MAHLE

Thermal Management

Damage scenarios: causes, remedies, and avoidance

Preface

MAHLE is a major development partner and manufacturer in the field of thermal management for cars and commercial vehicles, whether powered by combustion engines or hybrid, battery electric, or fuel cell drives. Our engineers work in conjunction with vehicle manufacturers worldwide to develop products of the highest quality.

The same high standards also apply to spare parts for the aftermarket.

Numerous checks during and after production ensure the consistently high quality of MAHLE products. However, if unexpected failures do occur in practical operation, the causes are often not to be found in the products themselves, but rather in their environment. For example, they may result from handling or installation errors, unsuitable operating media, or external influences.

This brochure summarizes typical damage scenarios, describes their causes, and provides tips for avoiding similar damage in the future. The aim is to make it easier to identify potential causes of damage. The advice provided in the brochure helps to ensure that our products continue to function reliably in the long term, thus prolonging the service life of the components.

Our experts are also confronted with complex damage scenarios that go beyond the scope of this brochure. In cases where damage to our products cannot be readily diagnosed, we are more than willing to examine them at our premises and put together an expert damage report for you. Please contact your local sales partner.

Contents

1. Cooling system

Cooling system design

The purpose of the engine cooling system is to cool the engine by transferring heat to the outside air. At the same time, the heat generated by running the engine can be used to heat the vehicle cabin. The engine cooling system and the air conditioning system are two separate systems, but they influence each other.

The individual cooling circuit components are connected to each other by hose lines to form a closed system. The coolant circulates in this system, driven by either a mechanical or an electric pump.

Fig. 1: Engine cooling system components

The heat generated by the combustion of the fuel is transferred to the coolant via the engine components.

Once a certain temperature is reached, the coolant thermostat opens and conducts coolant to the radiator at the front of the vehicle.

Circulation of the coolant dissipates heat to the outside air, causing the coolant to cool down. One or more radiator fans (mechanically or electrically driven), which can be installed upstream or downstream of the radiator, support the cooling process. Their role is particularly important when the vehicle is traveling slowly or stationary.

The thermostat opens to varying degrees to keep the combustion engine at a constant operating temperature.

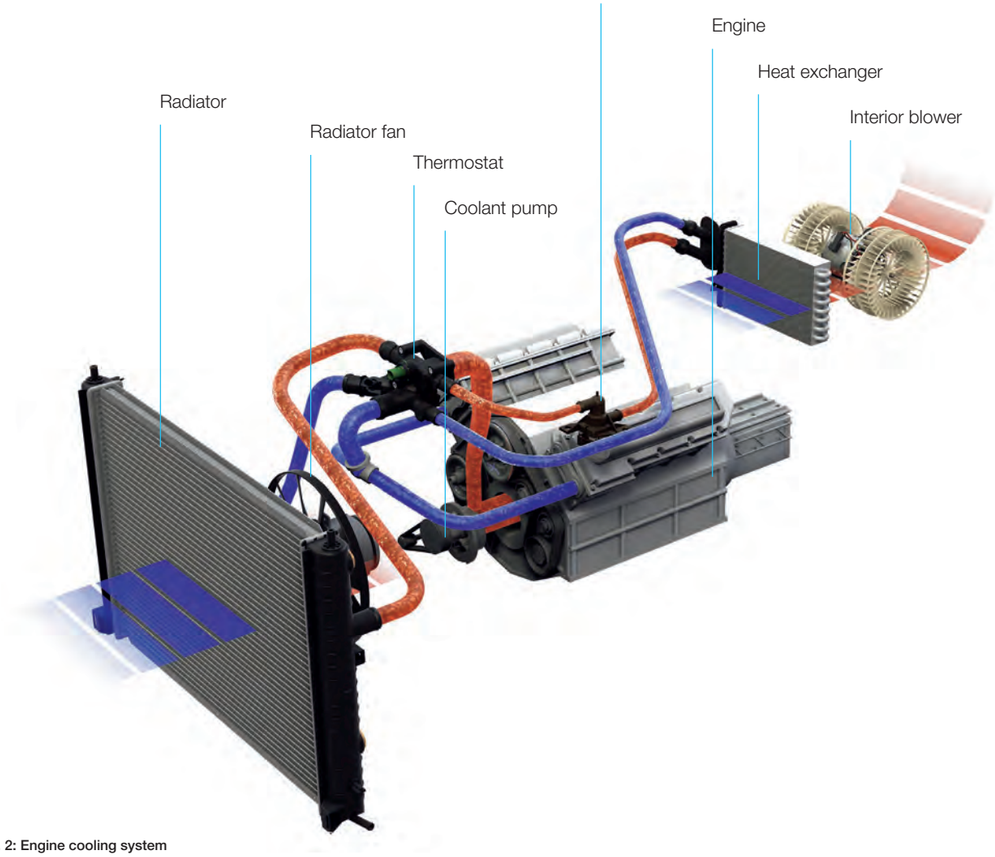


Fig. 2: Engine cooling system

1.1.1 Coolant pump with bearing damage

Findings:

- Noises
- Leaks
- Belt pulley flanks damaged
- Bearing damage
- Engine overheating

Cause(s):

- Bearing damage due to excessive belt tension
- Belt not in alignment
- No antifreeze in the system (seal in the pump needs antifreeze for lubrication)

Remedies/avoidance:

- When installing a coolant pump, make sure the belt is properly aligned.
- Set the correct belt tension.
- Use the correct blend of antifreeze and water.
- The coolant pump must not be run dry.

1.1 Coolant pump

The coolant pump circulates the coolant through the coolant circuits. It is driven mechanically (e.g., via a belt) by the combustion engine or electrically via a separate electric motor.

Fig. 1: Coolant pump

Fig. 2: Coolant pump with bearing damage

1.1.2 Loose impeller on coolant pump

Findings:

- Coolant pump is not circulating coolant
- Loose impeller
- Engine overheating

Cause(s):

- Too little antifreeze in the engine
- Engine has been started with frozen coolant, causing the impeller to detach from the shaft
- Engine/coolant has overheated, causing thermal damage to the plastic impeller

Remedies/avoidance:

- Check coolant level regularly. However, this should only be done when the engine is cold.
- Take care to use the correct blend of water and antifreeze so that the coolant does not freeze at low temperatures.
- If an engine's coolant temperature is too high, finding and eliminating the cause is vital in order to avoid consequential damage.

Fig. 1: Plastic impeller detached from shaft

Fig. 2: Metal impeller detached from shaft

1.1.3 Cavitation on coolant pump

Findings:

- Engine overheating
- Cavitation on impeller
- Corrosion on pump housing

Cause(s):

- Unsuitable antifreeze
- No antifreeze in coolant
- No overpressure in cooling system (defective valve in expansion tank)
- Exhaust gases are entering the coolant through a defective head gasket, changing the pH value of the coolant

Remedies/avoidance:

- Use coolant according to the manufacturer's specifications and mix it with deionized water as directed. Antifreeze not only lowers the freezing point of the coolant, but also increases its boiling point. In addition, antifreeze lubricates the coolant pump and provides protection against corrosion.
- Check the valves in the expansion tank cap.

Fig. 1: Cavitation on coolant pump

1.1.4 Defective e-water pump connections

Findings:

- Engine overheating (defective e-water pump)

Cause(s):

- Electrical fault (short circuit, interruption)
- Defective fuse
- Broken cable
- Corrosion on plug connection
- Defective pump

Remedies/avoidance:

- Check the power supply to the coolant pump. Possible causes of an interruption: the electrical fuse, corrosion on plug connections, a fault at the grounding point, defects in the cable harness.

Fig. 1: Corrosion on the connector plug

Fig. 2: Corrosion on plug connection

1.2 Thermostat

The thermostat regulates the coolant flow through the engine and radiator. This allows the engine to reach its optimal operating temperature quickly and protects it against overheating. The thermostat insert is installed in a housing in the engine block. The expansion element consists of a metal housing, around which the coolant flows.

The housing contains a technical wax and a rubber sleeve that holds a piston rod. The housing is closed at the top (crimping). The wax begins to melt and expand at a defined temperature (depending on the composition of the wax mixture), pushing the piston rod out of the expansion element. The valve disks that are connected to the expansion element and the piston rod open or close the coolant circuits.

1.2.1 Leaky thermostat on quick-release coupling

Findings:

- Coolant leaking from the thermostat

Cause:

- Seal on hose's quick-release coupling was not replaced

Remedies/avoidance:

- Always replace seals on all opened connections in the cooling system.

Fig. 1: Leaky O-ring

Fig. 2: Quick-release coupling

Fig. 3: Replace O-ring

1.2.2 Corrosion on thermostat, foreign objects in cooling system

Findings:

- Engine overheating
- Engine only reaches its operating temperature after a very long drive or not at all
- Heating does not warm up

Cause(s):

- Cooling system not bled correctly
- Thermostat jammed in “closed” position
- Thermostat jammed in “open” position
- Corrosion due to unsuitable or insufficient concentration of antifreeze
- Foreign objects (sealant residue, parts of the impeller of the old water pump, sealing compound) in the cooling system

Remedies/avoidance:

- After replacing any cooling system components, the entire system must be flushed to remove foreign objects and contaminants.
- Use coolant according to the vehicle manufacturer’s specifications.

Fig. 1: Foreign object blocking the valve

Fig. 2: Corrosion on thermostat

1.2.3 Leaky thermostat housing

Findings:

- Leaky thermostat housing
- Additional sealing compound applied to the thermostat

Cause:

- Seal damaged by additional use of sealing compound

Remedies/avoidance:

- When installing a new thermostat, use only the seal provided. Never use additional sealing compound. Most sealing compounds are oil-based and attack thermostat seals. Oil causes seals used for coolant to swell and crack.

Fig. 1: Sealing compound on thermostat housing

Fig. 2: Seal damaged by additional sealing compound

1.2.4 Heating fails when driving downhill

Findings:

- Engine temperature drops when driving downhill
- Engine does not reach its operating temperature on rural roads
- Heating does not warm up

Cause(s):

- Direct-shift transmission thermostat jammed in “open” position
- Foreign objects (sealant residue, parts of the impeller of the old water pump, sealing compound) in the cooling system
- If the direct-shift transmission thermostat stays open, too much heat is taken away from the combustion engine, preventing the heating from warming up properly when driving at slow speeds

Remedies/avoidance:

- The thermostat regulates the oil temperature in the transmission via the vehicle’s coolant circuit. The temperature of the transmission oil is controlled by a heat exchanger. If the thermostat malfunctions, the engine takes much longer to reach its normal operating temperature.
- Apply a thin coating of sealing compound to components only when specified by the vehicle manufacturer. When repairing the cooling system, flush the entire circuit to remove any foreign objects, corrosion, and deposits.

Find out more in this issue of
Technical Messenger:

Fig. 1: Transmission oil cooler thermostat

1.3 Radiator

Radiators are installed in the air flow at the front of the vehicle. Their task is to release the heat generated by combustion in the engine, which is absorbed by the coolant, to the outside air.

1.3.1 Reduced cooling performance, engine overheating

Findings:

- Inadequate cooling performance
- Increased engine temperature
- Radiator fan runs continuously
- Poor air conditioning performance

Cause(s):

- Inadequate heat exchange due to external soiling of the cooling fins (dirt, insects, leaf debris)
- Contaminants between condenser and radiator (leaves, dirt)

Remedies/avoidance:

- Clean the radiator regularly under a gentle stream of water to remove leaves and contaminants from the cooling fins.

Never use a high-pressure cleaner, as the water jet will damage the cooling fins.

Fig. 1: Contamination on the radiator

Fig. 2: Contaminants and deformed cooling fins

1.3.2 Leaky radiator

Findings:

- Coolant loss
- Crack in plastic water tank
- Pipe from radiator core leaking

Cause(s):

- Incorrect (too large) assembly screws were used
- Mechanical damage/stone chipping
- Corrosion from external sources (chemical effects, e.g., from road salt, wheel rim cleaner, insect remover)

Remedies/avoidance:

- When installing the new radiator, take care to use the correct screws at the various fastening points. A screw that is too large or too long can cause damage (e.g., crack) to the water tank.
- The radiator must be replaced if it has suffered mechanical damage.
- Do not clean the radiator with aggressive chemicals (e.g., wheel rim cleaner, insect remover). Clean only using a gentle stream of water.

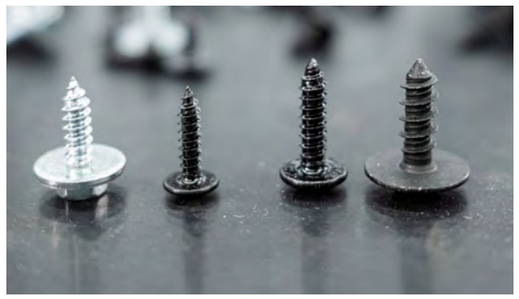


Fig. 1: Various assembly screws

Fig. 2: Crack at the fastening point

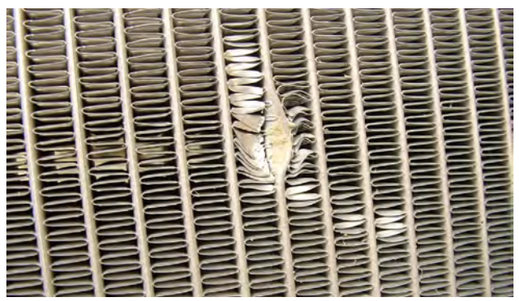


Fig. 3: Stone chipping on the radiator

Fig. 4: Corrosion on the exterior of the radiator

1.3.3 Leaky radiator, reduced cooling performance

Findings:

- Reduced cooling performance
- Coolant loss
- Pipe from radiator core leaking

Cause(s):

- Foreign objects and matter in the coolant circuit can block the narrow tubes in the radiator
- Radiator sealant in the cooling system
- Corrosion from within (coolant contaminated with rust and limescale residues)
- Unsuitable coolant used

Remedies/avoidance:

- Do not use radiator sealant.
- Thoroughly clean the cooling system when replacing the radiator, pump, or other components. To do this, flush the entire cooling system several times with a special cooling system cleaner while the engine is at operating temperature. The specifications of the vehicle manufacturer and flushing agent producer must be followed at all times. Finally, when no more residues or foreign objects are present, the system must be flushed with warm water until only clear water runs out.
- Only fill the system with coolant approved by the vehicle manufacturer.

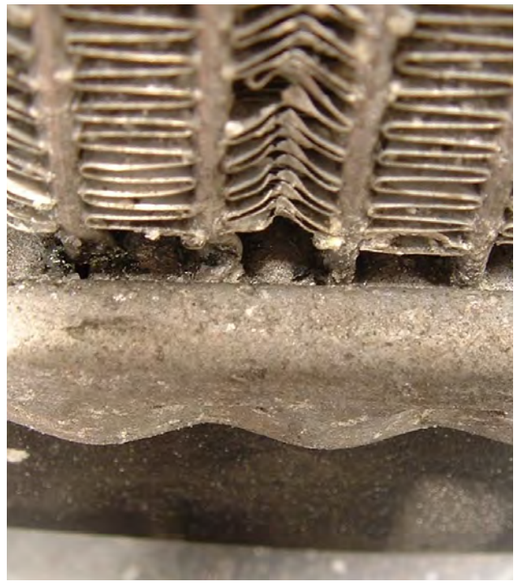


Fig. 1: Corrosion on the radiator

Fig. 2: Radiator blocked by sealant

Fig. 3: Corrosion and deposits in the coolant circuit

1.3.4 Radiator appears to be leaking

Findings:

- Coolant drips from the radiator immediately after installation

Cause:

- Cooling system overfilled

Find out more in this issue of **Technical Messenger**:

Remedies/avoidance:

- In truck radiators with top-mounted expansion tanks, space must be left to allow for pressure equalization. If this space is also filled with coolant, excess coolant will escape via the pressure relief valve in the blue cap and run down the outside of the radiator core. This gives the impression that the radiator is leaking.

