Cooling Module with New Evaporation Cooling for Fuel Cell Commercial Vehicles

The **optimum temperature** within the fuel cell is very important for its **efficiency and longevity**; the fuel cell feels most comfortable **at around 70 °C**. Due to the lower temperature difference to the outside temperature compared to the significantly hotter combustion engine, the cooling system of a fuel cell vehicle faces a greater challenge.

MAHLE therefore takes a holistic view of thermal management in the system. The new evaporative cooling system from MAHLE utilizes the cooling effect of evaporating water by spraying water onto the coolant radiator via a grid. This is so effective that **up to 50 kW** more cooling capacity can be offered in the same installation space.

This makes it possible **to reduce the fan output**, thereby lowering **hydrogen consumption by up to 1.5%**.

Bionic Fan – A World First

At the IAA Transportation 2024 in Hanover, MAHLE is presenting an **extremely quiet, bionically optimized high-performance fan** for the first time.

MAHLE's engineers were inspired by **owls' wings** when developing this world first, thereby solving another challenge of e-mobility: **loud fan noise**, which can be disturbing **under full load and also when charging the vehicle** at night in residential areas or at service stations.

The edges of the fan blades are modeled on the feathers of birds of prey, which are known to fly barely audibly. This makes the bionic fan from MAHLE **up to 4 dB(A) quieter than comparable fans**, which is equivalent to more than halving the sound power. At the same time, the unit has a 10 percent improvement in efficiency and a **10 percent reduction in weight**.

Coolant-to-Coolant Cooler for Fuel Cells

The fuel cell is **the heart of the fuel cell drive**. It must be constantly cooled. However, the coolant must **not be electrically conductive**, otherwise the fuel cell will be irreparably damaged.

In **MAHLE's coolant-to-coolant cooler, the heat is therefore transferred from the coolant of the fuel cell to the coolant** of the powertrain without mixing, which would make it conductive. This also allows the volume of the fuel cell circuit to be kept as small as possible.

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Indirect Heat Exchangers

Increasing comfort in the passenger compartment and **the development of new drive systems** are leading to steadily rising demands on thermal management. At the same time, the **installation space required** for this in the vehicle is and remains limited.

The indirect heat exchangers from MAHLE can be installed where they are needed in **a space-optimized** manner. Here, two refrigerant or coolant circuits that are decoupled from each other intersect.

Cooling takes place via the coolant coolers in the cooling module. An additional direct heat exchanger in the module is therefore no longer necessary. The length of the coolant lines can be kept as short as possible and thus the **amount of refrigerant or coolant can be kept as low as necessary**.

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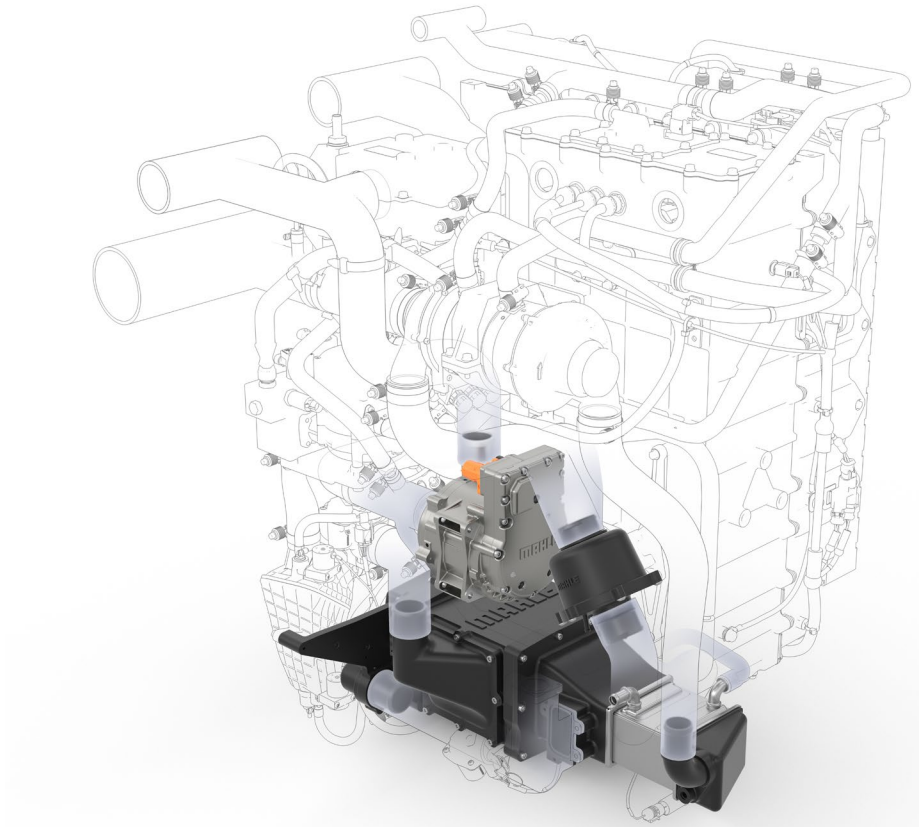
Fuel cell with MAHLE peripherals

