Comprehensive Emission Aftertreatment Solutions

You create performance

We create clean air

HJS Emission Technology

www.hjs.com

Introduction

Global tightening of emission limits

Whether they're installed in heavy-duty trucks, buses, construction machinery, forklift trucks, bulldozers or district heating plants, diesel and gas engines often have a really tough job to perform. And thanks to their outstanding performance, reliability and efficiency, they excel in their job. But there's another characteristic that's becoming ever more important: if the quality of the air we breathe is to improve, 'vehicles and mobile machines have to be environment-friendly, too. To achieve this goal, legislators have laid down binding limit values for exhaust emissions, limits that were tightened in the last decades and will be further reduced over the coming years. In particular, the authorities are targeting an effective and long-term reduction in particulate matter (PM), nitrogen oxide emissions (NO_x) and CO_2, which means fuel consumption.
Compliance with limits enforced to date in the non-road segment has partly been achieved by optimising engine out raw emissions. In their efforts to achieve this, vehicle and engine developers are essentially confronted with the contradiction that a low-emission combustion process also has the unfortunate side-effect of increasing fuel consumption. By investing substantial technical expertise and effort, manufacturers tried to avoid the use of external exhaust-gas aftertreatment in the past. With the current requirements of emission legislation, this is no longer possible. Instead, intelligent systems have to combine the reduction of both the exhaust emissions and fuel consumption.

But the tightening of emission limits is intensifying the conflict between reducing particulate and nitrogen oxide emissions on the one hand and developing powertrains that are as economical as possible on the other.

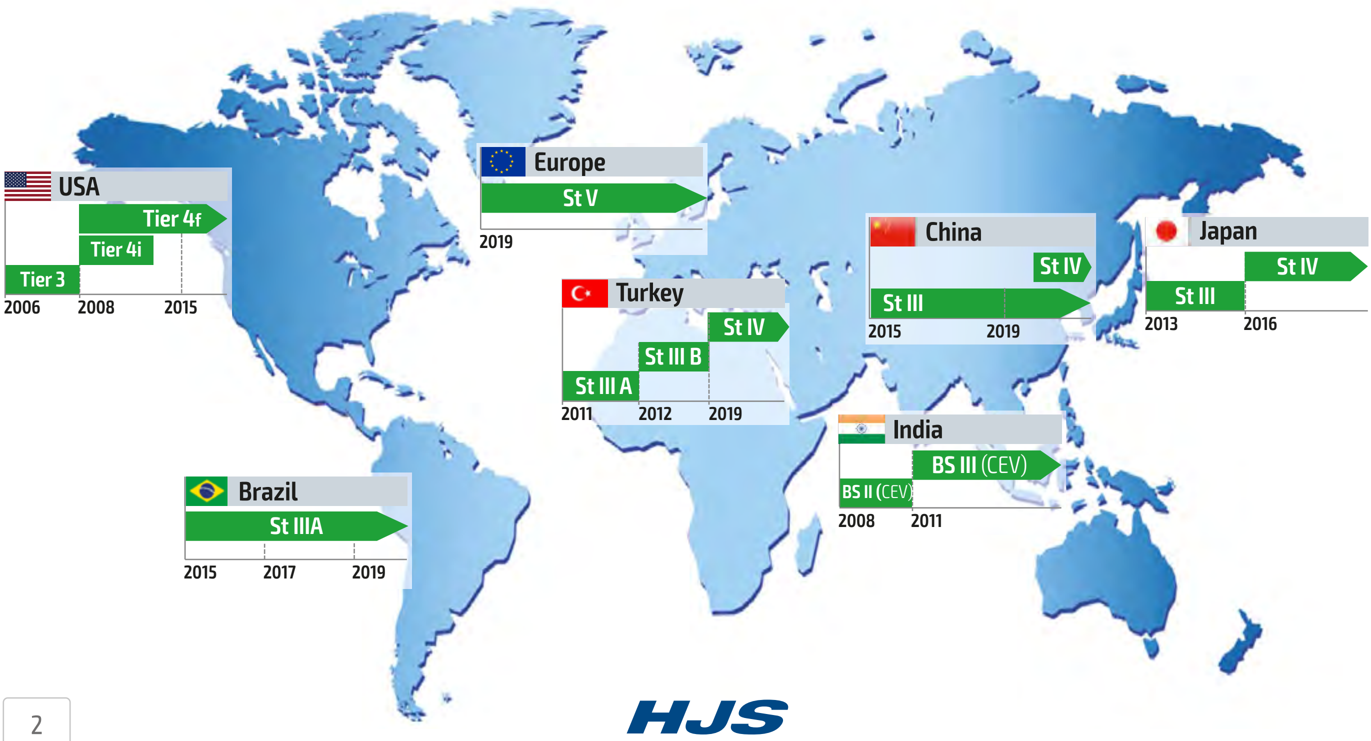
Legal requirements

The task of developing drive systems that are both as economical and as clean as possible will be an even greater challenge in future. 2014 saw even more stringent limits come into effect for heavy-duty commercial vehicles, such as trucks and buses, with the enactment of the Euro VI emission standard. In the USA, too, commercial vehicles are now, since the introduction of the EPA 2010 standard, already forbidden from emitting virtually any particulates and nitrogen oxides.

The situation is similar in the non-road sector, too, after 2011 Stage IIIB of the European Union's emission directive and the Tier 4 interim emission requirements in the USA were implemented. These were followed in 2014 by Stage IV and Tier 4 final, respectively, while the even more stringent Stage V standard has been phased in since January 2018 until January 2020 for different engine types.

In most cases, the ever more stringent legal requirements can only be met with the aid of additional exhaust-gas aftertreatment with effective, low-maintenance, heavy-duty and long-life emissions reduction systems. The conflict between fuel consumption and emission reduction can to a large extent be solved, and the latitude gained offers scope for outright optimisation of engines' fuel efficiency and consequently for the associated optimisation of the CO_2 emissions of commercial vehicles and mobile machinery.