Fig. 1: Radiator appears to be leaking

Fig. 2: Coolant dripping from expansion tank

1.3.5 Engine oil or transmission oil in the radiator

Findings:

- Oil in the expansion tank
- Oil in the radiator
- Coolant loss
- Coolant in the engine oil or transmission oil

Cause(s):

- Defective cylinder head gasket
- Leaky oil cooler (engine)
- Leaky oil cooler (transmission)

Remedies/avoidance:

- Identify and repair leaks. Flush cooling system to remove any oil residue. Change engine oil. If the transmission oil cooler is leaking, flush the transmission oil.

Fig. 1: Swollen seal from radiator

Fig. 2: Oil-in-water emulsion on the oil filler cap and in the oil filler neck

Fig. 3: Oil-in-water emulsion in the oil filler neck

1.3.6 Swollen radiator

Findings:

- Swollen radiator
- Deformed radiator

Cause(s):

- Loss of coolant. The coolant pump only operates intermittently, causing the coolant—when it is circulated—to evaporate rapidly in hot components. This results in an explosive increase in pressure.
- Defective cylinder head gasket.
- Coolant circuit blocked by foreign object.

Remedies/avoidance:

- Check coolant level regularly. In the event of coolant loss, pressure-test the system to locate leaks. When replacing any components (radiator, pump, thermostat, etc.), thoroughly clean the system to flush out residues and foreign objects.

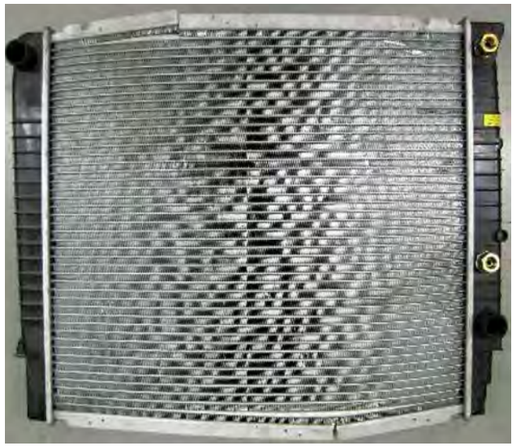


Fig. 1: Swollen radiator

Fig. 2: Burst water tank

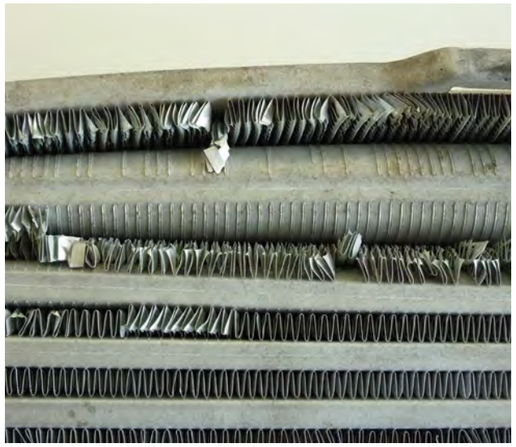
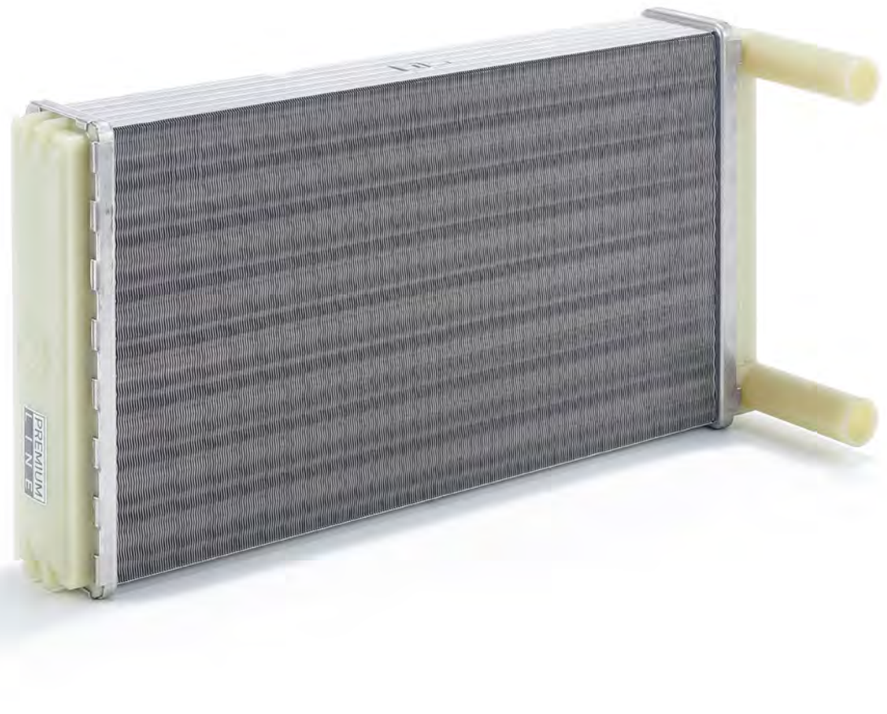


Fig. 3: Swollen radiator tube



1.4 Cabin heat exchanger

The waste heat from the combustion engine is used to heat the vehicle cabin. The air sucked in by the interior blower flows through the cabin heat exchanger and is heated in the process.

1.4.1 Reduced heating performance

Findings:

- Inadequate heating performance
- Odor development
- Fogged windows, sweet smell in the vehicle
- Film of lubricant on the inside of the windshield

Cause(s):

- External soiling
- Clogged cabin filter
- Leak, corrosion

Remedies/avoidance:

- Clean the heat exchanger with a suitable flushing unit. Then install a high-quality cabin filter to prevent future soiling.
- If there are leaks in the cooling system, the heat exchanger must be replaced. Never add sealant to the cooling system.

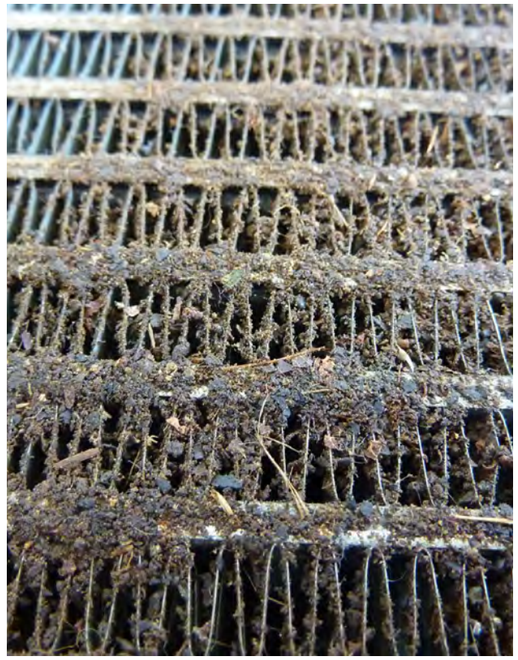


Fig. 1: Severely fouled heat exchanger

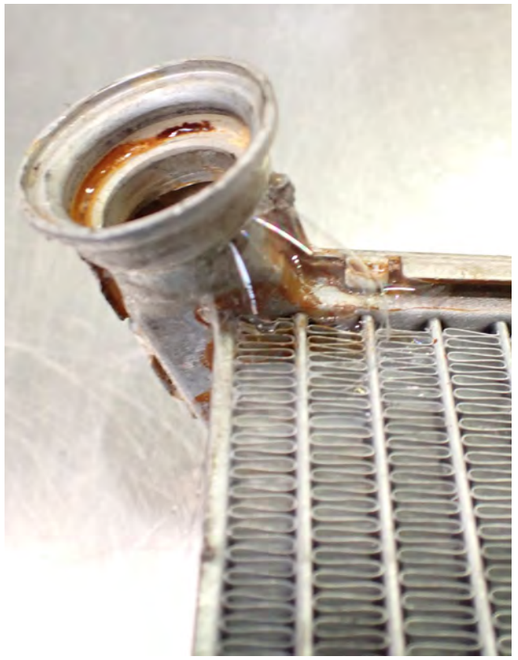


Fig. 2: Leaky heat exchanger due to corrosion

1.4.2 No heating

Findings:

- No heating
- Fogged windows, sweet smell in the vehicle
- Film of lubricant on the inside of the windshield

Cause(s):

- Clogged tubes (limescale, deposits of radiator sealant)
- Leak, corrosion

Remedies/avoidance:

- If there are leaks in the cooling system, never add sealant to the cooling system.
- When replacing any coolant circuit components, all remaining components should be flushed thoroughly.
- Only fill the system with coolant approved by the vehicle manufacturer.

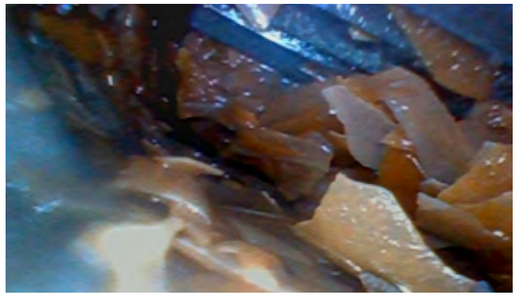


Fig. 1: Limescale and rust deposits blocking the heat exchanger

Fig. 2: Clogged heat exchanger

Fig. 3: Deposits and contaminants in the heat exchanger

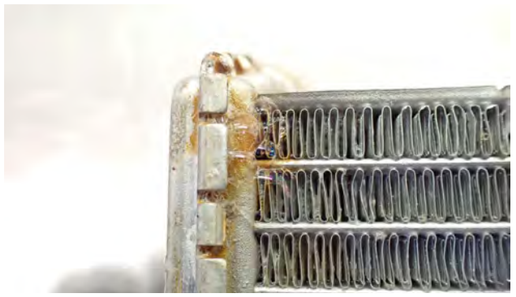


Fig. 4: Corroded heat exchanger

1.5 Expansion tank

The expansion tank in the cooling system is usually made of plastic and is designed to hold the expanding coolant. It is usually installed so that it is positioned at the highest point in the cooling system. To allow the coolant level to be checked, the expansion tank is transparent and has “Min” and “Max” markings.

1.5.1 Leaky expansion tank

Findings:

- Loss of coolant (leakage) at various system components or at the expansion tank itself
- Excessive coolant or engine temperature
- Cracked/burst expansion tank
- Defective expansion tank cap

Cause(s):

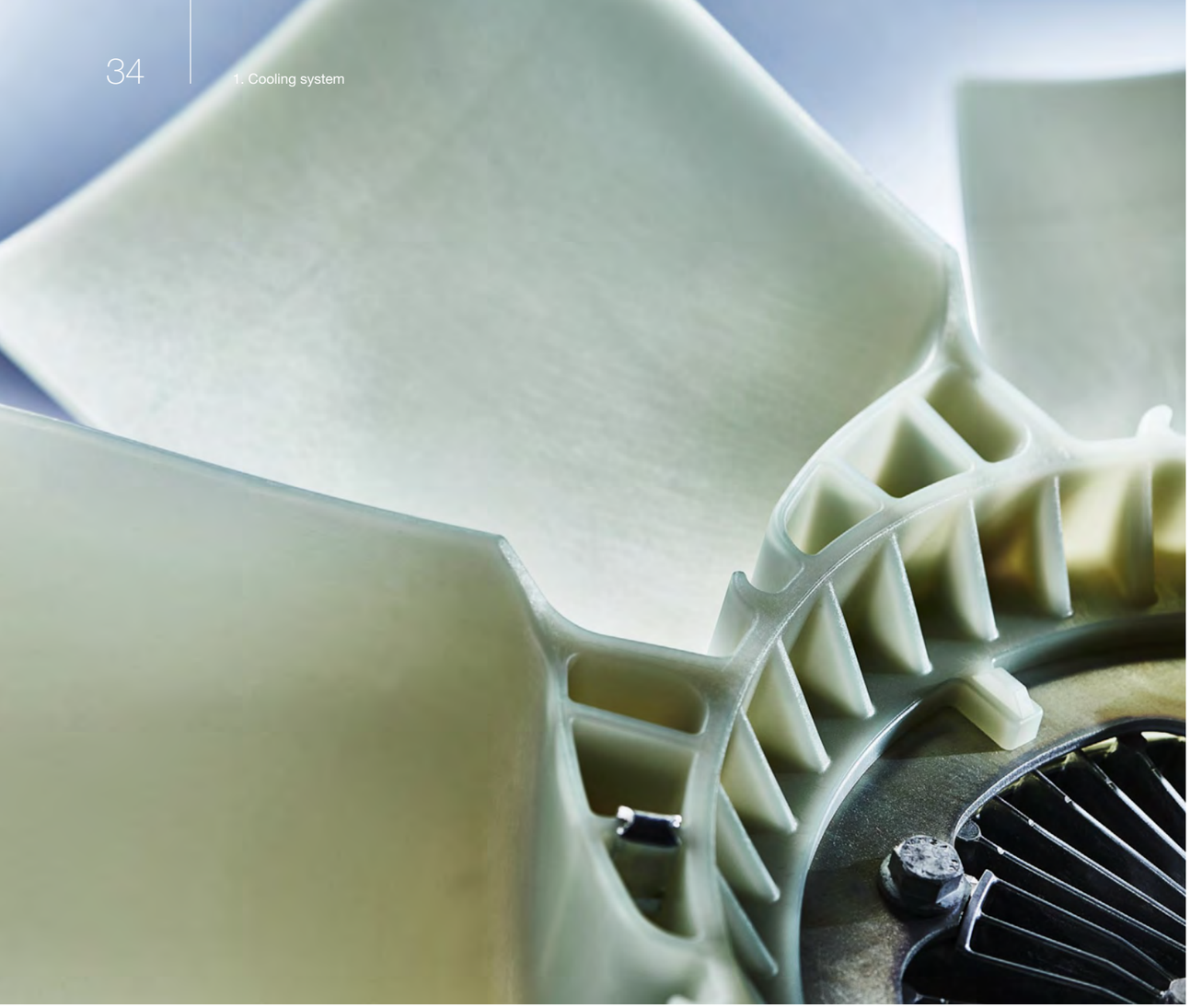
- Overpressure in the cooling system due to a faulty valve in the cap
- Obstruction in the cooling system
- Blockages (corrosion, sealant)
- Material fatigue due to thermal overload
- Material fatigue due to lack of antifreeze in the coolant
- Too little coolant in the system (if coolant only reaches hot components in the engine intermittently, it will evaporate explosively)
- Defective cylinder head gasket

Remedies/avoidance:

- When replacing the coolant tank, also replace the lid. The lid contains a vacuum valve and a pressure-relief valve. A defective pressure-relief valve can cause the expansion tank or hoses to crack.
- When replacing any cooling system components, the entire system should be flushed to remove foreign objects and contaminants. Use a blend of antifreeze and water that meets manufacturer specifications. Pure water can damage polyamide expansion tanks.

Fig. 1: Crack in the expansion tank

Fig. 2: Burst expansion tank



1.6 Coolant/condenser fan

The process of cooling the coolant is supported by one or more mechanically or electrically driven radiator fans. The fans are installed upstream or downstream of the radiator and can be controlled electronically.

The fan activates when the vehicle is stationary or when the ambient air is insufficient to cool the radiator and condenser.

1.6.1 Fan is making noises

Findings:

- Loud noises
- Vibrations

Cause(s):

- Counterbalance weights have been removed
- Broken fan
- Dirt on the fan

Remedies/avoidance:

- Fans are finely balanced during manufacturing to ensure they operate with minimal vibration. The balancing weights (metal clips on the fan blades) must **not** be removed.
- Mechanical damage, deformation, or fractures lead to noises and vibrations. Install the fan and fan shroud carefully and do not bend them.

Fig. 1: Metal clip as balancing weight

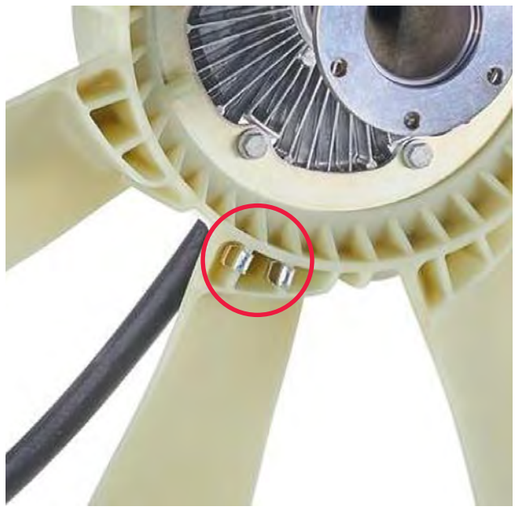


Fig. 2: Metal clips for balancing

1.6.2 Defective fan motor

Findings:

- Loud noises
- Inadequate cooling performance
- Rising engine temperature
- Total failure of the fan

Cause(s):

- Bearing damage
- Worn carbon brushes
- Electrical fault (short circuit, interruption, activation)

Remedies/avoidance:

- With the motor switched off, check by hand whether the electric fan turns freely. Stiffness or unusual noises indicate a defective fan motor. If the fan is not working, the electrical system must be checked.