The **fuel cell** is one way of **decarbonizing commercial vehicle transportation**. The drive makes the highest technical demands, especially on its peripherals.

The MAHLE peripherals, **charge air cooler, flat membrane humidifier, water separator and high-voltage pump increase efficiency**, protect the cell from premature ageing and enable a higher operating temperature. The result: more power and **improved efficiency** – **mainly due to a 50% reduction in pressure loss in the air path of the fuel cell**.

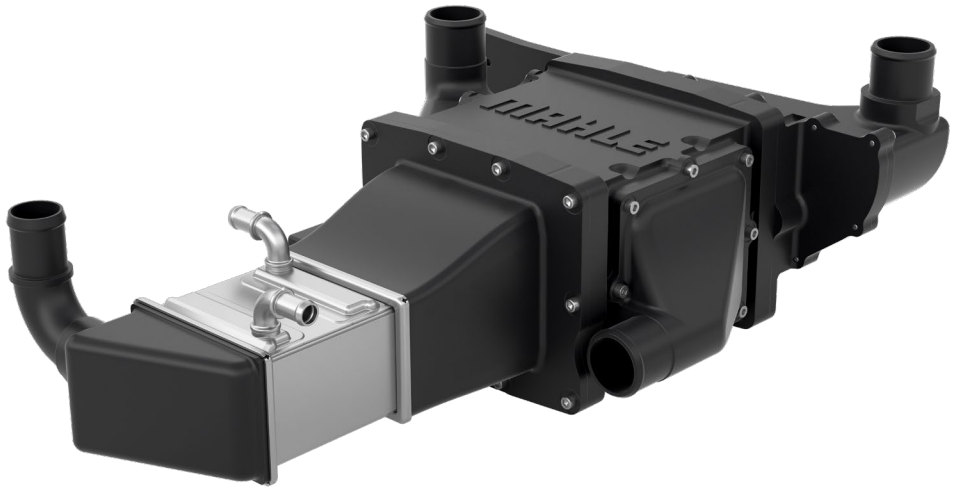


Cathode Module for fuel cells

Fuel cells are technically very complex and extremely sensitive. In order to work optimally, they require air at a constant, precise temperature and humidification throughout their entire service life.

This is ensured by flat membrane humidifiers, filters and charge air cooling. The MAHLE developers have brought all the players together in a **cathode module**. This is a highly integrated, systemic component. The cathode module is a **prime example** of MAHLE's systems expertise. This systemic approach also reduces costs.

The **flat membrane humidifiers** make a particularly important contribution. **Reliable humidification** is very important for the **efficiency and good for the service life** of a fuel cell. Flat membrane humidifiers therefore **increase efficiency and protect the cell** from damage. MAHLE is developing the flat membrane humidifier together with other partners. The project is funded by the German Federal Ministry of Economics and Climate Protection.