Non-Road Emission Legislation Worldwide Trends



HJS

The aftertreatment challenge: to meet future emission standards

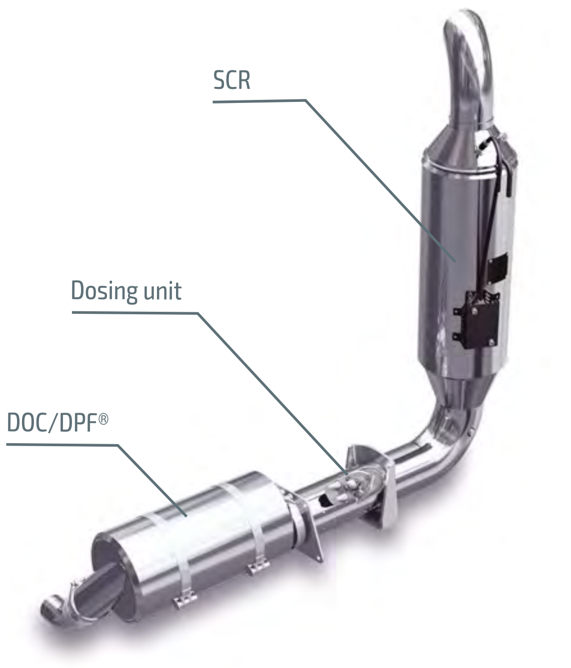
Now that we more fully understand the impact of pollution on the human body and the whole environment – particularly in cities – and in light of the amazing rates of growth in industrial output and mobility and the associated dramatic increase in energy consumption, the challenge of reducing overall emission pollution is immense.

The HJS solution: intelligently linked technologies

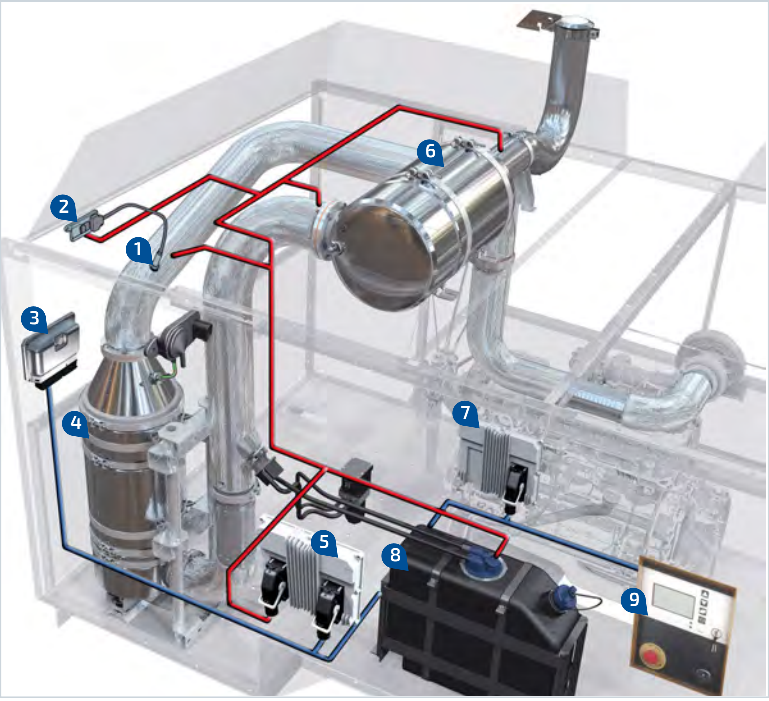
In order to meet the latest emission limits, HJS combines DOC, DPF®, SCR systems with other innovative technologies for use in various applications with different requirements. Here the exhaust gas temperature given by the application and how the end user operates it play a central role. The temperature necessary for soot oxidation and NO_x reduction is not reached by many applications. For this purpose, HJS implements both active and passive thermal management measures in order to provide the necessary temperature and guarantee full functional reliability at all times.

Another major challenge for engine manufacturers is to package the increasingly complex exhaust aftertreatment components in the limited installation space of mobile machines. To solve this, HJS has developed a modular system that can be adapted to a wide variety of engine sizes and space requirements.

Details about the latest HJS innovations, key technologies as well as our comprehensive development and engineering capabilities can be found on the following pages of this brochure.



HJS Stage V Aftertreatment Solution



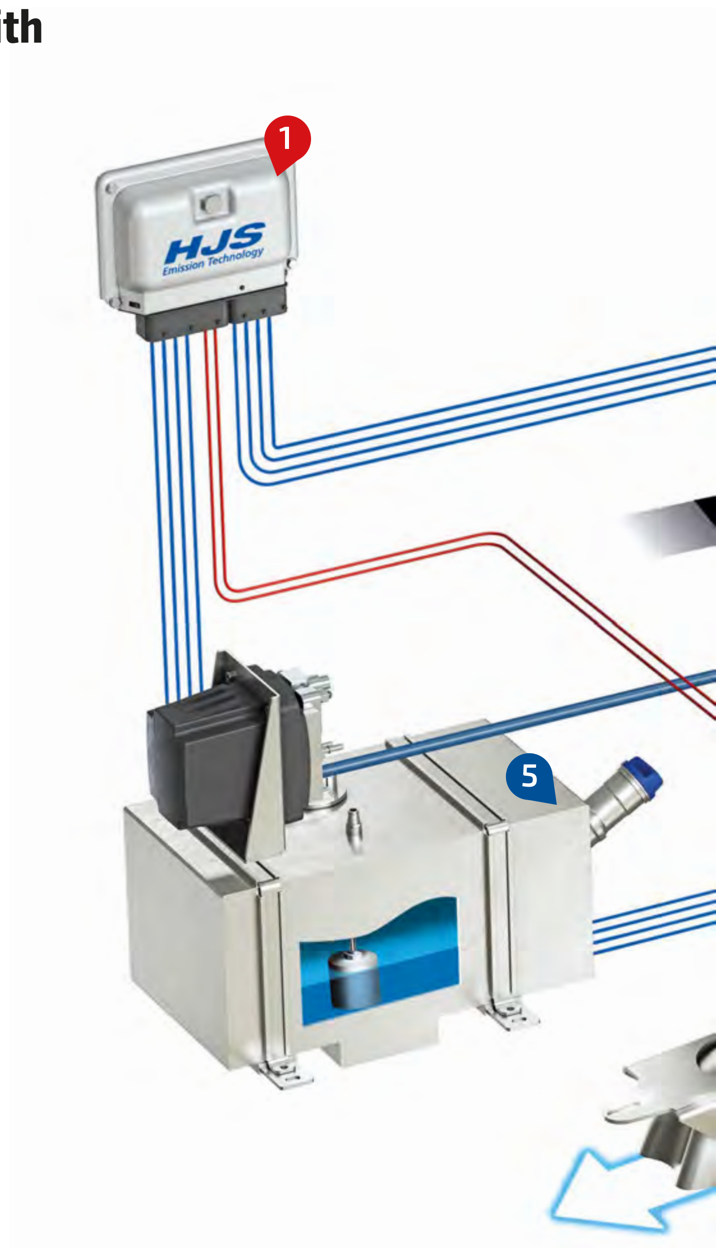
1. NOx Sensor
2. Differential Pressure Sensor
3. Electronic Control Unit
4. Oxidation Catalyst
5. Aftertreatment Control Unit
6. SCR Catalyst
7. Engine Control Unit
8. AdBlue® Tank
9. Display