Fig. 1: Bearing damage to the fan motor

Fig. 2: Broken cable to fan control unit

1.6.3 Electric fan is not turning

Findings:

- Inadequate cooling performance at low speeds
- Rising engine temperature in traffic jams
- Total failure of the fan

Cause(s):

- Worn carbon brushes
- Electrical fault (short circuit, interruption, activation)
- Damaged cable
- Defective thermal switch
- Defective climate control pressure switch
- Vehicle battery undervoltage

Remedies/avoidance:

- The thermal switch turns on the electric fan when the coolant temperature exceeds a certain value. The pressure switches in the air conditioning system also control the fan speed. If the coolant temperature rises when driving slowly or in traffic jams, thermal and pressure switches should be checked.
- Electrical cables and fuses must also be checked.

Fig. 1: Thermal switch

Fig. 2: Pressure switch

1.6.4 Motor controller/control unit

Findings:

- Inadequate cooling performance
- Rising engine temperature at slow speeds or in traffic jams
- Total failure of the fan

Cause(s):

- Defective fan motor control unit
- Corrosion on plug connection
- Electrical fault (short circuit, interruption, activation)

Remedies/avoidance:

- Check contacts and cables if the fan is not working.
- With the motor switched off, check whether the fan can be turned freely by hand. A stiff fan motor can cause the control unit to become overloaded (burnout).

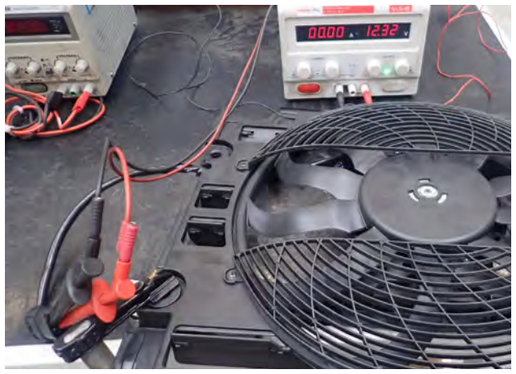


Fig. 1: Testing the fan

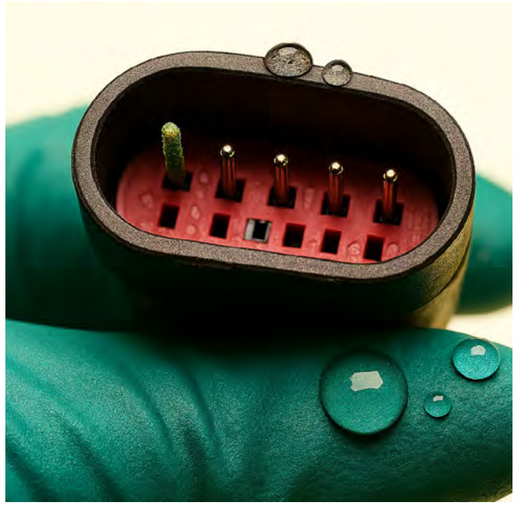


Fig. 2: Corrosion on the connector plug

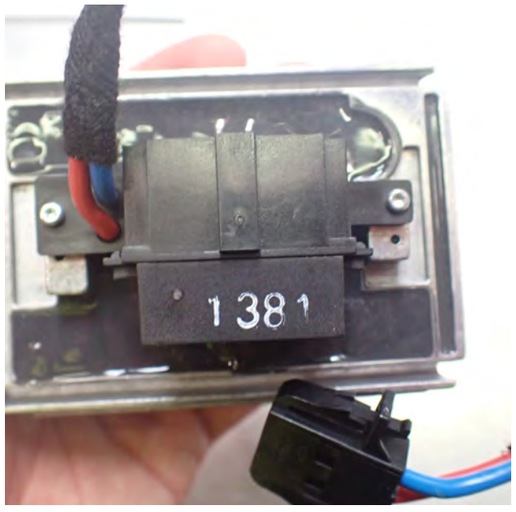


Fig. 3: Control unit

1.6.5 Visco® fan

Findings:

- Inadequate cooling performance
- Rising engine temperature
- Oil leaking from the new part (oil in the packaging)

Cause(s):

- Poor frictional connection due to oil leakage
- Incorrect storage/transport of the replacement part
- Contamination of the cooling surface or bimetal
- Damaged cable (with electrically controlled Visco® clutches)

Remedies/avoidance:

- Visco® clutches must be stored and transported correctly. Incorrect storage may cause silicone oil to leak from the inside, damaging the clutch. Always follow the storage and transport instructions on the packaging.
- Performing a functional test on a fan with a Visco® clutch is very complex and can only be done using a laser revolution counter. The speed difference between the fan and fan drive should be between 5% and 95% (depending on the cooling requirements).

Fig. 1: Visco® clutch

Fig. 2: Visco® clutch in a folding carton (follow storage instructions carefully!)

1.7 Interior blower

The interior blower directs air into the cabin. The air is cleaned by the cabin filter and cooled by the evaporator in the air conditioning system or heated by the heating heat exchanger.

1.7.1 Interior blower not working

Findings:

- Development of loud noise
- Contaminants (dirt, leaves, etc.)
- Inadequate performance
- Odor development
- Failure of the fan
- Burned out blower controller

Cause(s):

- Cabin filter heavily soiled/clogged
- Clogged water drain in the air trap
- Bearing damage (corrosion, fouling, imbalance)
- Worn carbon brushes
- Electrical fault
- Defective series resistor

Remedies/avoidance:

- Replace the cabin filter annually. The air flow reduces if the filter is heavily soiled.
- Check whether the disconnected blower can be turned freely by hand. Stiffness reduces the air flow. Stiffness can also overload the controller (burnout).
- Regularly clean leaves and dirt from the water drain holes in the car body. Any rain water that accumulates could get into the blower and cause damage.

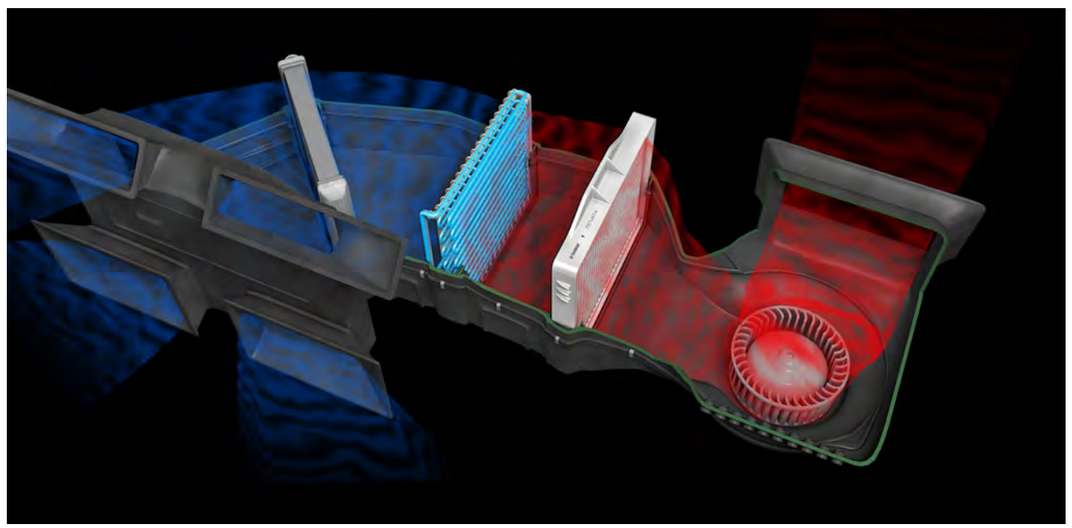


Fig. 1: Air tank

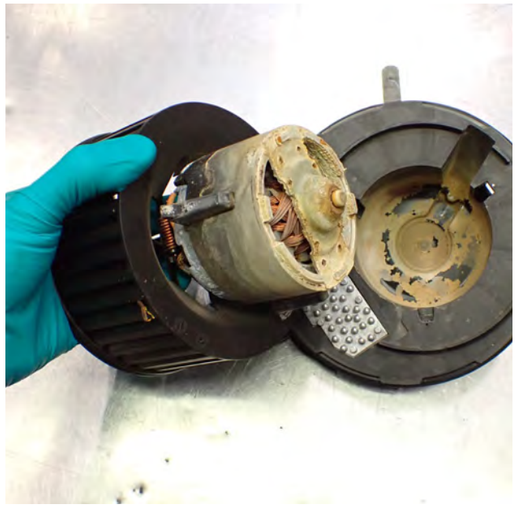


Fig. 2: Water ingress into the interior blower

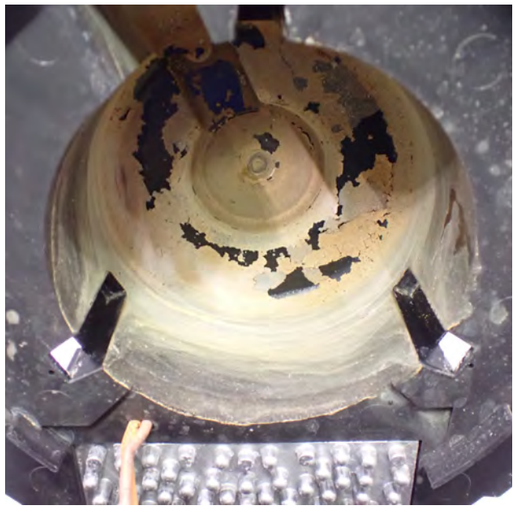


Fig. 3: Residue from water ingress into the motor housing

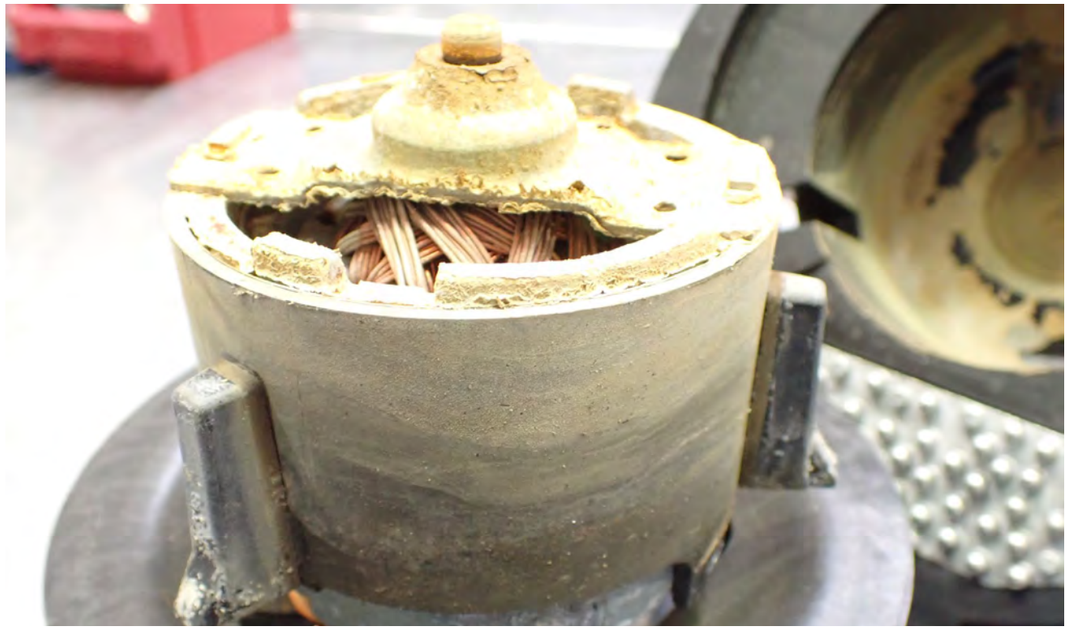
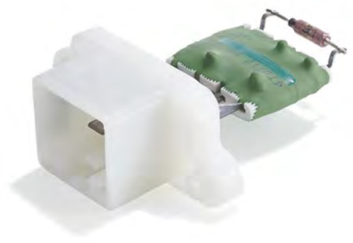


Fig. 4: Corrosion on the blower motor

1.8 Blower controller

The controller determines the speed of the interior blower via various resistors that are switched on or off, or via power electronics.



1.8.1 Interior blower not working reliably

Findings:

- Blower only runs on “MAX”
- Blower is not working

Cause(s):

- Burned-out resistor (excessive current consumption by blower motor)
- Tripped thermal fuse (controller overheated)
- Overloaded power electronics
- Corrosion in the blower motor bearings
- Clogged cabin filter

Remedies/avoidance:

- An overloaded, burned-out blower controller is a clear sign that the blower motor is drawing too much electrical current. A stiff, corroded blower motor is often the cause, so checking the interior blower motor is essential if the controller is defective.
- Because the controller needs to be cooled, it is installed in the air flow. The controller will also overheat if the cabin filter is clogged or the blower is mechanically blocked.

Fig. 1: Testing a burned-out controller

Fig. 2: Thermally overloaded blower controller

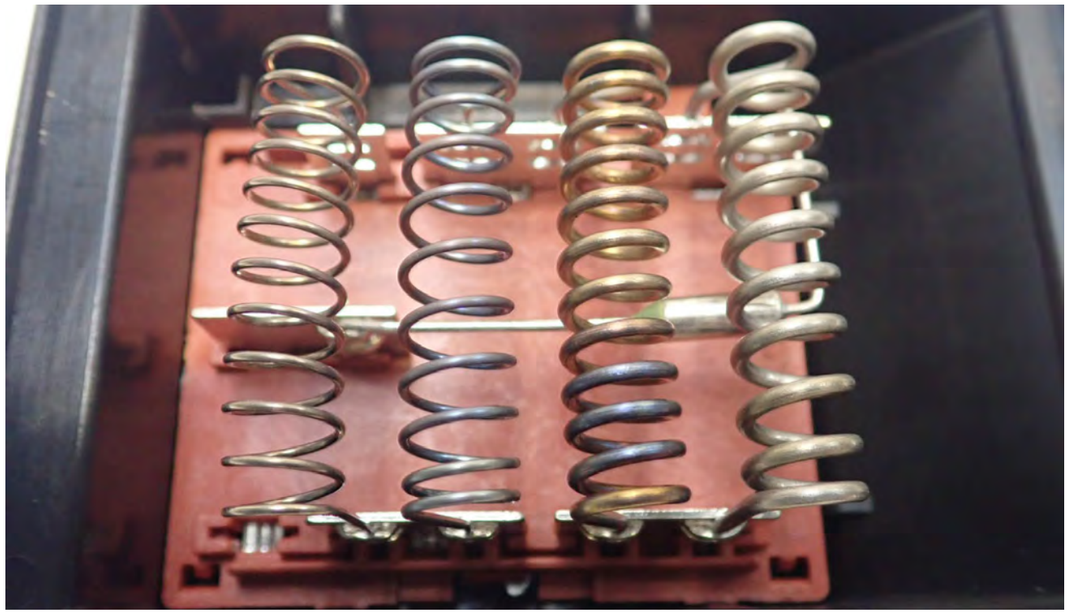


Fig. 3: Controller overloaded due to defective fan

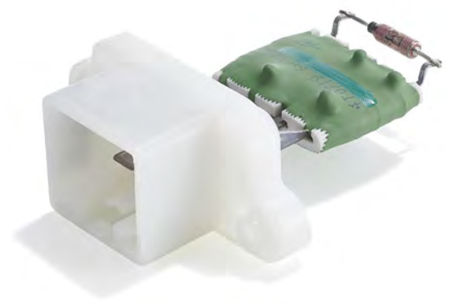


Fig. 4: Interior blower controller

Fig. 5: Interior blower controller

1.9 PTC heater

Electric auxiliary heaters are sometimes installed in vehicles with combustion engines in order to heat the interior on starting until sufficient waste heat from the combustion engine is available. Electric HV auxiliary heaters are installed as cabin heaters in electric and hybrid vehicles that are not fitted with heat pumps.