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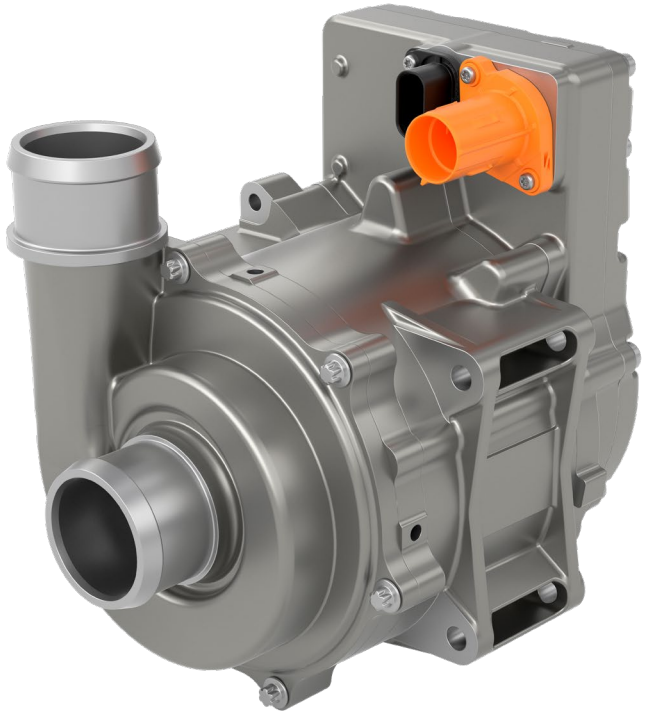
High-performance coolant pump for fuel cell applications

The fuel cell **requires a high cooling capacity**. The 800 V high-performance coolant pump from MAHLE **delivers up to 2.5 kW of power and can pump 300 liters of coolant per minute** at 2,5 bar. The pump could fill two bathtubs at a height of 25 meters in one minute. The **5 kW version could deliver even up to 500 liters per minute**. At the same time, it must not be contaminated with ions in order to prevent undesirable electrical conductivity of the coolant



Water separator

The **air compressor** in the fuel cell system **must be protected from droplets fuel cell exhaust air**. Before the expander, the exhaust air from the fuel cell, i.e. air and the water produced, must therefore be effectively freed from droplets. The MAHLE water separator utilizes the inertia of the air for this purpose: the air is accelerated in a rotor and the water is separated via centrifugal forces.

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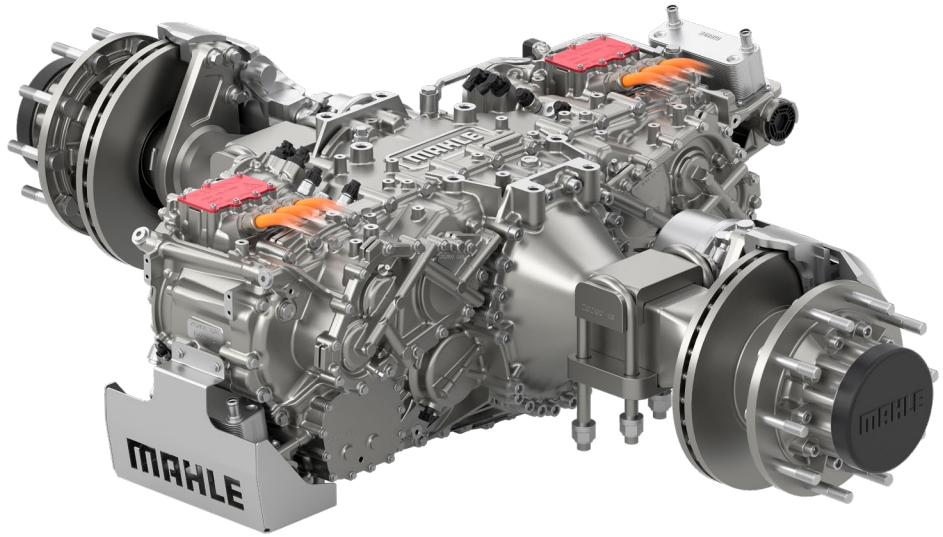
MAHLE E-Axle for Heavy Duty Applications