Highly efficient aftertreatment system with **active thermal management** strategies

Many commercial vehicle applications, mobile machines and stationary applications have load profiles that, owing to the low exhaust-gas temperatures, necessitate the use of active thermal management in order to guarantee full functional reliability of the exhaust aftertreatment system. This is important for regeneration of the particulate filter and the DeNOx system, which need a certain temperature for proper functionality, especially in the light of Euro VI or stage V emission standards and their emission requirements over life time.

Established methods include burner-based systems, systems for hydrocarbon (HC, i.e. fuel) dosing downstream of the engine, downstream HC conversion in a catalytic converter or a combination of the latter two. However, the high requirements of today's and future emission standards can only be partially met by engine based thermal management. HJS adapts this concept as a self-sufficient system architecture to exhaust aftertreatment. The HJS exhaust gas system with active thermal management (SCRT®TM) uses two interlinked actuators to ensure that the systems can be operated even with low loads under all environmental conditions. This ensures best possible reduction performance without influencing the engine. Our latest technical approach also includes an electrically heated oxidation catalyst.

Maximum efficiency and robustness – HJS systems make sure that even the most stringent emission standards cause no risk of non-compliance or machine downtime!



Active Thermal-Management

① After Treatment Control Unit (ACU)

The autonomous electronic system controls and monitors all electronic components of the exhaust aftertreatment system. It activates the eDoc and eShutter according to requirements and ensures optimal provision of the AdBlue® dosing quantity and diagnostics for all system components. The system status and any malfunctions that might occur can be provided to the engine ECU for further actions.

② Sensor architecture

An extensive sensor architecture controls and monitors the entire system: pressure, temperature and nitrogen oxide (NO_x) sensors feed the control unit with all the parameters necessary for autonomous operation.

③ eCat (DOC)

In addition to the reduction of carbon monoxide (CO), hydrocarbons (HC) and carbon dioxide (CO_2), the electrically heated DOC is an important element of active thermal management. The electronic temperature control regulates the temperature to a stable level above the nessesary temperature level for reliable SCR-functionality. Important additional function: The continuous soot oxidation of the Diesel Particulate Filter (DPF®) is ensured by the targeted formation of nitrogen dioxide (NO_2).

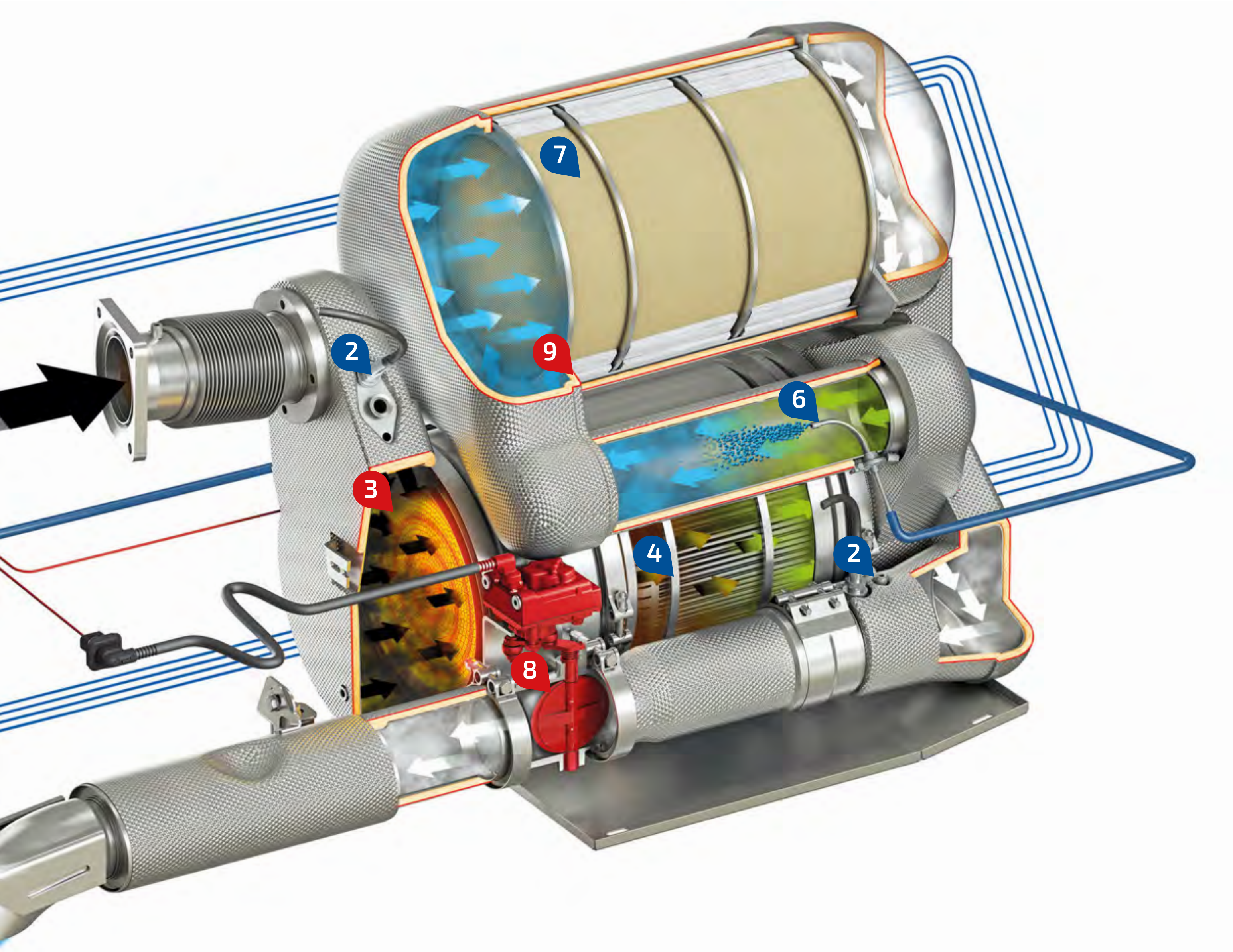
④ Diesel Particulate Filter (DPF®)