PTC elements are nonlinear ceramic resistors. PTC stands for positive temperature coefficient, which means that the electrical resistance increases in line with the temperature of the element.

1.9.1 PTC heater with low heating performance

Findings:

- Reduced heating performance when the engine is cold
- Error codes in the control unit

Cause(s):

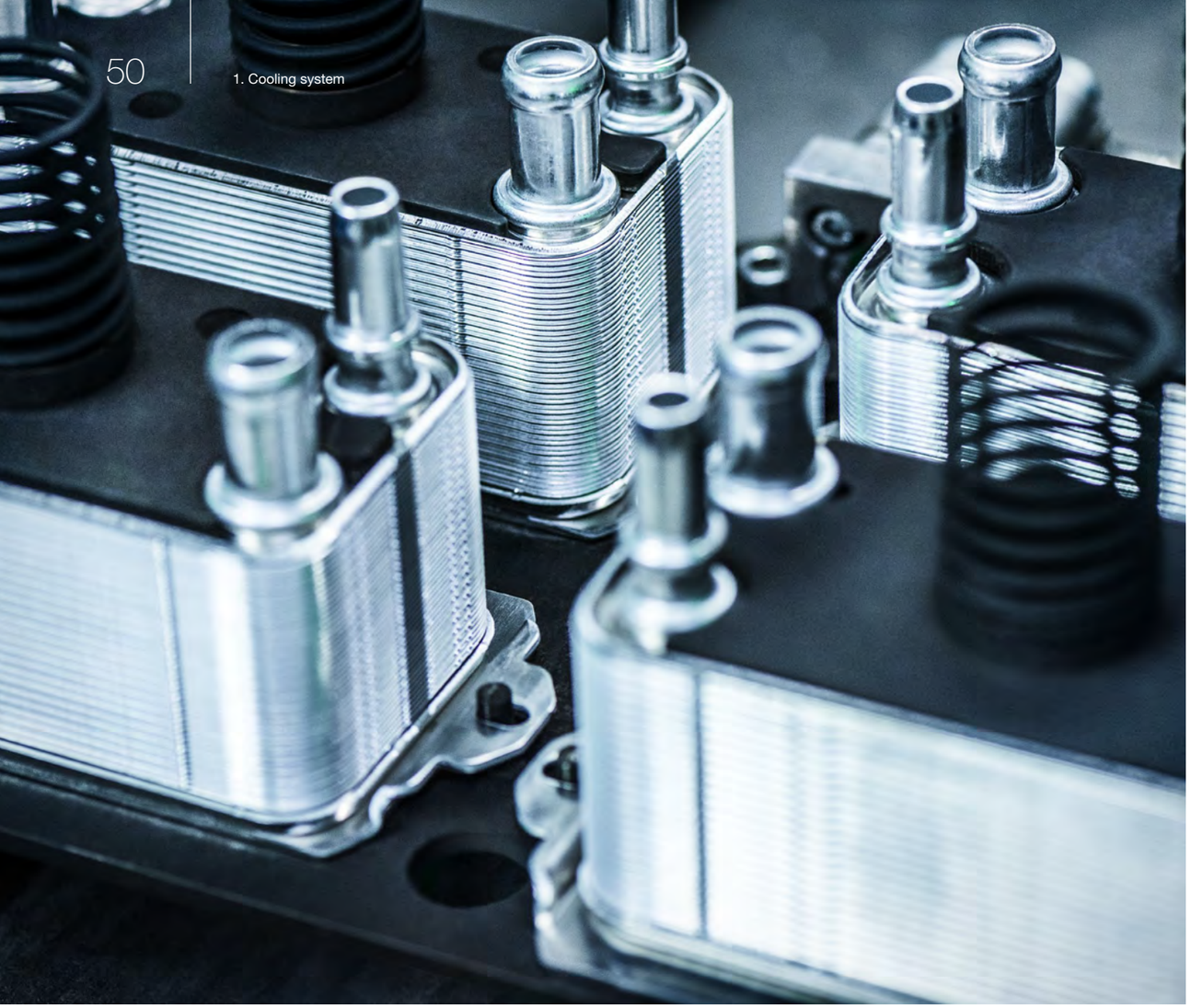
- Faulty electric actuation of or electrical connections to the PTC auxiliary heater
- Loose or corroded ground contacts
- Defective PTC auxiliary heater (power electronics or individual heating elements)

Remedies/avoidance:

- PTC heaters consume a great deal of power. The ground cable and electrical plug connection must be free of corrosion.
- In the event of reduced cooling performance, defective heating elements can be identified with a thermal imaging camera. Any heat generated by corroded cables can also be detected using this method.
- By measuring the resistance of the individual elements, it is possible to determine whether an element is defective.

Fig. 1: PTC heater

Fig. 2: Corrosion on the grounding point



1.10 Oil cooler

Oil coolers are used to cool engine oil. Transmission oil heat exchangers can heat or cool the transmission oil.

The oil cooler takes the form of a plate heat exchanger, comprising multiple profiled aluminum plates soldered together. The plate heat exchanger has four connections, two of which serve as the inlet and outlet for oil, and the other two as the inlet and outlet for coolant.

1.10.1 Leaky oil cooler

Findings:

- Oil droplets floating in the coolant expansion tank
- Light-colored slime on the inside of the oil filler cap
- Oil cooler damp on the outside

Cause(s):

- Leaky oil cooler
- Contaminants (foreign objects, remnants of sealing compound, etc.) in the coolant circuit

Remedies/avoidance:

- Replace leaky component, change engine oil, and flush coolant circuit thoroughly.
- Foreign objects in the coolant circuit can lead to cavitation damage in the heat exchanger.

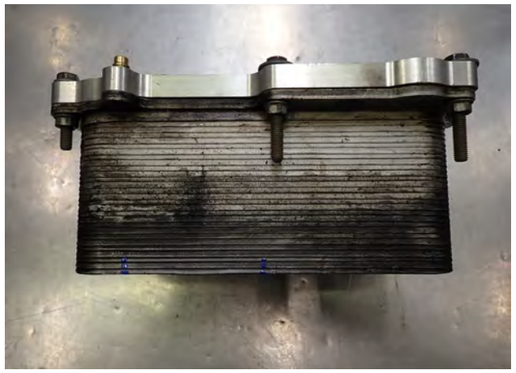


Fig. 1: Leaky oil cooler

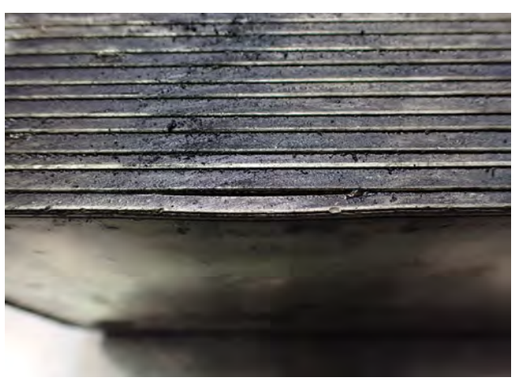


Fig. 2: Leaky oil cooler

Fig. 3: Oil-in-water emulsion in the oil filler neck

1.10.2 Radiator with leaky oil cooler

Findings:

- Oil droplets floating in the coolant expansion tank
- Light-colored slime on the inside of the oil filler cap
- Coolant in the oil

Cause(s):

- Leaky oil cooler
- Screw connection (hose connector) twisted when screwing on the oil line
- Hoses overtightened

Remedies/avoidance:

- When tightening the oil lines, it is essential to follow the torque specifications provided by the vehicle manufacturer.
- When tightening the lines, use a suitable wrench to prevent the hose connector twisting (hold it in place).

Fig. 1: Oil cooler in the water tank

Fig. 2: Oil-in-water emulsion

Fig. 3: Transmission oil line screw connection

Fig. 4: Crack between screw connection and oil cooler

1.10.3 Oil cooler (transmission) malfunction

Many automatic transmissions have a heat exchanger installed to bring the transmission oil to optimal operating temperature. The heat exchanger protects the transmission from thermal overload when subjected to heavy loads. It takes the form of a plate heat exchanger.

Findings:

- The heating does not warm up when traveling downhill
- Shifting difficulties with an automatic transmission
- Diesel particulate filter (DPF) clogged after short running times
- DPF regeneration cycle does not start

Cause(s):

- Blocked thermostat in the coolant line
- Leaky heat exchanger (mixing of transmission oil and coolant)
- Plate heat exchanger added (sealant)
- Coolant temperature permanently too low

Remedies/avoidance:

- Replace the thermostat if there are noticeable temperature fluctuations or if the coolant temperature is too low. In vehicles with thermostat-controlled transmission oil coolers, replace this thermostat as well.
- The DPF only regenerates when the coolant reaches a certain temperature. Regeneration of the DPF is prevented both by driving only short distances and by the coolant temperature being too low.

Fig. 1: Transmission heat exchanger

Fig. 2: Thermostat for transmission oil heat exchanger

1.10.4 Leaky oil cooler (retarder)

Hydrodynamic (fluid-operated) retarders are used in commercial vehicles to support the actual braking system as an almost wear-free hydrodynamic brake. The kinetic energy converted into heat, which is generated by decreasing the flow velocity of the oil, must be transferred back to the cooling system via a heat exchanger.

Findings:

- Coolant loss
- Oil loss
- Mixing of oil and water
- Shifting difficulties in the transmission
- Total failure of the braking function

Remedies/avoidance:

- Replace leaky component and flush both coolant circuit and oil circuit thoroughly.

Cause(s):

- Overheating of the cooling system due to lack of coolant, incorrect coolant, or incorrect coolant blend
- Overheating of the coolant as a result of incorrect handling (full vehicle braking at low engine speed, incorrect gear selection) and resulting cavitation (bubbling of the coolant due to high thermal loads)
- Damage to seals/hose connections
- Cross-sectional constrictions due to contamination within the heat exchanger or cooling system
- High or sudden thermal loads (temperature/pressure)
- Internal leaks in the heat exchanger
- Foreign objects in the coolant circuit, resulting in cavitation in the retarder

Fig. 1: Cavitation on the oil cooler tubes

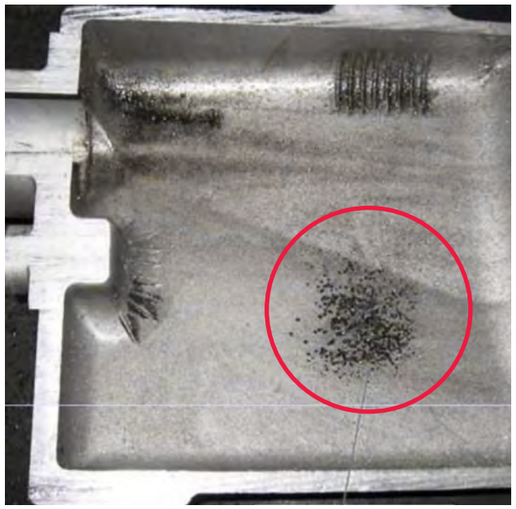


Fig. 2: Cavitation in the oil cooler housing

1.11 Charge air cooler

The turbocharger compresses the fresh air that is sucked in. Under compression, the air heats and expands. That is why a charge air cooler is installed in the charge air path between the turbocharger and the engine. This charge air cooler cools the compressed air from the turbocharger. At the same boost pressure, the cooled air contains more oxygen and improves combustion and engine performance.

1.11.1 Leaky charge air cooler

Findings:

- Reduced performance
- Black smoke from exhaust system
- Frequently clogged diesel particulate filter (DPF)
- Leaks in the charge air path

Cause(s):

- Mechanical damage (stone chipping, corrosion) to the charge air cooler
- Seals on quick locks not replaced
- Hose clips not sufficiently tightened

Remedies/avoidance:

- If compressed air is lost from the charge air path due to a leak, the performance of the engine will be reduced and combustion will be less efficient. The air mass flow sensor determines the intake air mass and transmits the values to the engine control unit. Since the control unit does not detect the air loss caused by the leak, the injection quantity is too high. As a result of inefficient (rich) combustion, the DPF becomes severely loaded with soot.

Fig. 1: Mechanical damage

Fig. 2: Leaky quick-release coupling

Fig. 3: Stone chipping

1.11.2 Leaky charge air cooler (indirect)

Findings:

- Leaky charge air cooler (indirect)

Cause(s):

- Overpressure in the charge air path
- Charge air cooler partially clogged (chips, foreign objects)
- Turbocharger VTG or wastegate are blocked
- Defective recirculation air valve

Remedies/avoidance:

- Check that the turbocharger regulation system is working properly and moving freely.
- In the event of serious turbocharger damage, the charge air cooler must be replaced.

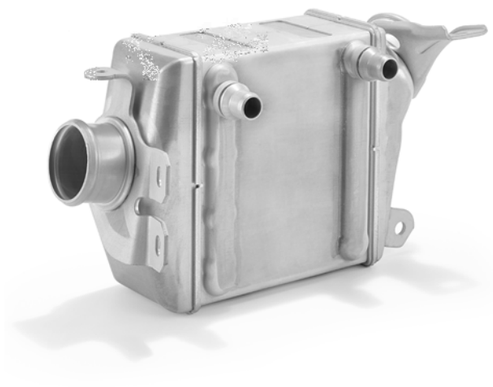


Fig. 1: Indirect charge air cooler

Fig. 2: Chips from turbo damage

1.11.3 Swollen charge air cooler

Findings:

- Reduced engine performance
- Black smoke from exhaust system
- Leak in the area around charge air cooler's air tank (plastic)
- Charge air cooler is swollen (deformed)
- Crimping on the air tank bent up

Cause(s):

- Boost pressure too high
- Turbocharger VTG or wastegate are blocked, causing excessively high boost pressure
- Defective recirculation air valve

Remedies/avoidance:

- A swollen charge air cooler is a clear sign of excessively high boost pressure. Check that the turbocharger regulation system is working properly and moving freely.
- A defective (closed) recirculation air valve can lead to extreme pressure peaks in the charge air path when the throttle valve is closed.

Fig. 1: Swollen tube

Fig. 2: Swollen charge air cooler

1.12 Exhaust gas recirculation (EGR) cooler

The EGR cooler cools the exhaust gases, which are fed back into the combustion chambers via the recirculation valve. The recirculation of exhaust gases reduces the SO_x values in he exhaust gas.

Targeted exhaust gas recirculation makes the combustion engine more efficient, improves emissions values, and reduces fuel consumption.

1.12.1 Leaky EGR cooler

Findings:

- Noises
- Leaks
- Broken flexible pipe

Cause(s):

- Screws tightened in wrong sequence
- Flexible pipe installed under tension
- Severe engine vibrations

Remedies/avoidance:

- To install the EGR cooler, remove all engine components from around the EGR cooler so that the EGR cooler can be installed without excess tension.
- Take care to ensure that the flexible pipe in particular is not installed under tension (follow the sequence and torques specified by the vehicle manufacturer).
- Check the exhaust system mounting to make sure that the flexible pipe will not be subject to strong vibrations.