The MAHLE electric axle integrates **two MAHLE SCT e-motors** with a total peak power of **520 kW and 480 kW continuous power** for challenging electrically driven commercial vehicle applications. The **oil management** of the high-performance motors is **optimally integrated into the axle**, with maximum efficiency and minimum pressure loss.

Both the SCT electric motors and the liquid management module have been developed ready for **series production**.



SCT E-Motor

With the SCT (Super Continuous Torque) electric motor, MAHLE presented **a real world first in 2022**. The traction motor, which is unique on the market, can **operate at high power for an unlimited period** of time and for the first time represents a **fully-fledged alternative** to the combustion engine. Its **high continuous output and efficiency** make it the ideal electric drive for heavy-duty transportation in all-electric trucks and in fuel cell applications.

This is made possible by **an innovative cooling concept**. The electric motor is unrivaled **in its small size, light weight and efficiency** and can also be built **without the use of rare earths** at the customer's request.

The SCT principle can also be combined with the principle of the MCT electric motor (Magnet-free Contactless Transmitter):
A perfect match!

MAHLE

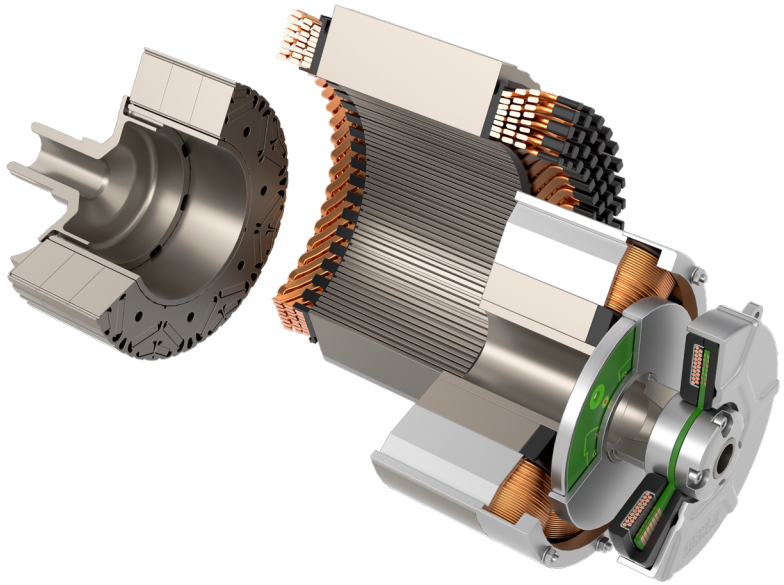
Technology Kit for Electric Motors – The Perfect E-Motor

MAHLE has succeeded in developing **two benchmark technologies for electric motors** over the past two years.

For the first time, it is now possible to combine the MCT (Magnet-free Contactless Transmitter) and SCT (Superior Continuous Torque) technologies.

The result is **a unique modular system for electric motors** that enables customized solutions for our customers.