The gaseous components can flow through the DPF®. The soot particles on the other hand are retained and the NO_2 continuously oxidizes the soot - "soot-free" exhaust gas leaves the DPF®.

⑤ AdBlue

The urea solution for the SCR react ⑦ , is stored in a The reducing age ammonia required action, see ⑥ and

HJS



® tank

n agent required ion, see 6 and n separate tank. ent provides the d for the SCR re- d 7.

6 AdBlue® injection and mixing section

The reducing agent carried in the AdBlue® tank 5 is injected into the exhaust system according to the NO_x content determined by the system electronics.
In the following mixing section it converts to ammonia.

7 SCR catalytic converter

Ammonia is required to reduce nitrogen oxides (NO_x). The exhaust gas mixture of ammonia and nitrogen oxides produced in the mixing section 6 is converted on the SCR catalyst into the harmless substances nitrogen (N_2) and water (H_2O).

8 Exhaust gas throttle

The exhaust gas temperature is raised with the aid of the electrically controlled eShutter regulator. For this purpose, the exhaust back pressure is controlled to a calibratable value. Within fractions of a second, the eShutter position is adjusted as a function of the exhaust gas mass flow and exhaust gas temperature.
At high temperatures and high mass flows, the e-Shutter is completely opened.

9 Insulation

A highly efficient integral insulation supports the temperature management of catalysts and filters, thus increasing the efficiency of the system. It's an insulation system consisting of an insulation mat and a stainless-steel foil with embossed surface structure as protection of the outer surface. Through the use of embossing tools, the insulation adapts perfectly to the contour of the object to be insulated.

HJS Swirl Cap Mixer

According to the latest emission standards, pollutant emissions in the non-road segment must be reduced by up to 98 percent. For many engine manufacturers, it poses a great challenge to fit the required aftertreatment components in the installation space of mobile work machines.

The Swirl Cap Mixer by HJS is a highly flexible AdBlue®/DEF mixture preparation system that is integrated in the DOC or DPF® output module. In the mixing section, the urea water solution (AdBlue®/DEF) is metered, mixed with the exhaust gas and evaporated. The diameter and length of the Swirl Cap Mixer are scalable in the modular system. Thus, HJS enables engine manufacturers to integrate the exhaust aftertreatment system into a wide variety of installation spaces. Even with a short mixing section, the best possible evaporation is achieved - the distribution uniformity before the SCR catalyst is very high.

Highest possible NO_x conversions and the minimization of critical deposits are the result.

