Four ways to a clean gasoline engine

Compact catalytic converter system from BASF removes gaseous pollutants as well as particulates

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- **Reduce emissions**

  Precious metal-containing catalytic converter on ceramic substrate cleans car engine exhaust gases.

- **Remove particulates**

  Compact catalytic converter system with integrated particulate filter.

- **Comply with limits**

  Four-way catalytic converter system helps to meet Euro 6 standard.

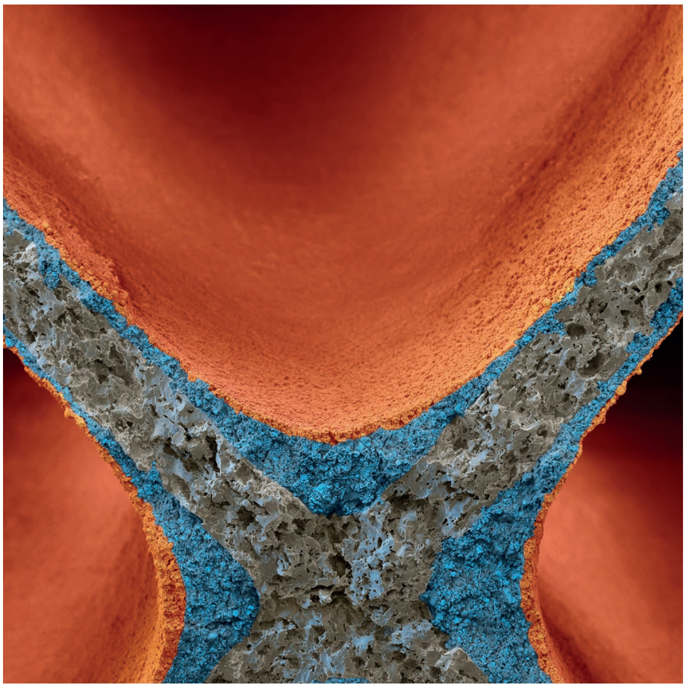
◄ The four-way conversion catalyst consists of a ceramic support coated with precious metals.

With growing prosperity in many emerging markets comes an increasing wish for personal mobility. Simultaneously, global urbanization is increasing vehicle density. LMC Automotive estimates that about 1 billion cars are currently on the roads around the globe, with this figure likely to reach almost 1.2 billion by the year 2018 – cumulatively impacting the air quality of the world's major cities. Propulsion concepts like electromobility – fully electric or as a hybrid variant – are steadily gaining importance. “However, the internal combustion engine will remain the dominant propulsion concept on the roads in the medium term,” says Dr. Klaus Harth, responsible for research on automotive catalytic converters at BASF. “Reducing pollutant contamination from internal combustion engines therefore remains an important global issue.” Official emission standards are becoming more and more restrictive worldwide. In the future, compliance with these standards will require further optimizing of the catalytic converter. A promising new technology for this purpose is the new four-way conversion catalyst from BASF.

Internal combustion engines produce environmentally harmful emissions because the fuel – a mixture of hydrocarbons – burns incompletely. To prevent pollutants such as nitrogen oxides, carbon monoxide, noncombusted hydrocarbons and particulates from entering the air, gasoline and diesel-powered vehicles are equipped with catalytic converters and, in some cases, also with particulate filter systems. They clean the exhaust gas flow before it leaves the exhaust system. This has drastically reduced pollution levels over the last four decades.

The well-known three-way conversion catalyst has been in use in North America since 1976 – and in Europe since 1986. Harth: “Catalytic converters are now capable of removing considerably more than 95 percent of the undesired substances from the exhaust gas flow.” This is achieved by the internal structure of the conversion catalysts: exhaust gas catalysts are made of a special ceramic support, the monolith, which contains numerous parallel channels. ►

Depending on their intended use, the channel walls have differently sized pores. This ceramic support is covered with a washcoat containing metal oxide particles with a very large internal surface. The washcoat contains finely distributed precious metal particles (such as palladium and rhodium in three-way conversion catalysts). These materials are catalytically active and ensure the conversion of carbon monoxide (CO), noncombusted hydrocarbons (HC) and nitrogen oxides (NO_x) into water (H_2O), nitrogen (N_2) and carbon dioxide (CO_2). As catalytically active substances,



Detailed view of a three-way conversion catalyst: palladium layer (blue) selectively oxidizes hydrocarbons and carbon monoxide to carbon dioxide and water, while rhodium layer (red) simultaneously converts nitrogen oxides to nitrogen, carbon dioxide and water with the aid of carbon monoxide or hydrogen (ceramic substrate: grey). The new four-way conversion catalyst from BASF also removes particulates (magnification 120:1, at 15 cm in width).

the precious metals enable and participate in the reaction but remain unaffected by it – a fundamental property of catalysts.