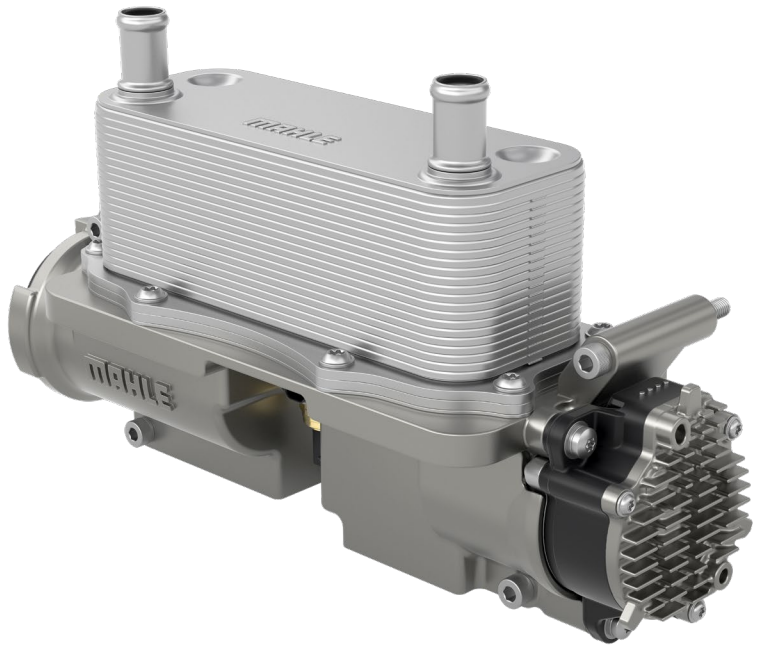
The perfect electric motor with the combined technologies combines **permanent high peak power** with **contactless, wear-free power transmission**. It **dispenses with rare earths** and **demonstrates maximum efficiency** at all operating points.



Liquid Management Module

The e-motors are the real "power packs". They must be protected from overheating. The **liquid management module** from MAHLE is a **highly integrated, extremely compact component** for precisely this important task.

The heat is transferred from the oil to the coolant circuit in a heat exchanger. The oil filter and the oil pump are already **integrated** in the module.



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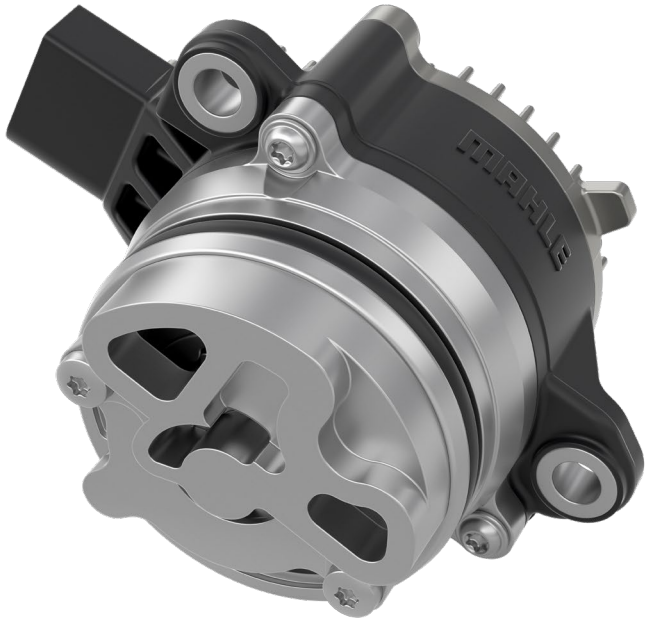
Electric Oil Pump Family

Whether purely battery-electric drives, hybrid drive forms, or fuel cell drives: MAHLE offers the right electric oil pump for every application.

The **oil pump family from MAHLE** is **scalable in terms of power as well as the number of suction and pressure stages**. Thus, power ratings of up to 250 watts are representable. MAHLE offers **12V and 24V systems** (48V optional).

Controlled via LIN or CAN interface, **the product family covers all typical requirements of e-drive axles** and also offers new functions such as the measurement of media temperature or the calculation of volume flow and pressure**.** If necessary, the pump can be individually adapted to the respective customer requirements.