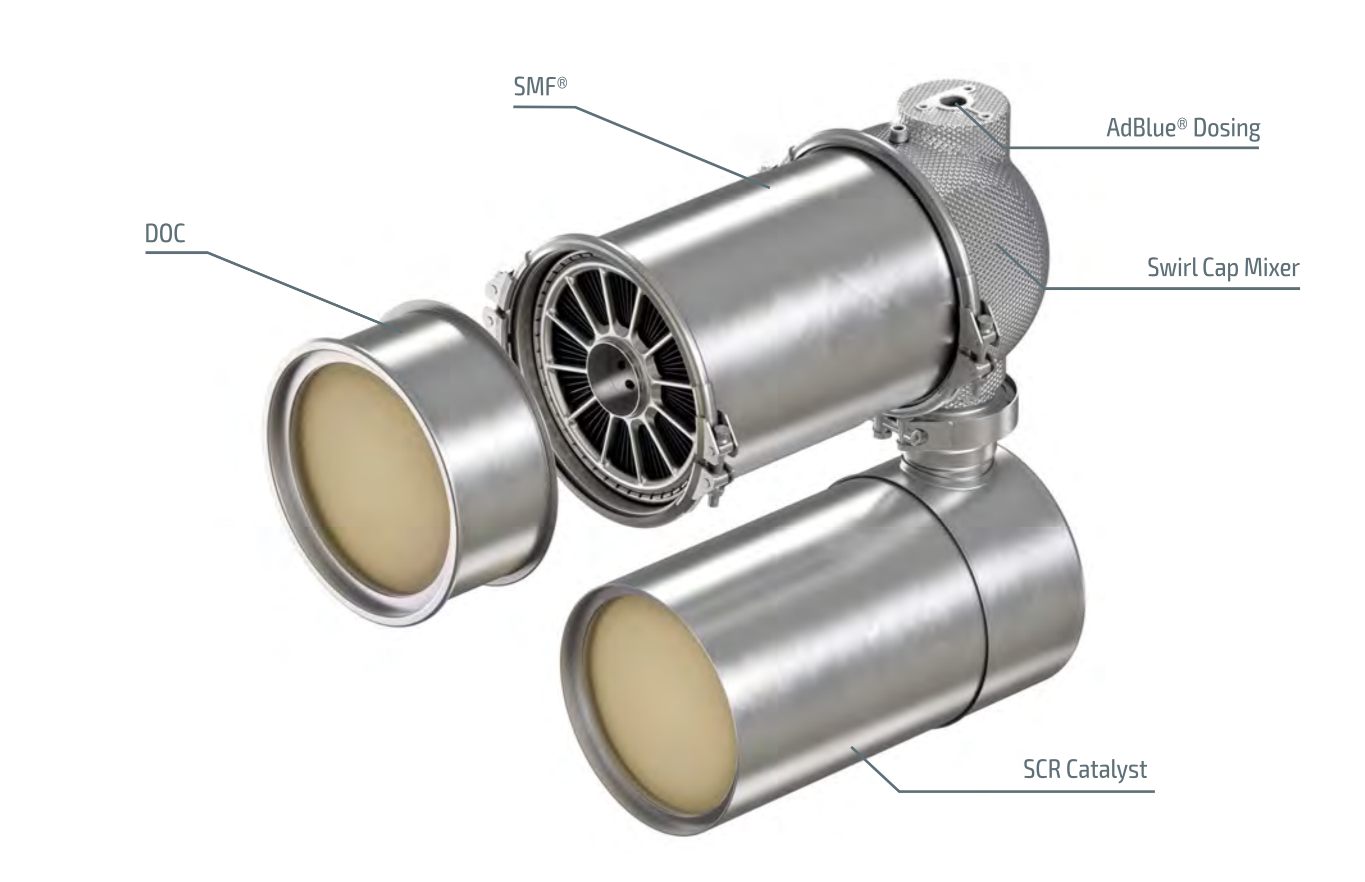
High robustness, low CO_2 and pollutant emissions - the new product from HJS dissolves this seemingly contradictory conflict of objectives.

Variable arrangement

The Swirl Cap Mixer is a suitable solution for all conceivable systems in virtually any power class, with variable arrangements right from the start. Whether horizontal or vertical, a flexible installation position close to the engine is possible. In the mixing section, a complete mixture preparation is achieved within the shortest possible route, which enables a very compact design.

HJS Swirl Cap Mixer

Compact SCRT® with Swirl Cap Mixer



Modular Kit for DPF® and SCR systems

HJS has already used modular systems for particulate filters for many years now. Over the course of the last years, HJS has taken advantage of its experience with modular approaches and has developed a modular DPF®-SCR kit which can be scaled to a wide range of engine sizes and power levels.

The modular system is characterised by its very compact design, light weight and high efficiency. The concept allows direct connection to the engine's turbo charger outlet and therefore full utilisation of the exhaust gas temperature. The HJS competence for compact mixing section designs, e.g. the HJS Swirl Cap Mixer, is the key to realizing a high degree of modularity. Minimal exhaust gas temperature losses and the intelligent and carefully optimised designs prevent crystal deposition of urea. Furthermore, the entire system is made of stainless steel, which completely protects it from corrosion.

For the flow distribution upstream the DOC, high requirements were set in order to optimally make use of the given surface of the catalyst and the associated precious metal loading. The arrangement between the DPF® and SCR system can be varied by different piping and component orientations. Compact, close coupled or in-line systems are possible. The connection of the systems to the engine or vehicle can be customized. Decoupling is in many cases not required. Design can be offered including the complete set of sensors, mechatronic components and Aftertreatment Control Unit (ACU) for standalone systems.

DOC -DPF®	SCR	System variant example
		
		
		

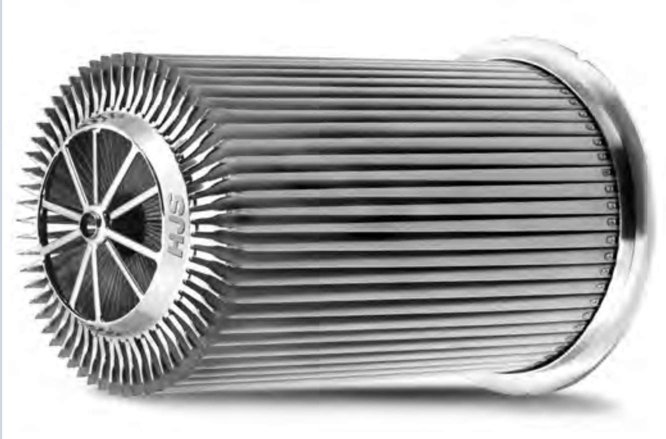
SMF® – Sintered Metal Filter

Due to the combustion, soot and other particulate matters are formed and pass through the exhaust gas. Those particulates will be trapped in the particulate filter, where only gaseous components can pass through the porous structure of the filter. Soot, as one part of the particulates, will be oxidised during the regeneration. The incombustible components on the other hand will remain in the filter as ash. This ash consists of various metallic compounds originating from lubricant additives, trace elements in the fuel, engine wear and corrosion products. As the ash load increases, the exhaust back pressure increases, too.