Three plus one makes four

BASF researchers have further developed the three-way conversion catalyst and optimized its cleaning effect: the new four-way conversion catalyst, FWC™, is a technology for vehicles with gasoline engines. The catalyst removes the gaseous pollutants, and also solids like particulates from the exhaust gas flow. “The compact four-way conversion catalyst now combines all the important properties in a single component. Compared to the three-way conversion catalyst and the downstream uncoated particulate filter, it occupies much less space,” says Harth. Another advantage: “We have succeeded in ensuring that the FWC produces only a slight backpressure to the exhaust gas flow,” explains the BASF expert. This is an important aspect for the automotive manufacturers. A high backpressure increases the resistance the exhaust gas flow has to overcome before it reaches the exhaust system. If the backpressure is too high, this impairs the performance of the engine and lowers fuel efficiency. To keep the backpressure as low as possible, BASF experts have developed innovative production and coating technologies. These make it possible, for example, to coat the porous inner walls of the monolith specifically with the catalytically active material. The four-way conversion catalyst has a pronounced cleaning effect. “Our many years of experience with catalyst technologies have equipped us to create tailor-made catalytic structures,” adds Harth. This results in an enormously large surface with catalytic activity. By that, less precious metal is needed in the four-way conversion catalyst. The porous monolith wall also acts as a filter for the particulates, which are retained by the wall and combusted to carbon dioxide at ▶

5.8

billion euros will be the value of the global catalytic converter market for vehicles in 2015 (in 2012 it was 4.2 billion euros).

84

million vehicles (excluding trucks) were produced worldwide in 2013; in 2020, the figure is likely to be 113 million.