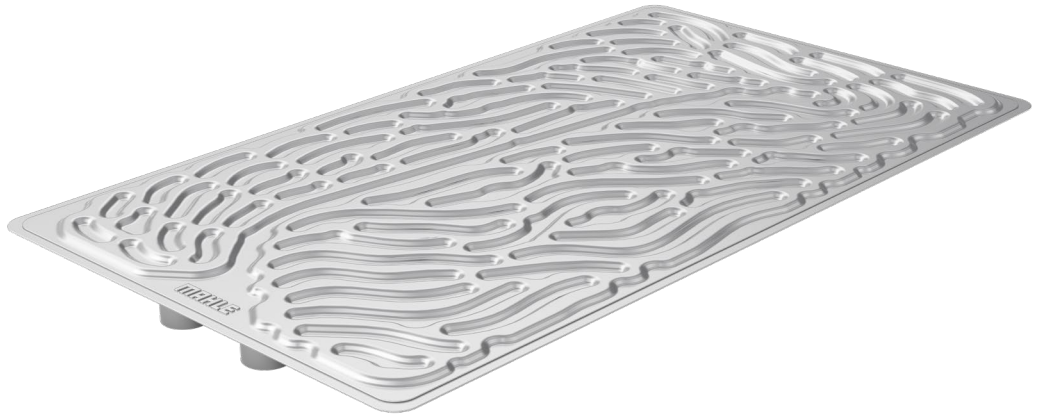


Bionic Battery Cooling Plate

MAHLE has been developing systems for cooling lithium-ion batteries for well over a decade, making it one of the pioneers in this field of technology.

The **bionic battery cooling plate from MAHLE keeps the lithium-ion battery in the optimal temperature window** between 10 to a maximum of 40 °C at all times. Within the cooling plate, the coolant flows into fluid channels.

In this innovation, which MAHLE presented in 2023, the **channel design** imitates flow patterns **found in nature**. This reduces pressure loss by up to 20 percent while **increasing the cooling power** by 10 percent. It also enables the battery to be charged more quickly and helps to extend the service life of the battery.



800-Volt PTC Heater

Battery electric vehicles lack the heat from the combustion for interior heating in the cold season.

Here, a highly efficient heat pump can often provide pleasant interior comfort. But every now and then, additional heating must be provided electrically.

The **800-volt PTC heater from MAHLE heats the interior air directly**. This is **fast** and **highly efficient**, with up to **eight kilowatts of heating power**.

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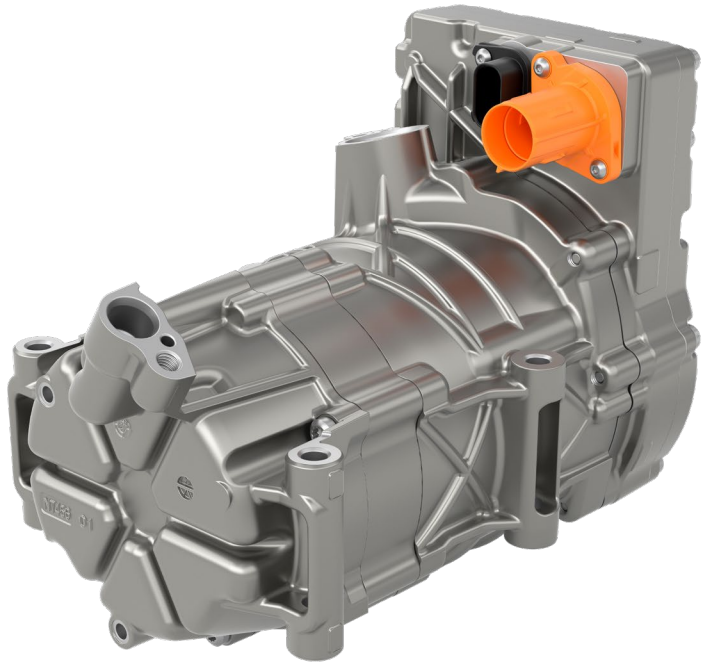
800-Volt e-Compressor

The **e-compressor** is important for the temperature control of the e-drive and thus **crucial for the service life, high charging speed and range of the battery**.

It also ensures the **high level of interior comfort** and **pleasant interior acoustics**.

MAHLE currently offers its **extremely compact** high-voltage compressor in **voltages of 800 volts**, **displacements of up to 57 cubic centimeters** and **outputs of up to 18 kilowatts**.