Ash build up in the DPF® directly affects fuel consumption:

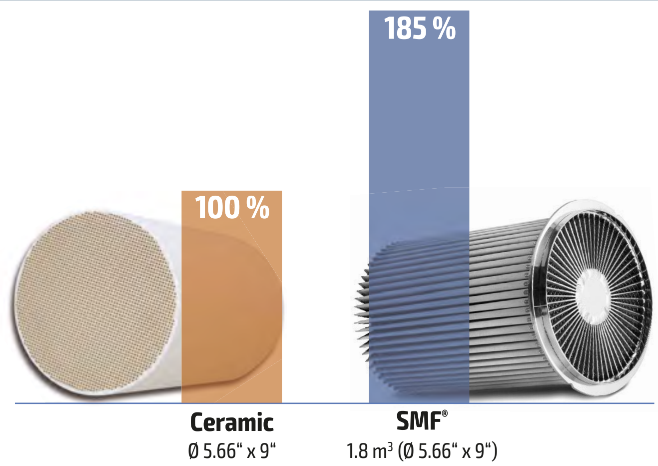
- Increased exhaust flow restriction and backpressure
- decreased filter regeneration intervals (higher regeneration frequency) through a reduction in filter soot storage capacity

HJS SMF® Sintered Metal Filter



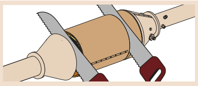
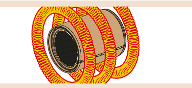
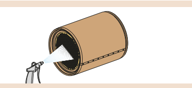
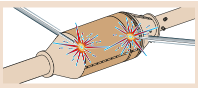
Furthermore, the ash also reduces the regeneration efficiency in catalysed systems, requiring an increased reliance on active regeneration measures or higher temperature operation for successful passive soot oxidation. In order to avoid high back pressure and increased fuel consumption, the selection of a filter type, which can handle ash loading more efficiently, is a key factor.
Due to the unique design approach, the HJS SMF® has significant advantages in comparison to honeycomb filters with respect to ash loading capacity and cleanability, which results in a significantly lower total cost of ownership (TCO) over its life time. The theoretical ash loading capacity is approx. 1.8 times higher, which leads to 25 - 30 % more mileage between the cleaning cycles. A second key factor is the cleanability. The design of the SMF® allows access to the stored ash and thereby the possibility to remove the ash with pressurized air or water by more than 99 %. Due to the unlimited cleaning cycles of SMF® in combination with long cleaning intervals, the cleaning of the filter can be done locally and doesn't have to be sent to a special cleaning company.

Comparison ash storage capacity

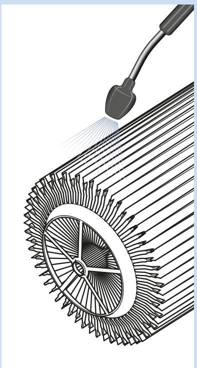


The higher ash storage capacity results in higher possible mileages between cleaning cycles within a range of 25 - 30 %.

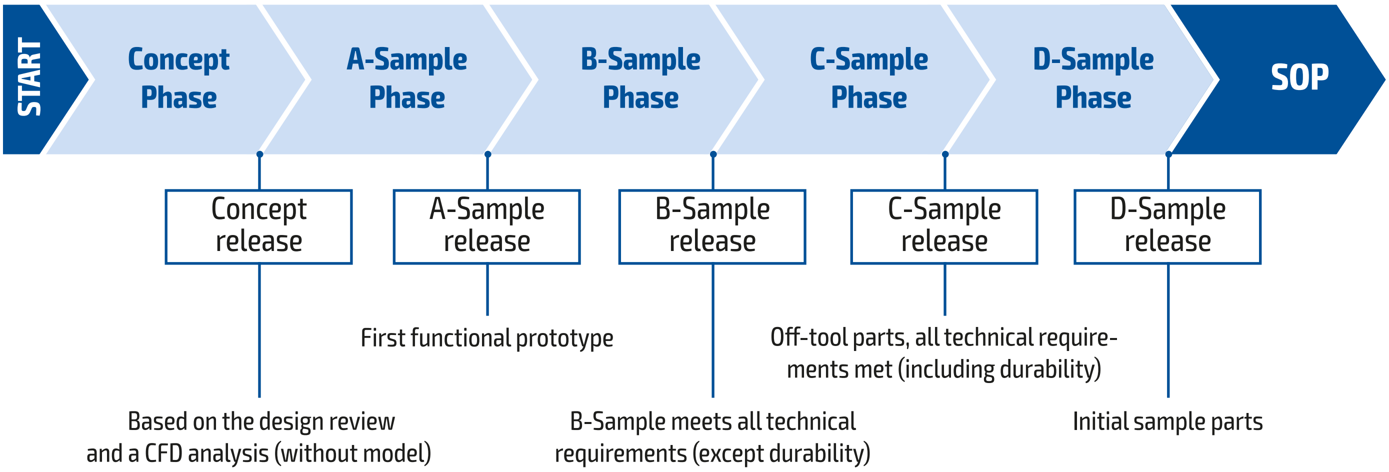
Cleaning Ceramic Filter

	**Shipping**
	**Cutting**
	**Heating**
	**Cleaning success: approx. 90 %**
	**Welding**
	**Shipping**
	**Specialised filter cleaner; Duration: approx. 3 - 4 days**

Cleaning SMF® (Sintered Metal Filter)

	**Dismounting**
	**Cleaning success: 100 %**
	**Mounting**
	**Possible in local workshop; Duration: approx. 1 hour**

HJS Product Development Process

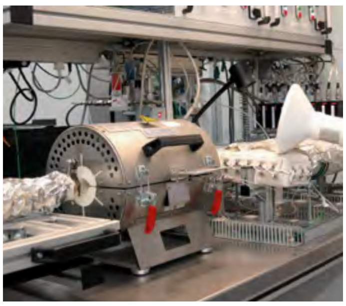


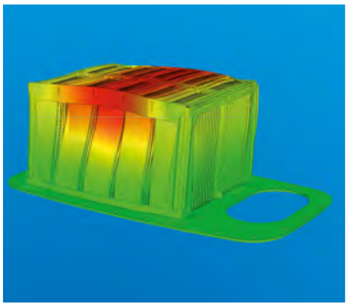
R&D is at the centrepiece of HJS. HJS is committed to innovation, quality and reliability in everything it does or sells. To guarantee product performance on one hand and durability on the other, HJS makes use of state-of-the-art engineering methods, tools and facilities. Besides experience and technical competence, transparent processes towards customers and legal authorities are essential to assure sustainable compliance with increasing emission challenges worldwide.