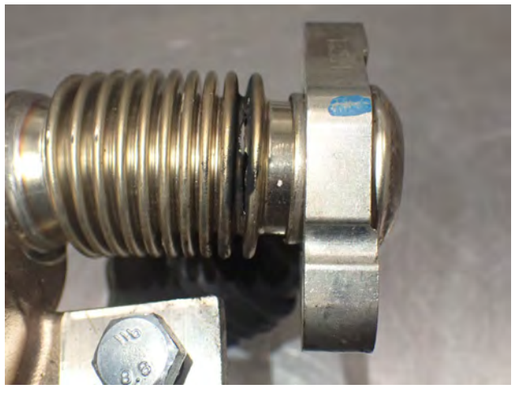


Fig. 1: Crack in the flexible pipe from the EGR cooler

Fig. 2: Crack in the flexible pipe from the EGR cooler

2. Air conditioning system

Air conditioning system design

The air conditioning system plays a vital role in safety and driving comfort. The individual refrigerant circuit components are connected by hose lines to form a closed system. Refrigerant circulates around the system, driven by the air conditioning compressor. The circuit is divided into two sides: The section between the compressor, condenser, and filter-drier to the expansion valve is called the high-pressure side (HP: yellow/red). The section between the expansion valve and the air conditioning compressor is known as the low-pressure side (LP: blue). The air conditioning compressor compresses the gaseous refrigerant, heating it to a high temperature. The refrigerant is then forced through the air conditioning condenser at high pressure in a process that extracts heat from the hot refrigerant, causing it to condense, i.e., change state from gas to liquid. Next, the filter-drier separates out contaminants and any moisture from the now liquid refrigerant. This ensures the effectiveness of the system and protects the components from damage due to contaminants. The refrigerant now passes from the filter-drier to the expansion valve, which basically functions like a weir. Upstream of the weir, the value maintains a constant pressure, but downstream of the weir, the increase in volume causes the pressure to drop. Since the expansion valve is located directly upstream of the evaporator, the refrigerant expands into the evaporator. During evaporation (the change of state from liquid to gas), evaporation cooling is released. The evaporator is similar to the air conditioning condenser in that it is a heat exchanger. It has an extremely large surface area, via which it releases evaporation cooling into the environment. The interior blower blows this cold air into the vehicle cabin, where it supports passenger well-being. On the low-pressure side, the refrigerant (which is now in gaseous form once again) travels back to the air conditioning compressor, where the cycle starts all over again.

Fig. 1: Air conditioning system components

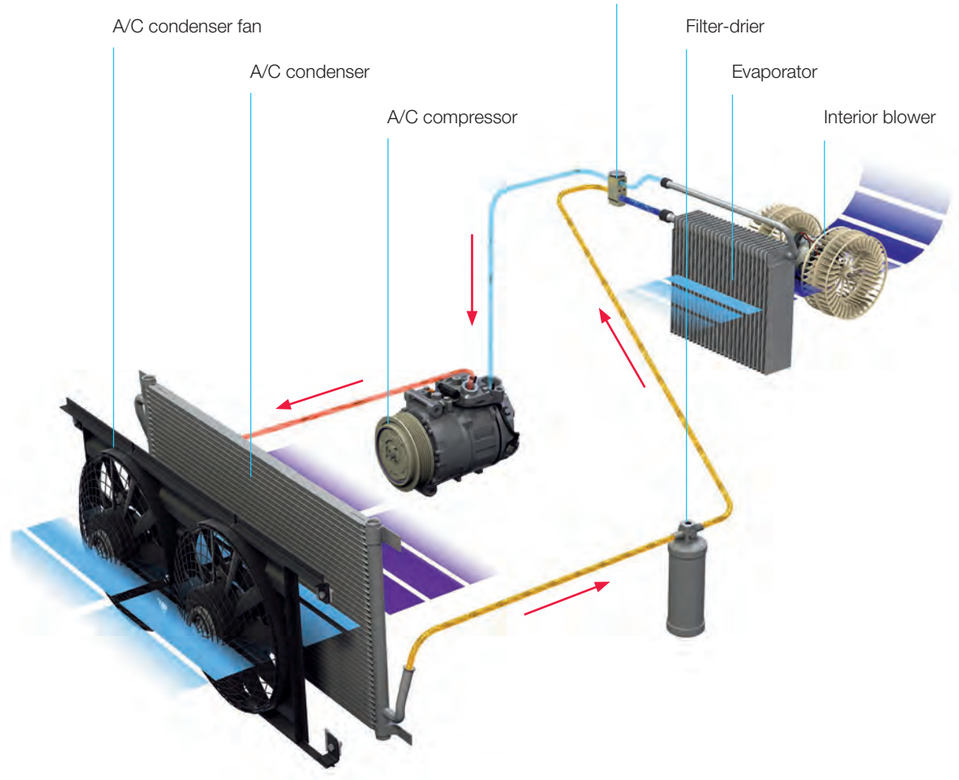


Fig. 2: Schematic diagram of an air conditioning system

2.1 Air conditioning

The air conditioning compressor is the heart of the air conditioning system. Any damage to the air conditioning system will usually also affect and damage the air conditioning compressor.

2.1.1 Troubleshooting the A/C system

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

Yes

No

2
- Check fuse
- Check relay, switch, cabling of all components

3 Set temperature to max cooling. Magnetic clutch activated?

Yes

No

4
- Check cabling/electrical connections, electrical power supply (+/–)
- Check temperature switch/sensor, pressure switch
- Incorrect refrigerant charge

Continue to **5**

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

Yes

No

6 If outlet temperature too high:
- Heating switched off?
- Cabin filter replaced?
- Check temperature switch/sensor and thermostat (if present)
- Check ventilation doors, heating valves, condenser ventilation

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

Yes

No

8 See section 2.1.3

Air conditioning system working

2.1.2 Troubleshooting air conditioning temperatures

One of the basic methods of locating and fixing potential air conditioning problems quickly and inexpensively is by means of temperature diagnostics. The temperature ranges in this section serve as a guide and apply to air conditioning systems with expansion valves and to readings taken at an ambient temperature of 20°C.

To obtain a reliable diagnosis, follow the steps outlined here.

Step 1: Start the engine.

Step 2: Switch on the air conditioning, set it to the lowest temperature, and turn the blower up to the highest setting.

Step 3: Wait for the engine to reach operating temperature.

Step 4: Measure temperatures at the various components.

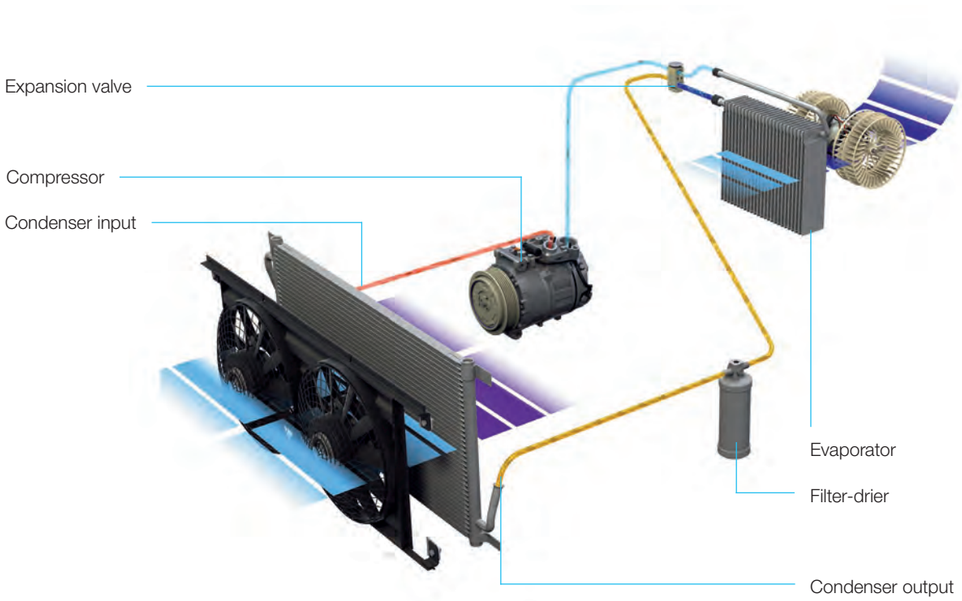


Fig. 1: Design of the air conditioning system

Component	Setpoint values	Divergent values	Possible sources of faults
Condenser input From compressor	60°C–90°C	Above 90°C	▪ Insufficient lubrication ▪ Oil film diluted by too much UV leak detecting agent ▪ Fans run too slowly or not at all ▪ Condenser fouled from within (blocked) ▪ Dirty or corroded condenser fins ▪ Incorrect refrigerant quantity (too much)
Condenser output To filter-drier	40°C–60°C	Above 60°C	▪ Contaminated refrigerant ▪ Nitrogen or air in the air conditioning system ▪ Clogged filter-drier ▪ Blocked expansion valve ▪ Compressor runs continuously
Compressor Directly on component	60°C–90°C	Above 90°C	▪ Insufficient or complete lack of compressor lubrication ▪ Dirty, deformed, or corroded condenser fins ▪ Air conditioning condenser fouled from within ▪ Clogged filter-drier ▪ Fan runs too slowly or not at all ▪ Incorrect or contaminated refrigerant ▪ Refrigerant level too high or too low
Low-pressure side of compressor From evaporator to compressor	5°C–15°C	Below 5°C	▪ Defective expansion valve ▪ Low-pressure hose iced up ▪ Refrigerant level too low ▪ Moisture in the system (filter-drier saturated) ▪ Foreign object or corrosion in the expansion valve ▪ Compressor overloaded (speed)
Expansion valve Directly on component	2°C–5°C	Above 10°C	▪ Insufficient or incorrect compressor lubrication ▪ Missing or damaged condenser fins ▪ Flow in air conditioning condenser restricted ▪ Clogged filter-drier ▪ Fan runs too slowly or not at all ▪ Incorrect or contaminated refrigerant ▪ Refrigerant level too high or too low

Fig. 2: Expansion valve

Component	Setpoint values	Divergent values	Possible sources of faults
Evaporator Directly on surface	0°C–5°C	Below 0°C	▪ Incorrect or contaminated refrigerant ▪ Air in the air conditioning system ▪ Moisture in the air conditioning system ▪ Compressor runs continuously due to defective climate control system
		Above 10°C	▪ Insufficient or incorrect compressor lubrication ▪ Missing or damaged condenser fins ▪ Flow in condenser restricted ▪ Flow in filter-drier restricted ▪ Fan runs too slowly or not at all ▪ Incorrect or contaminated refrigerant ▪ Refrigerant level too high or too low ▪ Too much compressor oil in the system ▪ Evaporator severely fouled (low-grade cabin filter)
Condenser incl. filter-drier Line from condenser to filter-drier	30°C–50°C	Above 50°C	▪ Insufficient lubrication ▪ Oil film diluted by too much UV leak detecting agent ▪ Fans do not work or do not run at all speeds ▪ Condenser fouled from within ▪ Dirty or corroded condenser fins ▪ Incorrect refrigerant quantity (too much) ▪ Contaminated refrigerant ▪ Nitrogen or air in the air conditioning system ▪ Clogged filter-drier ▪ Blocked expansion valve ▪ Compressor runs continuously

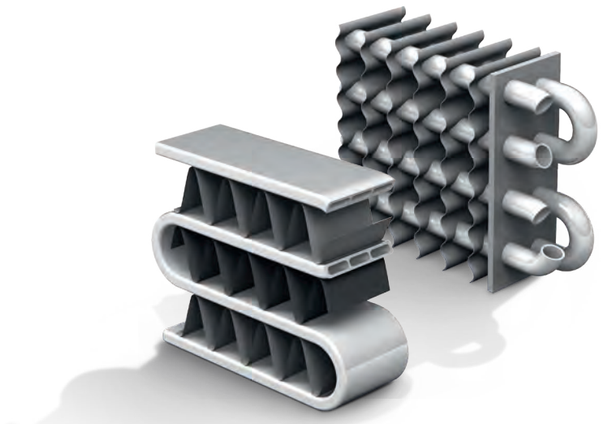


Fig. 3: Serpentine condenser

Fig. 4: Parallel flow condenser

Temperature difference at the A/C condenser

Measure the temperature at the input and output of the condenser. The temperature difference reveals a lot. There are different setpoint values depending on the design of the condenser.

Condenser	Setpoint values	Divergent values	Possible sources of faults
Serpentine	14°C–19°C	5°C–14°C	▪ Cooling air flow restricted ▪ Dirty condenser surface ▪ Bent fins or tubes ▪ Missing or corroded fins ▪ Faulty A/C fan or fan clutch ▪ Air conditioning system overloaded
Parallel flow	19°C–29°C	30°C–45°C	▪ Condenser fouled or clogged from within ▪ Malfunctioning condenser

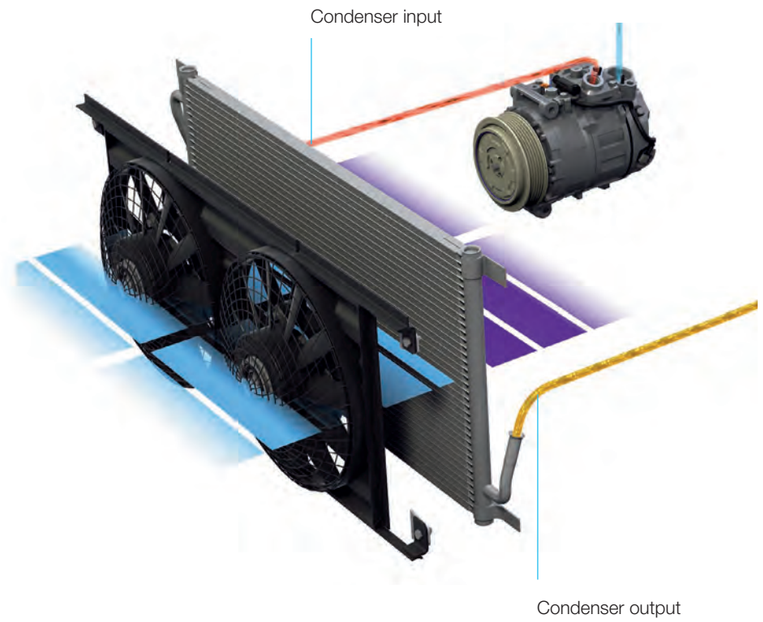
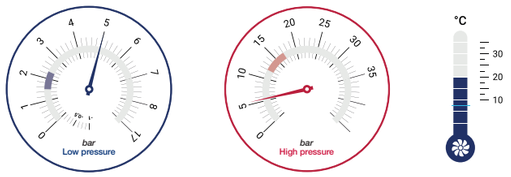


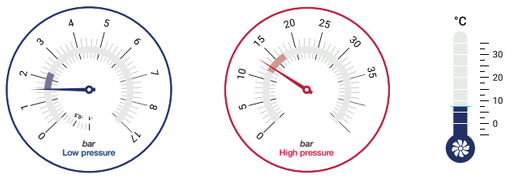
Fig. 5: Front section of the air conditioning system

2.1.3 Troubleshooting air conditioning pressures



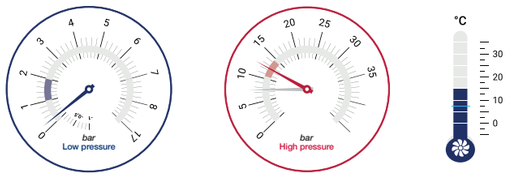
Scenario 1: Air conditioning OFF

When the air conditioning is switched off, high pressure and low pressure indicate the same value. At an ambient temperature of 20°C, that value is around 5 bar.* This means that there is refrigerant in the system. However, it is not possible to say how much refrigerant is in the system—whether there is too little, too much, or just the right amount.



Scenario 2: Air conditioning ON

Set the air conditioning to the coldest level (LO). High pressure 12 to 15 bar, low pressure 1.5 to 2.1 bar, temperature at middle air outlet nozzles +2°C to +8°C. Air conditioning is working well. We recommend checking the refrigerant volume every two years (A/C service).

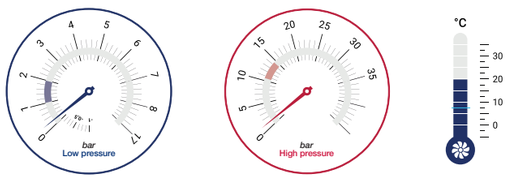


Scenario 3: Too little refrigerant in the system

Poor cooling performance. High pressure varies between 7 and 12 bar (too low). Low pressure approx. 0 bar (too low).

Common causes:

a) A/C service not performed for a very long time
b) Damage and leaks in the air conditioning system



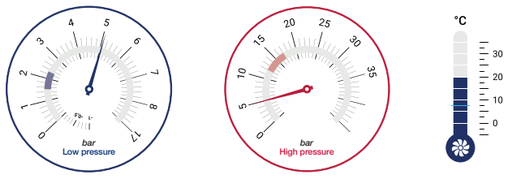
Scenario 4: No refrigerant in the system

High pressure and low pressure 0 bar. No cooling performance, compressor magnetic clutch does not switch on.

