<td>5,000 ml</td>
<td>R134a</td>
<td>Air conditioning systems in refrigerated trucks</td>
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<tr>
<td>8FX 351 214-061</td>
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<td>ISO 32</td>
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<td>R604a; R407c; R401b; R401c; R402a; R403a; R408a; R409a</td>
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<td>PAO AA2 PLUS UV</td>
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<td>Air conditioning systems in refrigerated trucks</td>
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<tr>
<td>8FX 351 214-081</td>
<td>PAO AA3 clear version</td>
<td>ISO 100</td>
<td>1,000 ml</td>
<td>R1234yf; R134a; R413a</td>
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<td>8FX 351 214-281</td>
<td>PAO AA3 PLUS UV</td>
<td>ISO 100</td>
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<td>R134a; R413a</td>
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<td>Especially for vane compressors</td>
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</table>
## PRODUCT OVERVIEW

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Compressor type</th>
<th>Refrigerant</th>
<th>Viscosity classification</th>
<th>Content</th>
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<tbody>
<tr>
<td><strong>PAG oil</strong></td>
<td>Vehicle air-conditioning systems*</td>
<td>All types**</td>
<td>R134a</td>
<td>PAG I (ISO 46)</td>
<td>240 ml</td>
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<td>(can)</td>
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<td>240 ml</td>
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<td>(Spotgun</td>
<td>Vehicle air-conditioning systems*</td>
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<td>cartridge)</td>
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<td><strong>PAG OIL YF</strong></td>
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<td>R1234yf</td>
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<td>Electric compressors</td>
<td>R1234yf</td>
<td>AA1 (ISO 48)</td>
<td>1,0 l</td>
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<td>Refrigerator trucks (fresh product vehicles)</td>
<td>Piston compressors**</td>
<td>R1234yf</td>
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<td>Refrigerator trucks (deep-freeze vehicles)</td>
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<td>Refrigerator trucks (fresh product vehicles)</td>
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<td>Refrigerator trucks (deep-freeze vehicles)</td>
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<td>5,0 l</td>
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<td>Vehicle air-conditioning systems*</td>
<td>Vane compressors**</td>
<td>R134a</td>
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<td><strong>PAO oil</strong></td>
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<td>68 Plus UV</td>
<td>Refrigerator trucks (fresh product vehicles)</td>
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<td>Refrigerator trucks (deep-freeze vehicles)</td>
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<td>AA1 (ISO 48)</td>
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<td>Vehicle air-conditioning systems*</td>
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<td><strong>POE oil</strong></td>
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<td>AA3 (ISO 100)</td>
<td>1,0 l</td>
<td>8FX 351 214-281</td>
</tr>
</tbody>
</table>

* Passenger cars, trucks, agricultural and construction machinery
** Except electric compressors