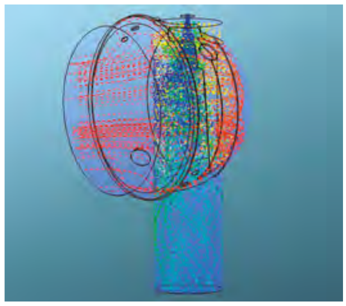
Development tools and methods

HJS uses the same CAD systems as its clients, plus a selection of simulation and calculation programs. The flow mechanics (backpressure and uniformity), strength and acoustic properties are optimised very early on in the project. Proven methods and tools as Computational Fluid Dynamics (CFD) and the Finite Element Method (FEM) are used to obtain a high level of product maturity at a very early stage to avoid additional and excessive development work.
This enables us to speed up development and cut costs, particularly when it comes to highly complex tasks such as optimising 2-phase flows using vaporised media like AdBlue®/DEF or diesel. If, for example, the exhaust temperature is to be raised to 650°C by injecting diesel fuel downstream of the engine and using a diesel oxidation catalyst, high levels of uniformity in the distribution both of the exhaust gases and the hydrocarbons must be ensured, because the DOC could otherwise potentially suffer undesirably high thermal loading in the event of unfavourable local combinations of exhaust mass flow and fuel mass flow.


Hot gas test bench


Synthetic gas laboratory


FEM


CFD

Development tools such as FMEA (Failure Modes and Effects Analysis) and the Design Verification Plan and Report (DVP&R, for short) are constituent parts of all development phases.

Verification of the development results is conducted on a wide range of different test benches. The main verification tests are:

- Flow mechanics test on flow bench
- Fatigue strength test on hot-shake test bench
- Function tests of the entire system, conducted on the engine test bench

Final testing to verify the overall system installed in the vehicle is conducted in cooperation with the client. This approach enables us to deliver development results within even the tightest time schedules and target costs.

Development expertise: Controls Units and Software

Development in accordance with V process

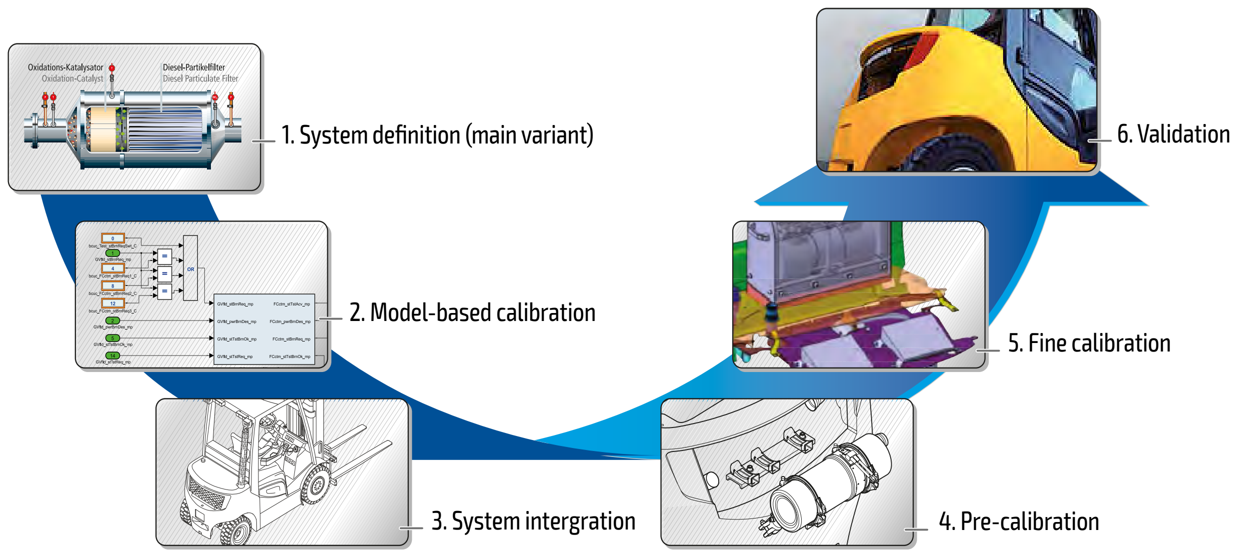
As a recognised standard that is widely used by vehicle and engine manufacturers alike, the V process is employed by HJS in the development of its control unit platforms. We have systematically built up and expanded our expertise in this field over the past years, to such an extent that the first model-based software versions are already tested and optimised very early on in the project in field trials, with the aid of rapid control prototyping. The result is a new generation of control units that sets the benchmark for platform control units in the exhaust-gas aftertreatment segment.

HJS ACU (Aftertreatment Control Unit)

Modular SW concept

Thanks to the distinct modularity of the software, it is possible to assemble a perfectly scaled system to satisfy any customer's demand. The high-level software consists of a large number of modules, each module having been developed specifically to the respective requirements. These are implemented in the overall architecture/API by means of sub-APIs (Signal Conditioning, SCR, DPF®, etc.)

HJS Engineering and Development Approach



Development expertise: Applications

Owing to the huge number of different vehicles, machine and engine variants in the on-road and non-road sectors and the resulting number of system variants, a way must be found to minimise the amount of time, resources and costs spent on each individual application. This is why the development path known as "Standalone Diesel Emissions Aftertreatment" is being followed, which, through the use of functionally combinable modules, provides the necessary degree of flexibility to achieve the best application.

Step 1: System definition (main variant)
Formulation of the requirement profile based on the raw emissions and of the emissions target. Based in turn on this requirement profile, the right system configuration is determined by carrying out simulations.

Step 2: Model-based calibration
The system configuration defined is assigned further detail and parameters in the simulation environment. The exhaust-gas aftertreatment system mapped as a model in this way is then linked with the models of the control unit modules and an emission simulation.

A computer-aided pre-calibration of the control units is then conducted on this basis.

Step 3: System intergration
In this step, the system is actually integrated and put into operation.

Step 4: Pre-calibration
Based on selected operating points, initial validation of the system developed and of the pre-calibration is carried out and the approach defined ensured in the process.