Common causes:

a) Condenser damaged (e.g., stone chip)
b) Broken line (e.g., accident or vibration fracture)
c) Defective seals (e.g., seals have become brittle because A/C system has not been used for a long time during the winter months)

* Temperature readings in scenarios 1 to 7 refer to the temperature at the middle air outlet nozzle at an ambient temperature of 20°C.

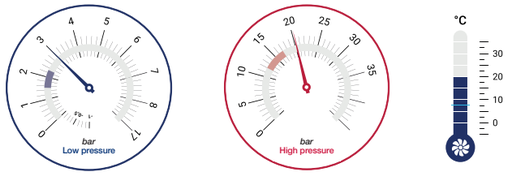


Scenario 5: Defective air conditioning compressor

High pressure and low pressure 5 bar, no cooling performance.

Common causes:

a) Piston seizing due to too little refrigerant in the system
b) Magnetic clutch overheated/burned out
c) Poor electrical contact (e.g., corrosion) on the plug connection, solenoid coil, or control valve
d) Worn out teeth in the belt pulley hub due to vibrations
e) Overload clutch has been triggered by overload or belt vibrations
f) Control valve jammed by foreign objects in the circuit
g) Valve plate damaged by hydraulic shock

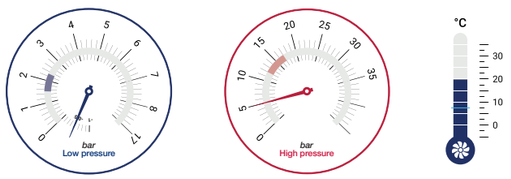


Scenario 6: Reduced heat transfer in the air conditioning condenser

Poor cooling performance. High and low pressure too high.

Common causes:

a) Dirt on the outside of the air conditioning condenser
b) Rusted fins
c) Tubes in the condenser fouled from within by sealant



Scenario 7: Clogged filter-drier

No cooling performance. High pressure and low pressure far too low. Line between filter-drier and expansion valve iced up on the outside.

Common causes:

a) Filter-drier clogged because it was not replaced following an air conditioning system repair
b) Sealant has entered the system and clogged the filter-drier

2.2 Air conditioning compressor

The air conditioning compressor is driven by the vehicle engine via a V-belt. The pistons in the compressor suck in the gaseous refrigerant and compress it.

Fig. 1: Air conditioning compressor

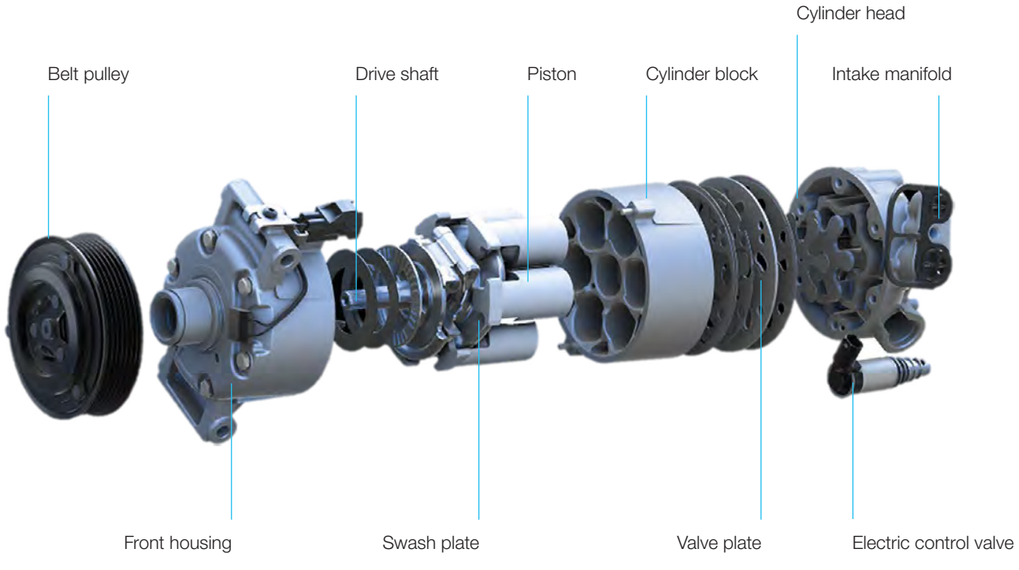


Fig. 2: Air conditioning compressor

2.2.1 Damaged belt pulley

Findings:

- Cracked/torn belt
- Crack in the belt pulley
- Deformed belt pulley
- Belt pulley material breaking down

Cause(s):

- Transport damage
- Improper fitting (installation error)
- Accident damage

Remedies/avoidance:

- Transport the compressor carefully. Improper fitting may cause the belt pulley to deform.
- After accident damage, check the belt pulley for runout using a dial gauge

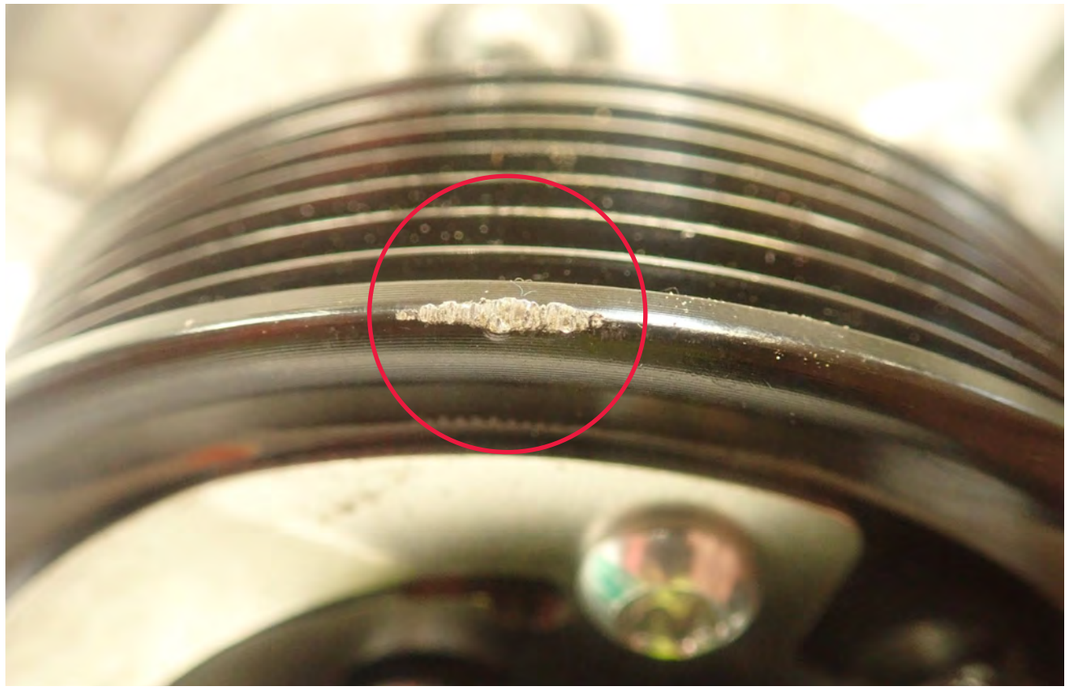


Fig. 1: Damaged belt pulley

2.2.2 Broken overload protection

No transmission of power to belt pulley/drive. The purpose of the overload protection in the compressor belt pulley is to protect the belt drive. If the compressor absorbs a significantly higher torque than the usual approx. 35 Nm, the overload protection will trigger at approx. 80 Nm, disconnecting the compressor from the belt drive.

Findings:

- Air conditioning system not working
- Compressor not being driven by the belt pulley
- Overload protection in the belt pulley triggered

Cause(s):

- Hydraulic shock: too much oil and/or refrigerant in the system
- Seizure in the compressor (inadequate lubrication)
- Vibrations in the belt drive (defective overrunning alternator pulley)

Remedies/avoidance:

- It is important to fill the compressor with the correct amount of oil for the vehicle.
- The system must be flushed to remove all the old oil from the system.
- If the system is not to be flushed, the amount of oil in the new compressor must be adjusted accordingly. To do this, the amount of oil in the old compressor must be determined. The new compressor may then only be filled with this quantity so that the total quantity is not exceeded.
- In a compressor with no oil drain plug, the system must be flushed, because the amount of oil cannot be adjusted in this type of compressor.

Fig. 1: Broken overload protection

Find out more in this issue of **Technical Messenger**:

2.2.3 Worn out teeth in the belt pulley hub

No transmission of power to belt pulley/drive. The compressor's belt pulley and drive shaft are connected to each other by means of interlocking teeth.

Findings:

- Air conditioning system not working
- Air conditioning compressor not being driven by the belt pulley
- Missing central screw
- Worn out teeth in the hub

Cause(s):

- Vibrations in the belt drive
- Defective overrunning alternator pulley
- Hard-shifting automatic transmission
- Engine running unevenly as a result of defective or uncalibrated injection nozzles
- Brittle rotary damper on crankshaft
- Defective damper on belt tensioner

Remedies/avoidance:

- Vibrations in the belt drive put the teeth under load in both directions of rotation, causing mechanical wear to the teeth. As a result, the belt pulley no longer transmits power to the compressor.
- Check whether the overrunning alternator pulley is working properly. Inspect the belt tensioner and vibration damper on the crankshaft.
- If the automatic transmission is shifting hard, a transmission oil flush is strongly recommended.

Fig. 1: Loosened central screw

Fig. 2: Worn out teeth in the hub

Fig. 3: Worn out teeth

Fig. 4: For comparison: new teeth

2.2.4 Magnetic clutch burned out, electrical defect

No transmission of power from the belt pulley via the magnetic clutch to the drive shaft of the air conditioning compressor.

Findings:

- Air conditioning system not working
- Compressor not being driven by the belt pulley
- Compressor does not turn on
- Worn-out friction material in the magnetic clutch
- Burned-out magnetic clutch coil
- Grease leaked from ball bearings
- Defective belt pulley ball bearings

Cause(s):

- Electrical defect (broken cable, ground cable, corrosion on connector plug, etc.)
- Voltage drop at the magnetic clutch is causing the clutch to slip
- Frictional heating is destroying the insulation on the solenoid coil, overheating the ball bearing, and wearing out the friction material

Remedies/avoidance:

- A drop in the electrical voltage at the magnetic clutch is causing the clutch to slip. Frictional heating is destroying the insulation on the solenoid coil and overheating the ball bearing. The friction material is suffering very heavy wear due to the clutch slipping.
- In this damage scenario, checking the connection cables, plug connections, and grounding point is essential.

Fig. 1: Solenoid coil melted due to slipping clutch

Fig. 2: Corrosion on the grounding point

2.2.5 Magnetic clutch burned out, bearing damage

Findings:

- Defective belt pulley ball bearings
- Grease leaked from ball bearings
- Worn-out friction material in the magnetic clutch
- Burned-out magnetic clutch coil

Cause:

- Belt tension is too high (tensioner defective or set incorrectly). Ball bearing is overloaded and becomes very hot. Result: the belt pulley runs at an angle and rubs against the coil housing.

Remedies/avoidance:

- Replace the compressor and belt.
- Check belt tensioner is working properly and replace if necessary.

Fig. 1: Scuff marks on the coil body and burned-out coil

Fig. 2: Defective ball bearing

2.2.6 Bent pin on electrical connection

Findings:

- Compressor not working at all

Cause(s):

- Electrical defect in the connector plug
- Pin was bent on the solenoid valve during fitting

Remedies/avoidance:

- Do not insert the connector plug at an angle or force it into the solenoid valve.

Fig. 1: Bent pin

2.2.7 Pressure-relief valve, kinked line

Findings:

- System not working
- Pressure-relief valve has activated (no protective film on the valve)
- Air conditioning not working shortly after switching on
- Low pressure (LP) too high
- High pressure (HP) too low
- If the air conditioning is switched off and then switched back on again, it works for a short time

Cause(s):

- Blocked air conditioning system
- Blocked line between compressor and expansion valve
- Clogged filter-drier
- Line kinked (e.g., after an accident)
- Defective fabric hose on the LP side: inner rubber layer has detached from the fabric; negative pressure is causing the inner layer to collapse and seal itself shut

Remedies/avoidance:

- When the pressure-relief valve activates, the protective film is blown away. This is a clear indication of a constriction or blockage in the refrigerant circuit.
- Check lines and hoses and replace if necessary. Replace the filter-drier.

Fig. 1: Pressure-relief valve has activated

Fig. 2: Protective film indicates that valve has not activated

Fig. 3: Kinked HP line

2.2.8 Piston seizure

Findings:

- Compressor sluggish or blocked
- Metallic abrasion particles in the oil
- Black, burned oil
- Too much contrast agent
- Rubber abrasion particles/foreign objects in the oil
- Seizure marks on the piston, swash plate, and slide shoe

Cause(s):

- System was not flushed when the compressor was replaced
- Seizure marks on piston and swash plate: poor lubrication due to lack of refrigerant
- Too little refrigerant: compressor overheats and receives too little oil
- Lubricating effect of the oil reduced due to large amount of contrast agent
- Unsuitable cleaning agent used during flushing dissolving rubber hoses
- Sealant added to the system
- Filter-drier supersaturated, resulting in moisture in the system

Remedies/avoidance:

- When replacing the compressor, the system must be flushed to remove the old oil, contaminants, and foreign objects.
- Perform an air conditioning service regularly (approx. every two years). The right amount of refrigerant ensures a good oil supply to the compressor.
- Too much oil in the system reduces the cooling performance and can damage the compressor. Too much contrast agent reduces the lubricating effect (oil becomes thicker). Pistons twist through the swash plate, grinding against the housing. More friction on the piston skirt.

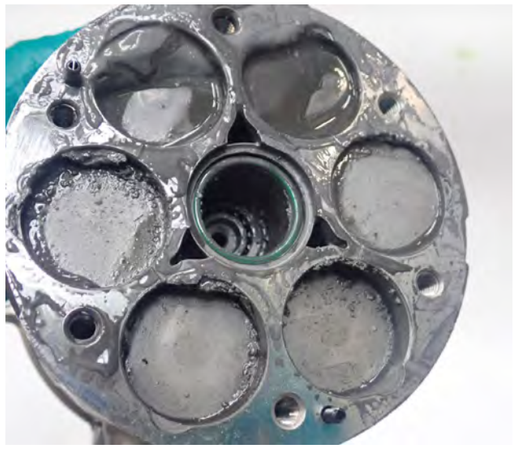


Fig. 1: Severe seizure marks on pistons and cylinder

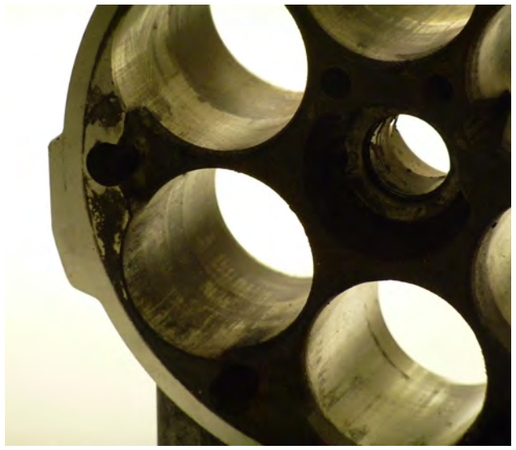


Fig. 2: Seizure marks on the cylinder

Fig. 3: Seizure marks on pistons and swash plate

Fig. 4: Chips and black oil on the solenoid valve

2.2.9 Valve plate

Findings:

- System not working
- Noises (ticking)
- Significant pressure fluctuations at low and high pressure
- Broken valve flap

Cause(s):

- Blocked air conditioning system
- Hydraulic shock due to refrigerant
- Hydraulic shock due to compressor oil
- Defective expansion valve

Remedies/avoidance:

- Follow the manufacturer specifications for compressor oil and refrigerant filling quantities. The air conditioning system must be flushed to completely remove all the old compressor oil from the system.
- Replace expansion valve. If the old expansion valve is blocked in the open position, liquid refrigerant will enter the compressor.