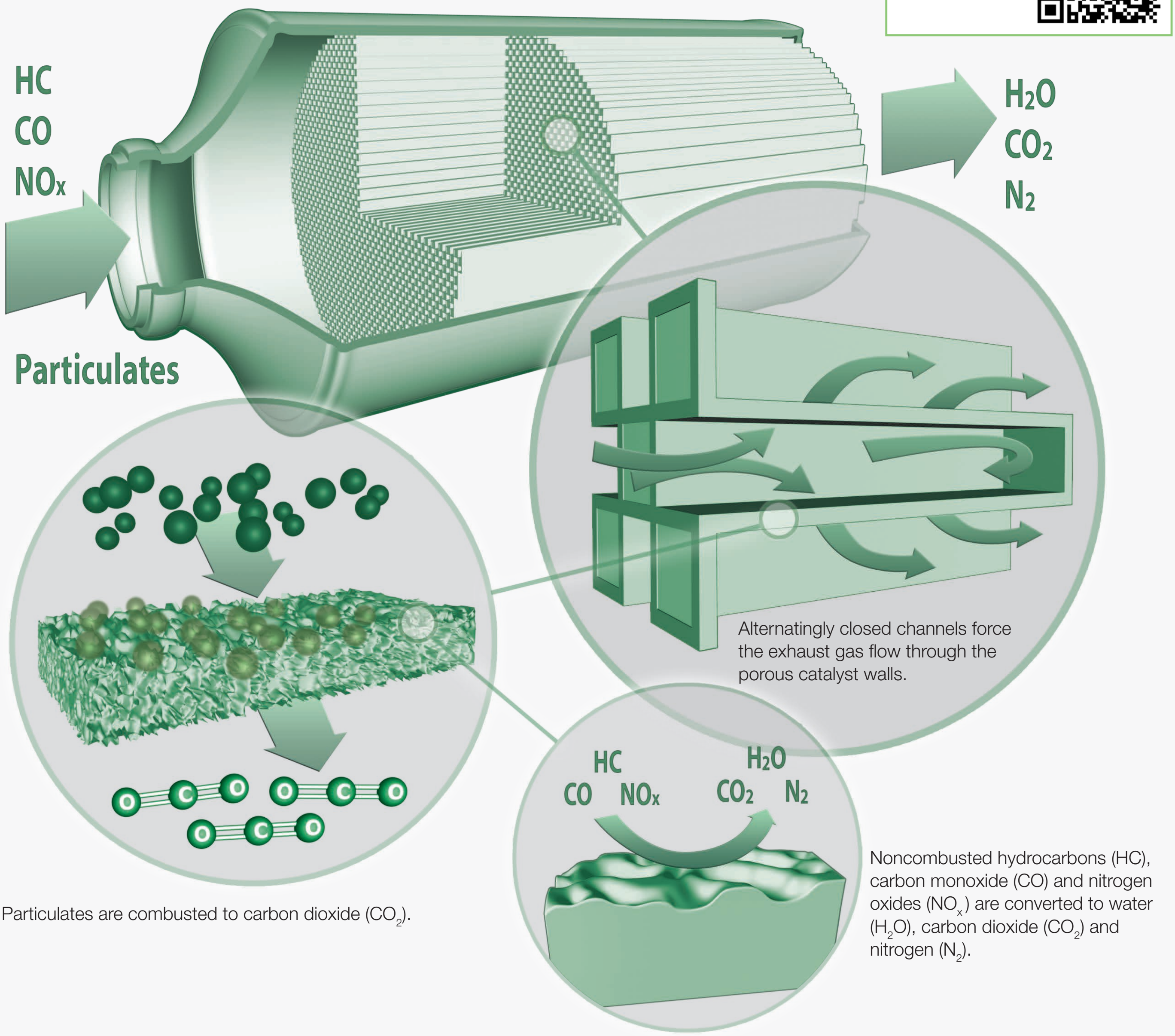
4.5

milligrams of particulates per kilometer are the allowed emission level for diesel or gasoline engine powered automobiles with direct injection (Euro 6c standard).

high temperatures and with the aid of the catalytic coating. The four-way catalytic converter from BASF therefore does more than a system with an uncoated filter: Because most of the particulates are combusted to CO_2, the pores of the catalyst do not easily clog – ensuring that the components remain functional. The long-term stability has already been demonstrated in a series of tests: even after more than 160,000 kilometers driven, the four-way conversion catalyst still cleans the exhaust gas effectively achieving stringent emission limits. The system was launched in April 2013 and is now in the development and test phase with numerous automotive manufacturers – always with a view to serial production. “The four-way conversion catalyst helps automotive manufacturers to comply with the strict emission regulations like the Euro 6 standard,” says Harth. “In a few years our system will be part of the established technology for exhaust emissions cleanup.”

Functions of the four-way conversion catalyst

A video animation on this topic can be found online:



Alternatingly closed channels force the exhaust gas flow through the porous catalyst walls.

Particulates are combusted to carbon dioxide (CO_2).

Noncombusted hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NO_x) are converted to water (H_2O), carbon dioxide (CO_2) and nitrogen (N_2).

„The biggest issue will be diesel NO_x and particle emission limits“

Dirk Bosteels, Executive Director of the Association for Emissions Control by Catalyst (AECC). The AECC is an international association of European companies making technologies for engine exhaust emissions control.

Dirk Bosteels from AECC (Association for Emissions Control by Catalyst) about the new Euro 6 emission standard and what it means for car drivers and the automotive industry.

The European Commission adopted a new policy package on clean air. And the new Euro 6 standard is in force now, there will be a second step in 2017. What are the consequences for car drivers and buyers?
The main effects of Euro 6 will be reduced NO_x emissions from diesel cars and better particle emission control from direct-injection gasoline engines. Users of Euro 6 cars will contribute to improved air quality. Buyers of new cars will not directly notice that, but they will emit fewer emissions when driving them. There is also a proposal to develop EU-harmonized voluntary ‘top runner’ benchmarks for ‘Super Ultra-Low Emission Vehicles’ – so-called SULEVs – this could be used by member states to tackle air pollution in hotspot areas. For car drivers in general, one result of the clean air package could be the extension of Low Emissions Zones.

What is different – compared with Euro 5?
The main difference is that for diesel cars the limit on NO_x emissions is reduced from 180 mg/km to 80 mg/km which is still 20 mg/km higher than the limit for gasoline cars. A second difference is that for direct injection gasoline cars a limit is introduced on the number of particles that can be emitted. From September 2017 this will be the same as the particle number limit for diesel cars, but until then manufacturers can ask to meet a limit that is 10 times higher.

What are the main challenges for the automotive industry?
The European Commission’s proposal to introduce a test and some form of limits for ‘Real Driving Emissions’ is perhaps the greatest challenge for the automotive industry. A new test cycle and emissions measurement procedure will be introduced in Euro 6 which should be more representative of current driving behavior and hence generate more realistic emissions values. For gasoline vehicles, the biggest issue will be how to meet the 2017 particle number emissions limits. Gasoline particulate filters[1] are one technology that is available.

Could you outline how the emission standards will develop in the next 10 or 15 years?
It seems that the new worldwide-harmonized procedures[2] and those for the measurement of ‘Real Driving Emissions’ will be a key influence on emissions requirements into the next decade. The introduction of the new worldwide-harmonized procedures is initially intended to ensure that measured CO_2 emissions and fuel consumption more accurately reflect real-world driving, but should also help to ensure that vehicles meet existing emissions limits.
The new worldwide-harmonized procedures will continue to develop in further stages. Phase 2, currently planned to run to 2018, will add further test procedures including low-temperature emissions, durability, real driving emissions and in-service conformity, which will eventually replace the current tests. Phase 3 is intended to then introduce globally harmonized emissions limits. The challenge at that stage may be to ensure that EU limits are not compromised by the desire to achieve wider harmonization.

[1] Editor’s note: BASF’s four-way conversion catalyst employs this technology
[2] Worldwide harmonized Light vehicles Test Procedures

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