Step 5: Fine calibration
In the fine calibration step, the focus is put not only on the emission characteristics but also on optimising variables such as efficiency, cost effectiveness and monitoring strategies (OBD).

Step 6: Validation
The final step consists of checking if all aspects have been satisfied. In addition to the points already mentioned, this includes also long-term durability testing under even the harshest environmental conditions.

Development expertise: Acoustics, Piping and Decoupling

Limits governing pollutant emissions such as particulates and nitrogen oxides are not the only regulations applicable to commercial vehicles and mobile machinery. These applications are also subject to regulations stipulating noise emissions. One example in the case of mobile machinery is the EU Directive 2005/88/EC „Noise Emission in the Environment by Equipment for Use Outdoors". This directive requires that a machine equipped with an exhaust gas aftertreatment system has to be fitted with an additional silencer if necessary.

HJS has more than 40 years of extensive know-how in the field of acoustic components and silencers for industrial applications – particulary in relation to the six crucial requirements for acoustic components: exhaust backpressure, surface-borne noise, orifice noise, service life, weight and cost.
An acoustic component is manufactured specifically for a respective application in line with these requirements.

There is a choice of three options:

- a reflexion (or baffle) silencer
- an absorption silencer
- a combination of these two

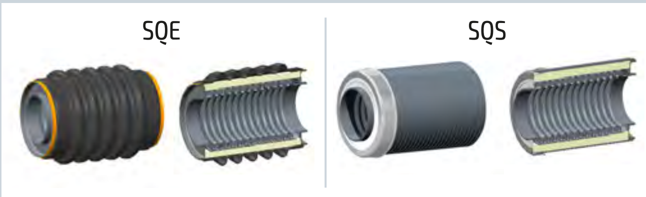
HJS has developed a modular range of components that alowes gives the flexibility to design a solution customised specifically to each customer's needs. The range of folded standard silencers is available in diameters of up to 300 mm and lengths of 600 mm. Silencers with an oval shape of 340 x 530 mm and a length of up to 1250 mm can also be supplied. There are also welded versions for engine power outputs exceeding 600 kW. Another specialty of HJS is the design, production and homologation of silencers with integrated aspirators. Calculation tools for linear and non-linear optimisation methods are being used. Spectral examinations using low-reflection engine test benches and roller dynamometers are just as feasible as mobile measurements for evaluation of customers' requirements.

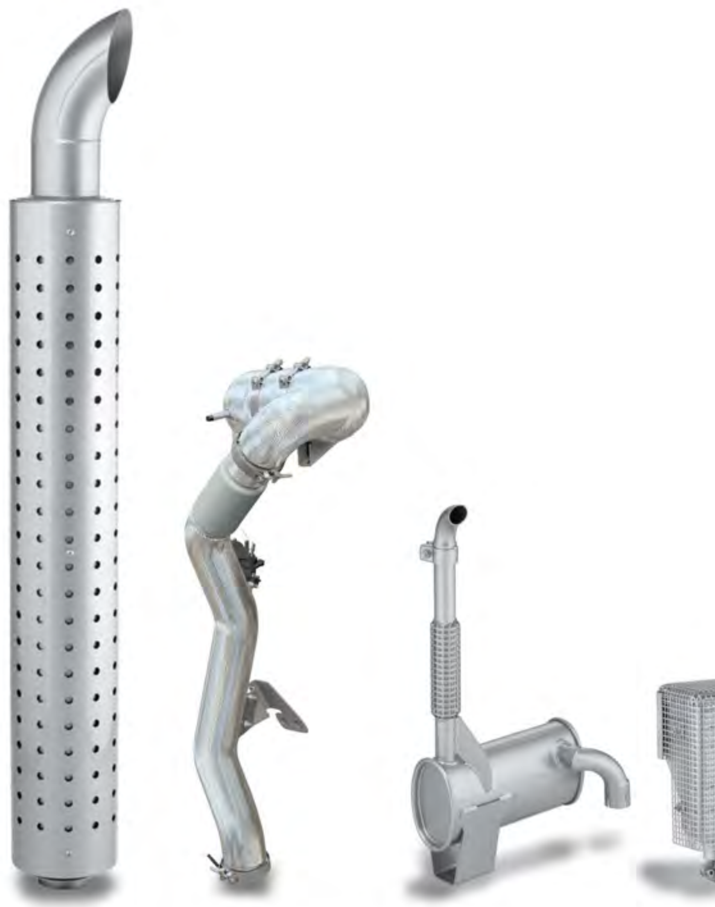
All in all, HJS offers the entire range of acoustic components required for non-road machinery:

1. Standard exhaust systems (front pipes, vibration isolating elements, silencers and tailpipes) for machines for which future legislation does not require exhaust aftertreatment systems
2. Add-on components for HJS exhaust aftertreatment systems, with optimised acoustic components for compliance with the limits
3. Integration of AdBlue®/DEF mixing sections, particulate filters and catalytic converters, which are certified and supplied together with engines

A newcomer to the HJS portfolio is the insulated decoupling element (flex hose), which is available in two different material choices for the insulation: stainless steel hose or a elastomeric hose. An insulation mat is used for both versions.
Extensive tests with an inlet temperature of 600°C under realistic conditions have shown that the insulation causes a 30°C higher exhaust gas temperature at the pipe outlet (568°C) compared to the same pipe with a non-insulated decoupling element (538°C) - while keeping the crucial flexibility of this component. The external surface temperature of the insulated flex hose confirms this result: it's significantly lower than without the HJS insulation (190°C vs. 444°C).

HJS TIGHT - Thermal Insulated Gas Hose Technology





Made in Germany

Into a clean future with HJS Emission Technology

- Technologies for diesel, gasoline and CNG/LPG engines
- Systems for NO_x- and particulate reduction
- Products for OEM and retrofit

HJS Emission Technology
GmbH & Co. KG
Dieselweg 12
D-58706 Menden/Sauerland
Telefon +49 2373 987-0
Fax +49 2373 987-199
E-Mail hjs@hjs.com
Internet www.hjs.com

HJS Emission Technology