Fig. 1: Broken valve

Fig. 2: Deformed HP-valve limiter

Fig. 3: Deformed limiter

2.2.10 Scroll compressor, e-compressor

Advantage of scroll and e-compressors	Disadvantage of scroll and e-compressors
▪ Small size ▪ Very quiet	▪ Very sensitive to contamination

Findings:

- High pressure too low
- Compressor sluggish or blocked
- Metallic abrasion particles in the oil
- Black, burned oil
- Too much contrast agent
- Rubber abrasion particles/foreign objects in the oil
- Seizure marks on compressor scroll

Cause(s):

- System not flushed when compressor replaced
- Seal on compressor scroll damaged by poor lubrication due to lack of refrigerant
- Too little refrigerant: compressor overheats
- Lubricating effect of the oil reduced due to large amount of contrast agent
- Unsuitable cleaning agent used during flushing dissolving rubber hoses
- Sealant added to the system
- Filter-drier supersaturated, resulting in moisture in the system

Remedies/avoidance:

- When replacing compressors, the system must be flushed to remove old oil, contaminants, and foreign bodies.
- Perform an air conditioning service regularly (approx. every two years). The right amount of refrigerant ensures a good oil supply to the compressor.
- Too much oil in the system reduces the cooling performance and can damage the compressor.
- In the case of electric air conditioning compressors, the addition of contrast agents to the system is strongly discouraged.

Fig. 1: Scroll in scroll compressor heavily worn

Fig. 2: Seal on front face of scroll destroyed

2.3 A/C compressor oils

In addition to refrigerant, the air conditioning system also contains a defined quantity of compressor oil. This oil is used to lubricate the moving parts in the compressor and help seal the piston/cylinder and valves. The compressor oil is also necessary to keep the elastomer seals in the system supple.

PAG oils must have the correct viscosity and be compatible with the individual vehicle's refrigerant. PAG oils are hygroscopic. Once a container has been opened, the contents must be used within two weeks.

PAO multigrade oils (instead of PAG):

- PAO oils are nonhygroscopic, suitable for all viscosities, and compatible with common refrigerants. Opened bottles can be used for a long time.
- PAO 68 AA1 is compatible with all piston and scroll compressors, all common refrigerants, and electric vehicles.
- PAO 68 AA3: used for vane compressors.
- PAO oils with UV leak detecting agent are only approved for R134a refrigerant.

2.3.1 Clear oil

The color of the oil from a defective compressor can be used to identify the cause of failure.

Findings:

- Clear oil
- Light-green oil

Cause(s):

- No discoloration and no chips indicate that there is no mechanical wear inside the compressor.
- Light-green oil contains UV leak detecting agent.

Remedies/avoidance:

- We always recommend flushing the old oil out of the system before installing a new compressor. If flushing is not carried out for cost reasons, the amount of oil in the old compressor must be determined. This is the only way to correctly adjust the amount of oil in the new air conditioning compressor.
- In a compressor with **no** oil drain plug, the system must always be flushed.

More information about
A/C compressor oils

Fig. 1: Clear oil

2.3.2 Green oil

The color of the oil from a defective compressor can be used to identify the cause of failure.

Findings:

- Dark-green oil
- Sticky, viscous oil

Cause(s):

- Too much contrast agent in the oil
- Mixing with contaminated oil (system was not flushed when the compressor was replaced)
- Addition of leak detecting agent during the A/C service, even though leak detecting agent is already in the system

Remedies/avoidance:

- We recommend not adding any leak detecting agent to the system. The use of forming gas is the most reliable leak detection method today.
- An excessively high concentration of leak detecting agent reduces the lubricating effect of the compressor oil. Too much leak detecting agent can also negatively affect the viscosity of the oil, causing it to become sticky and block the pistons.
- If there are contaminants in the oil from the old compressor, the system must be flushed.

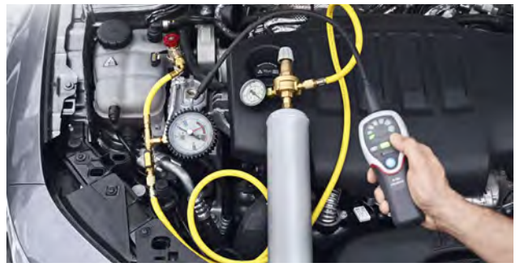


Fig. 1: Leak detection using forming gas

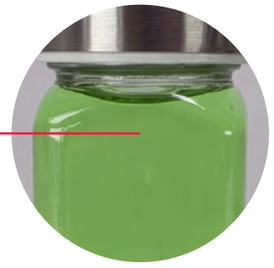


Fig. 2: Green oil

2.3.3 Silvery oil

The color of the oil from a defective compressor can be used to identify the cause of failure.

Findings:

- Silvery, dark-green oil

Cause(s):

- Contaminated oil from previous damage if the system has not been flushed
- Too much leak detecting agent has reduced the lubricating effect of the compressor oil
- Decreased oil circulation due to insufficient refrigerant in the system
- Oil contains metallic abrasion particles from mechanical components such as pistons or swash plate

Remedies/avoidance:

- If contaminated oil containing abrasion particles and chips is found in the old compressor, the entire system must be flushed thoroughly and the filter-drier and expansion valve/orifice tube replaced.
- Flushing must be carried out against the direction of flow.
- Perform an air conditioning service regularly (approx. every two years) to make sure there is always enough refrigerant in the system.

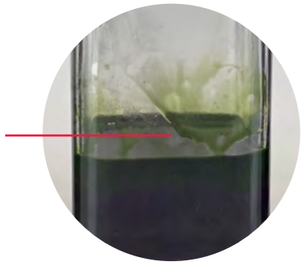


Fig. 1: Silvery, dark-green oil

2.3.4 Black oil

The color of the oil from a defective compressor can be used to identify the cause of failure.

Findings:

- Type plate on compressor burned
- Black oil
- Oil smells burned

Cause(s):

- Compressor under extreme thermal overload
- Far too little refrigerant in the system, resulting in reduced oil circulation
- Inadequate condenser cooling performance due to corrosion and missing cooling fins
- Severe contamination between condenser and radiator (leaves, dust, etc.)
- Electromagnetic control valve blocked by contaminants

Remedies/avoidance:

- Black, burned oil in the old compressor indicates that the compressor got extremely hot.
- Before installing a new compressor, the system must be flushed to remove all residues and foreign objects from all lines, the condenser, and the evaporator.
- Not only the air conditioning compressor but also the expansion valve/orifice tube and filter-drier must be replaced.

Fig. 1: Black, burned compressor oil

2.3.5 Orange oil

The color of the oil from a defective compressor can be used to identify the cause of failure.

Findings:

- Orange oil

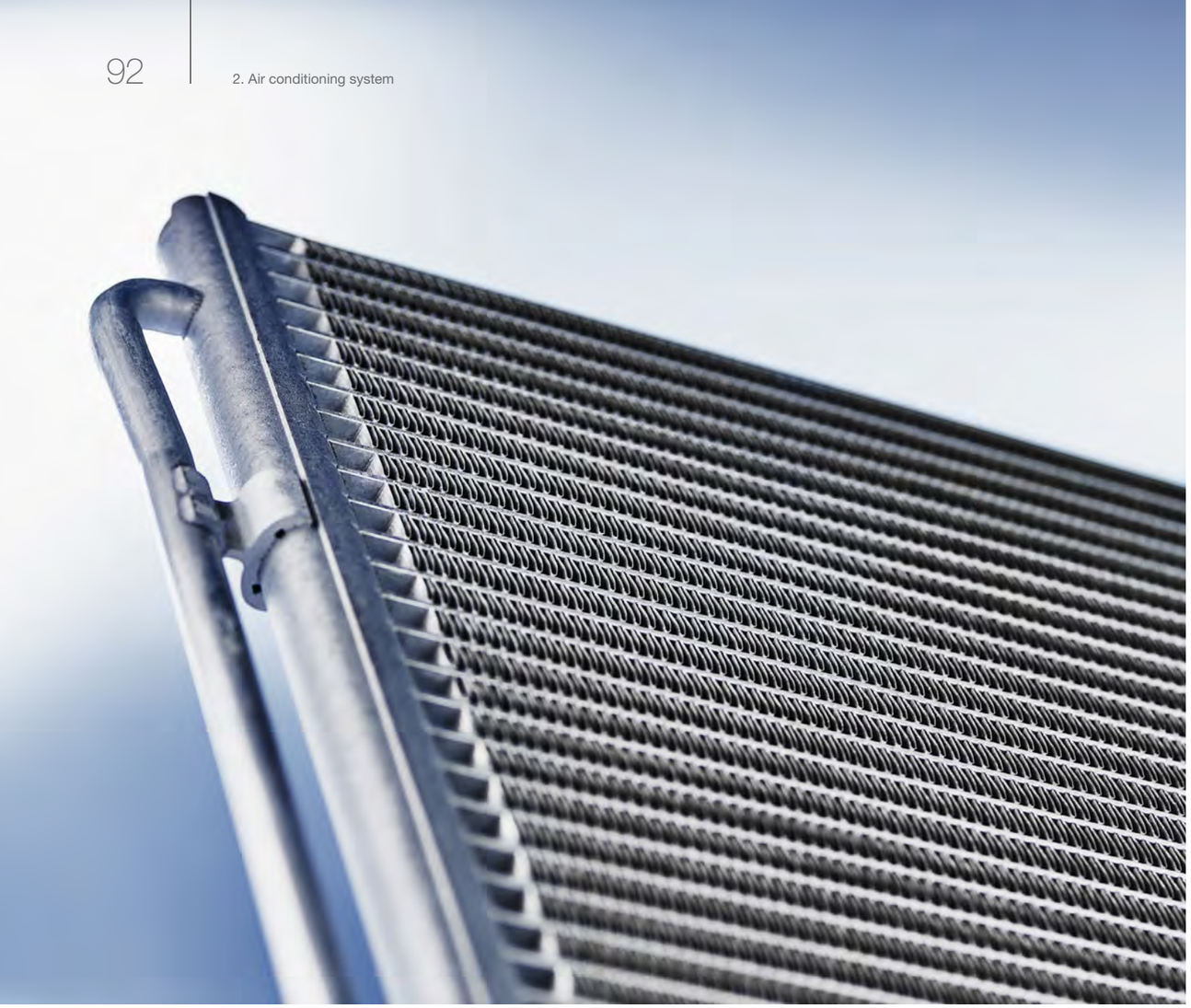
Cause(s):

- Too much moisture in the compressor oil
- Moisture causes orange discoloration
- The filter-drier was not changed when a component was replaced, e.g., the condenser

Remedies/avoidance:

- The filter-drier should be replaced at every air conditioning service, every two years. If the air conditioning system is opened to replace a component, a new filter-drier must be fitted. The absorption capacity of the granules (silica gel) in the drier is limited. Moisture that enters the compressor oil reacts chemically with the oil. This causes orange discoloration and also produces acids that attack nonferrous metals in the system in particular. The chemical reaction between moisture and PAG oil is irreversible. The vacuum of an air conditioning service unit cannot remove moisture from the oil.
- The system must be flushed thoroughly.
- Filter-drier and expansion valve must be replaced.

Fig. 1: Orange oil



2.4 Air conditioning condenser

The air conditioning condenser is located upstream of the engine radiator and cools the refrigerant coming from the air conditioning compressor. This causes the hot, gaseous refrigerant to cool down in the air conditioning condenser to such an extent that it becomes liquid.

2.4.1 Reduced cooling performance

Findings:

- Inadequate cooling performance
- Air conditioning condenser fan runs continuously
- Condenser overheats
- Total failure of the air conditioning system

Cause(s):

- External soiling of the cooling fins
- Corrosion on the cooling fins
- Blockage due to foreign objects (air conditioning compressor damage)
- Defective fan motor
- Defective fan motor control unit
- Defective pressure sensor
- Defective climate control unit

Remedies/avoidance:

- If the cooling fins are dirty, clean the condenser carefully using a gentle stream of water. If the cooling fins are corroded or partially missing, the condenser should be replaced.
- Multiflow condensers, in which multiple tubes run in parallel, cannot be flushed.

Fig. 1: Corrosion on the condenser

Fig. 2: Corroded cooling fins

2.4.2 Air conditioning condenser not working

Findings:

- Leaky air conditioning condenser

Cause(s):

- Leak (e.g., after stone chipping, accident)
- Mechanical damage when unpacking the new part
- Corrosion
- Chemical cleaning agents, salts
- Abrasion marks or vibration fractures due to improper installation and resulting vibrations

Remedies/avoidance:

- Leaky condensers must be replaced. Never add sealants to the system. These sealants have little or no effect, and they will damage all the valves in an air conditioning service unit.
- Care should be taken not to damage the tubes when unpacking and installing the condenser.
- When washing the vehicle, do not spray wheel rim cleaner or insect remover onto the condenser.

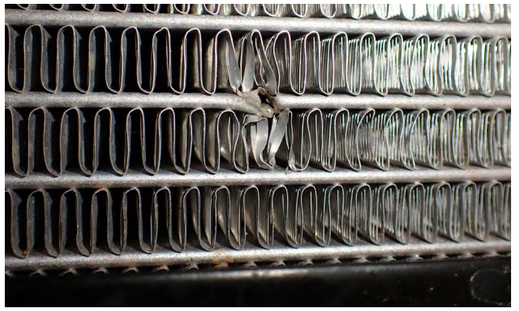


Fig. 1: Mechanical damage (stone chipping)

Fig. 2: Corrosion on the condenser

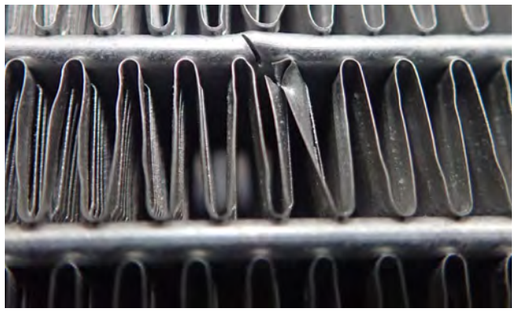


Fig. 3: Mechanical damage (cut)

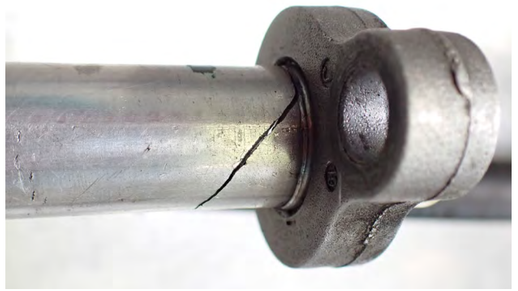


Fig. 4: Broken connection (vibration fracture)

2.5 Filter-drier

The filter-drier is designed to remove moisture and foreign objects from the liquid refrigerant. It also serves as a refrigerant store. Inside the housing, there is a filter pad containing granules that absorb moisture from the system.

The capacity of the granules is limited, so the filter-drier must be replaced each time the system is opened.

2.5.1 Clogged filter-drier

Findings:

- Inadequate cooling performance
- Total failure of the air conditioning system (damage/clogging of other components)
- Corrosion of metals in the air conditioning system

Cause(s):

- Saturation of the filter pad
- Filter pad defective due to excessive aging
- Too much moisture in the compressor oil acidifying the oil

Remedies/avoidance:

- The filter-drier should be replaced at every air conditioning service (every two years).
- Each time the system is opened to replace a component, the filter-drier must be changed.
- When the filter-drier is saturated, the moisture reacts with the compressor oil. As a result, the oil becomes acidic and attacks metals in the air conditioning system.

Fig. 1: Filter-drier granule outlet

Fig. 2: Clogged filter-drier

Fig. 3: Clogged filter-drier

2.6 Expansion valve/orifice tube

The expansion valve or orifice tube is the point of transition from high pressure to low pressure. The liquid refrigerant is passed through a constricted cross section, which reduces the pressure. From here, the liquid refrigerant in the evaporator begins to turn to gas, extracting heat from the fresh air in the process.