Its compact design, combined with its high performance, means that it can be used **in all vehicle classes-from passenger cars to heavy commercial vehicles**.

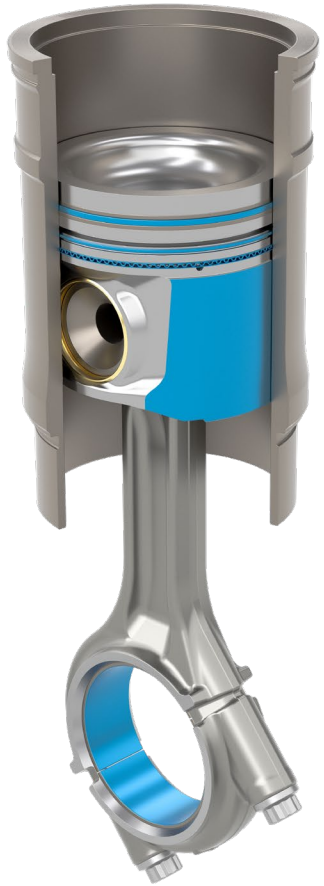


Hydrogen Powercell Unit

MAHLE uses its **expertise in combustion engines** to make its components for this classic form of drive **fit for the use of hydrogen** and thus for climate-neutral operation.

MAHLE has over 100 years of experience in the development and series production of **hydrogen engine components**, enabling this carbon-free fuel to be used **highly efficiently** and with a **long service life**.

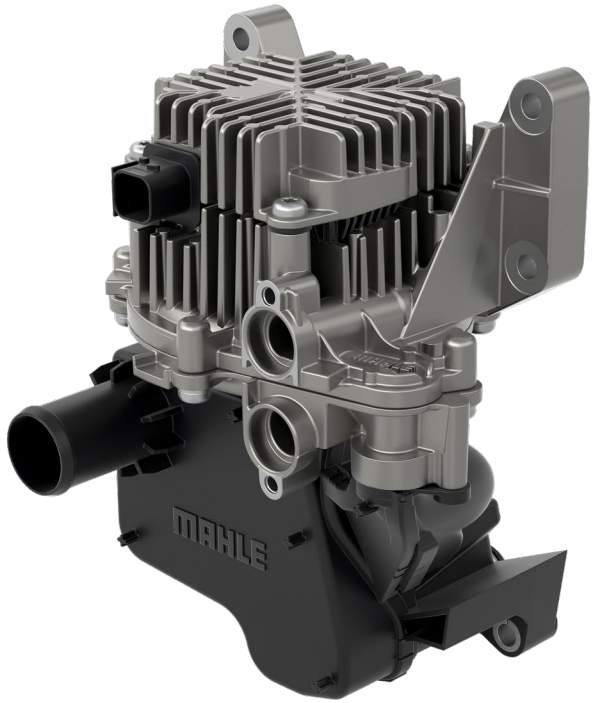
The Powercell unit reduces **oil consumption** and the so-called **blow-by**, i.e. the slight leakage of hydrogen into the crankcase, to a minimum. It therefore guarantees **robust and trouble-free operation**.



High Pressure Impactor

During combustion in the cylinders, a small portion of combustion gas always ends up in the crankcase – the so-called blowby gas.

The **High Pressure Impactor actively flushes the crankcase** with air and prevents alternative fuels (e.g. hydrogen) from building up there.



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Sintered hydrogen filter

Regardless of whether the **alternative fuel hydrogen** is used in fuel cells or in combustion engines, it must be **free of harmful particles** before it reaches the critical areas of the drive.

The cause of such unwanted contamination can be residual dirt in the pipe systems or in the H2 tank, for example. The **sintered stainless steel hydrogen filter from MAHLE cleans** the fuel between the hydrogen tank and the engine or fuel cell with a **very high separation quality**. The sintering process makes it possible to manufacture the filter in just one step to precisely fit any application.