2.6.1 Expansion valve/orifice tube clogged/corroded

Findings:

- Humming noises in the cabin when the air conditioning is switched on
- Air conditioning not cooling
- Air conditioning too cold
- Fluctuating air conditioning temperature

Cause(s):

- System was not adequately flushed following compressor damage
- Expansion valve and filter-drier were not changed when compressor was replaced
- Clogged orifice tube (dirty)
- Incorrect orifice tube (color code) fitted
- Blocked expansion valve, resulting in evaporator icing up or not cooling

Remedies/avoidance:

- The system should be flushed when replacing the compressor. Contaminants from the old air conditioning compressor (chips) and loosened rubber particles from seals or hoses can clog or block the orifice tube or the valve in the expansion valve. When replacing the orifice tube, be sure to use the correct color code.

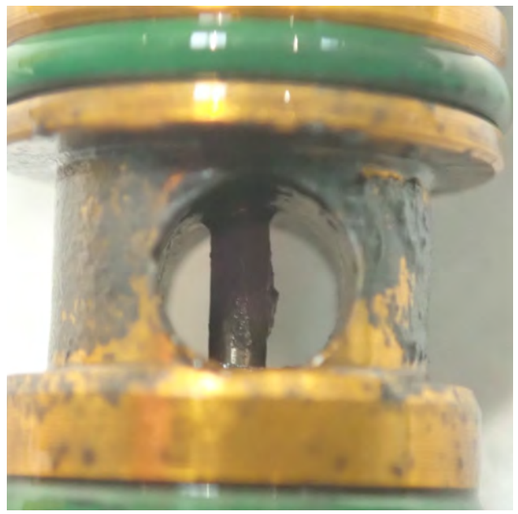
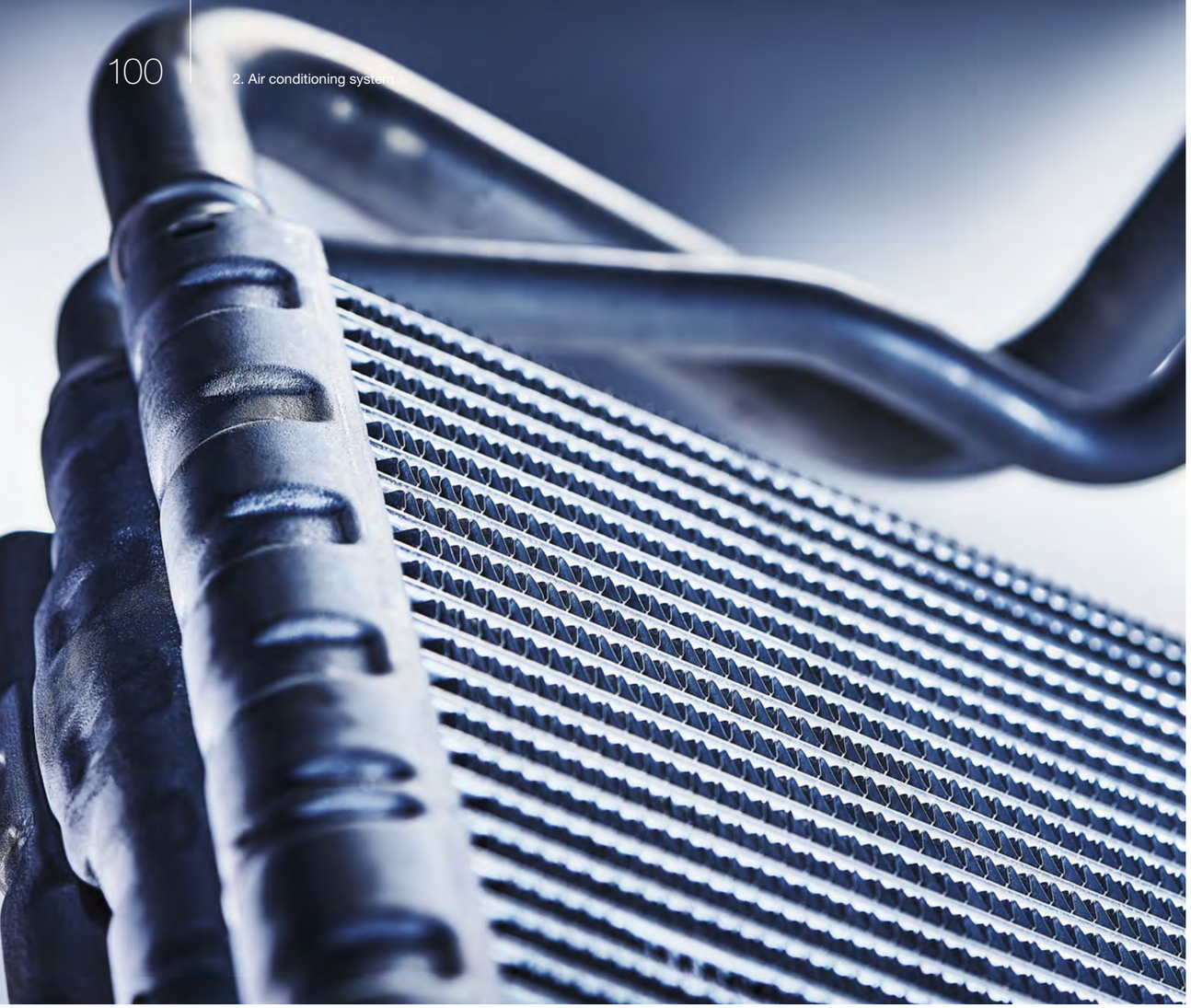


Fig. 1: Corrosion in the expansion valve

Fig. 2: Contaminants in the expansion valve



2.7 Evaporator

In the evaporator, the liquid refrigerant turns to gas. The change in the refrigerant's physical state extracts heat from the environment. The warm ambient air is cooled and directed into the cabin by the interior blower.

2.7.1 Reduced cooling performance

Findings:

- No cooling performance
- Fluctuating cooling performance

Cause(s):

- Fouled from within (system not flushed after previous damage, or so-called air conditioning sealant was added to the system)
- Blocked expansion valve
- Loose temperature sensor on the evaporator
- Evaporator sometimes ices up
- Cabin filter heavily soiled
- Defective interior blower

Remedies/avoidance:

- Start by replacing the cabin filter. If there is a temperature sensor on the evaporator, check that it is correctly attached.
- Check all interior blower speed settings are working properly.
- The system should be flushed when replacing a defective compressor. Replace the filter-drier and expansion valve.

Fig. 1: Heavily soiled cabin filter

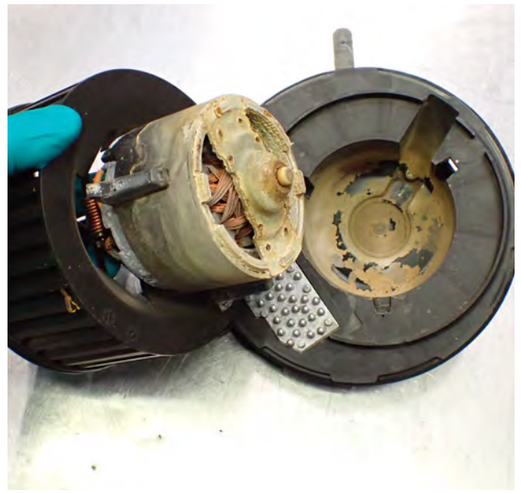


Fig. 2: Defective interior blower

2.7.2 Leaky evaporator

Findings:

- Leaky evaporator

Cause(s):

- Expansion valve blocked in the open position
- Evaporator ices up
- Evaporator destroyed by frozen ice crystals

Remedies/avoidance:

- Moisture from the air condenses on the outside of the evaporator when the air conditioning is switched on. Temperature sensor on the evaporator and thermostat in the expansion valve prevent the surface temperature from falling below +0.5°C.
- When water (condensation) freezes, its volume increases by 10%, deforming and cracking the evaporator tubes. That is why checking the temperature regulation system is essential in this damage scenario.

Fig. 1: Deformation of the tubes from the outside inward

Fig. 2: Deformation and crack

Fig. 3: Leaky evaporator

2.7.3 Fouled evaporator

Findings:

- Development of odors in the cabin
- Reduced cooling performance

Cause(s):

- Severe contamination from the outside
- Mold formation on the outside of the evaporator
- Replacement interval for cabin filter significantly exceeded
- Use of a low-grade cabin filter

Remedies/avoidance:

- Always fit high-quality cabin filters and replace them regularly—every year or every 15,000 km.
- Switch off the air conditioning 5 minutes before reaching your destination to allow the surface of the evaporator to dry.
- Treat the cabin using MAHLE OzonePRO, for example.
- Clean and disinfect the evaporator with an alcohol-based cleaner.

Fig. 1: Fouled and clogged evaporator

Fig. 2: Clogged evaporator

2.8 Pressure switch

Pressure switches perform several functions. Because the pressure of the refrigerant correlates with the temperature in the system, the pressure switch is also used to monitor the temperature.

Pressure switches prevent the compressor from turning on when the pressure is too low. Pressure switches turn on the air conditioning fan when the condenser becomes too warm. Pressure switches turn off the compressor when the system is too hot.

2.8.1. Pressure switch not working

Findings:

- Air conditioning compressor does not turn on
- Air conditioning switches off
- Air conditioning fan runs continuously
- Air conditioning fan does not run at all

Cause(s):

- No refrigerant in the system (pressure <2 bar)
- Defective pressure switch (voltage spikes)
- Defective electrical connection to the climate control unit (broken cable)
- Corrosion on contacts/plug connection
- Defective climate control unit

Remedies/avoidance:

- Use an air conditioning service unit to check whether the system contains the correct amount of refrigerant and perform a leaktightness test.
- The next step is to check and measure the cables and signals to the pressure switch.
- Loose contacts can lead to current and voltage spikes that destroy electronics.
- On most vehicles, the pressure switch can be replaced without having to evacuate the refrigerant beforehand. Please refer to the vehicle manufacturer's specifications to determine whether a valve is fitted in the hose connector.

Fig. 1: Pressure switch

Fig. 2: Pressure switch

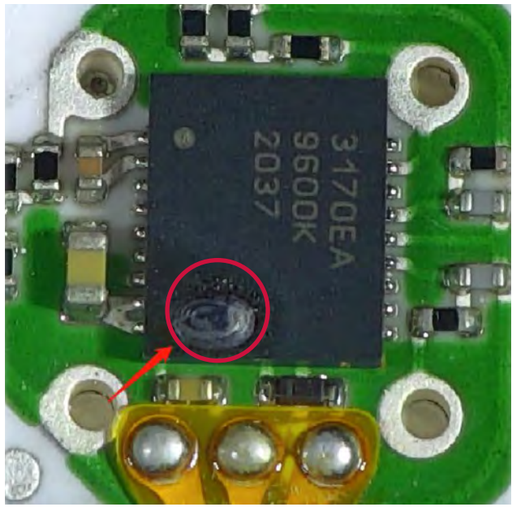
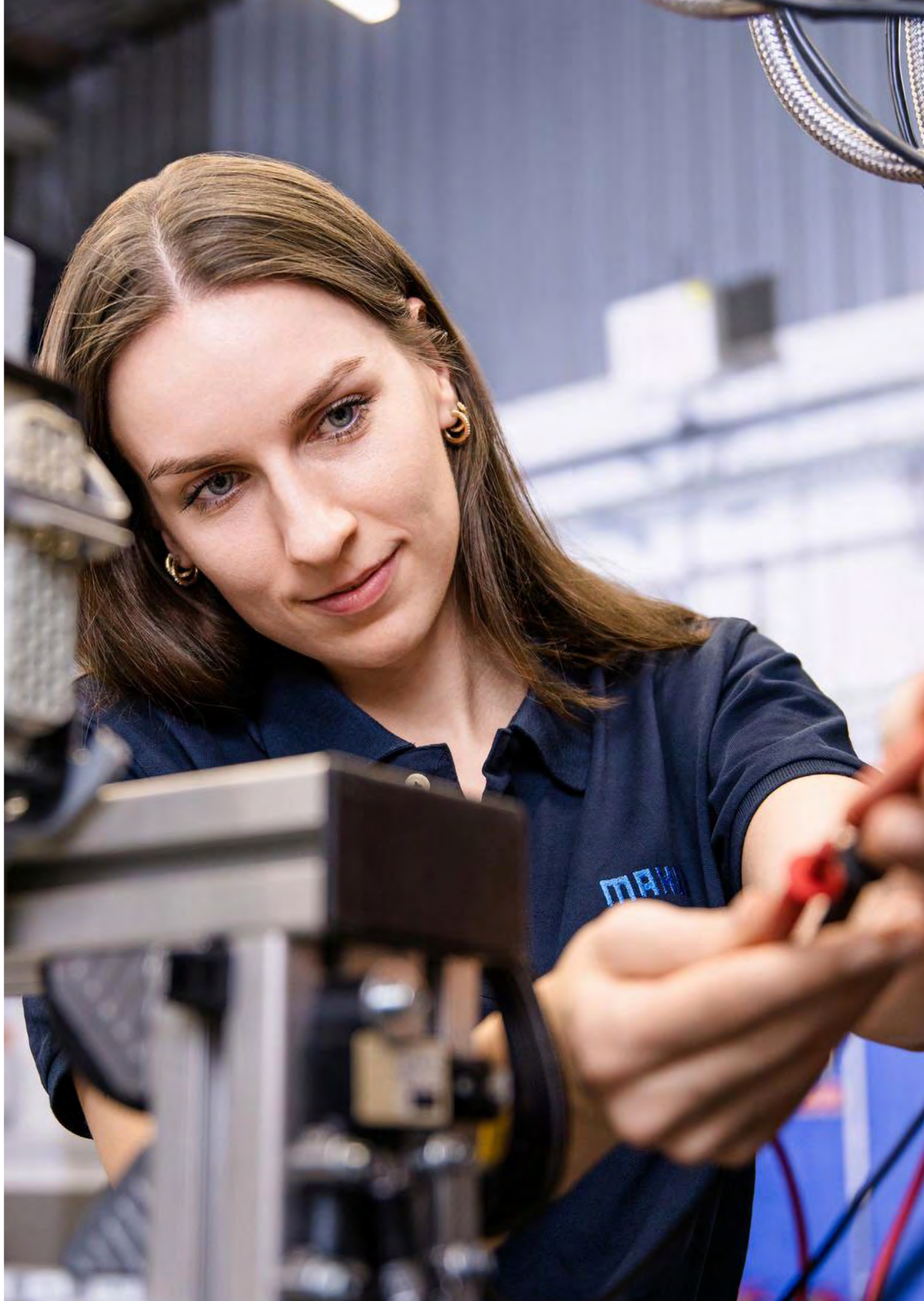


Fig. 3: Burned-out pressure switch (sensor electronics)

Fig. 4: Testing a pressure switch in the laboratory



2.9 Chiller

The chiller is an evaporator that takes the form of a plate heat exchanger. The compressed, liquid refrigerant turns to gas in the chiller and extracts heat from the coolant, thereby reducing the temperature of the coolant.

The cold coolant can cool any connected components that are too hot. Examples include the high-voltage battery, power electronics, drive motor, and, in some vehicles, the cabin heat exchanger (A/C system).

If any of these components require heat, the coolant is directed to the low-temperature radiator at the front of the vehicle and cooled or heated. The heat pump uses the temperature differential to supply heat to the components via the indirect condenser.

2.9.1 Leaky chiller

Findings:

- Leaking (coolant loss)
- Coolant in the refrigerant circuit

Cause(s):

- Contaminants in the coolant (radiator sealant)
- Sealing compound in the coolant
- Defective O-ring

Remedies/avoidance:

- When repairing and replacing components in the coolant circuit, it is important to flush the system. Foreign objects and sealant residue can lead to cavitation on the chiller. See also section 1.10.4 of this brochure.
- All components that have been removed must be fitted with new seals. No sealant pastes or sealants should be used.

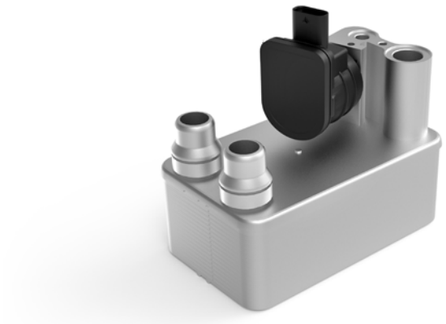


Fig. 1: Chiller with an electric expansion valve

Fig. 2: Leaky chiller

Fig. 3: Indirect condenser

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