

KOLBENSCHMIDT PIERBURG GROUP



EXHAUST FLAPS –
for Emission Reduction and
Improve Comfort

Areas of use for exhaust flaps

Exhaust flaps are growing in importance due to emission reduction requirements and the need to improve comfort factors. Notable examples are operation in conjunction with:

- DeNO_x-catalysts,
- low-pressure exhaust gas recirculation,
- acoustic optimization of the exhaust system (for example, cylinder shut-off),
- performance improvement through resonance effects,
- noise reduction,
- use in the heating system and
- compound turbocharging.

Load profile for exhaust flaps

The following loads are of particular significance in the design of an exhaust flap, especially of its bearing components. The dynamic gas exchange pulsation of the exhaust system causes vibrations and canting effects. Contact with splashed water, variations in outdoor temperature and fast load

changes (partial load, full load) can induce significant thermal stresses. With regard to surface wear and proper sealing on the outside, the bearing must last for over 1 million working cycles.

The design, construction and testing technology for an exhaust flap are based on the following implementation specification (excerpt):

- operating temperatures: -40°C outdoor temperature to 950°C gas temperature
- external seal: max. 1 l/min (at 20°C, $\Delta p = 300$ mbar)
- internal sealing: max. 30 kg/h (at 20°C, $\Delta p = 300$ mbar)
- installation location: close to the engine, underbody area, not splash-protected
- durability: 1,000,000 working cycles
- max. permitted wear (axial, radial) of the metallic bearing shaft is less than $< 100 \mu\text{m}$



Example of a DeNO_x catalytic converter

The stricter legal requirements with regard to pollutant reduction in particular are intensifying the search for a solution for series production use of exhaust flaps close to the engine. In the DeNO_x catalytic converter (Fig. 1), the inlet temperature is regulated via the exhaust flap, allowing the catalytic converter to perform with optimum efficiency. The catalytic converter is also protected against overheating, so that the aging process is slowed considerably. If the temperature increases, more exhaust is conducted through the cooling system; if the temperature drops, the flap is closed and the catalytic converter triggered directly.

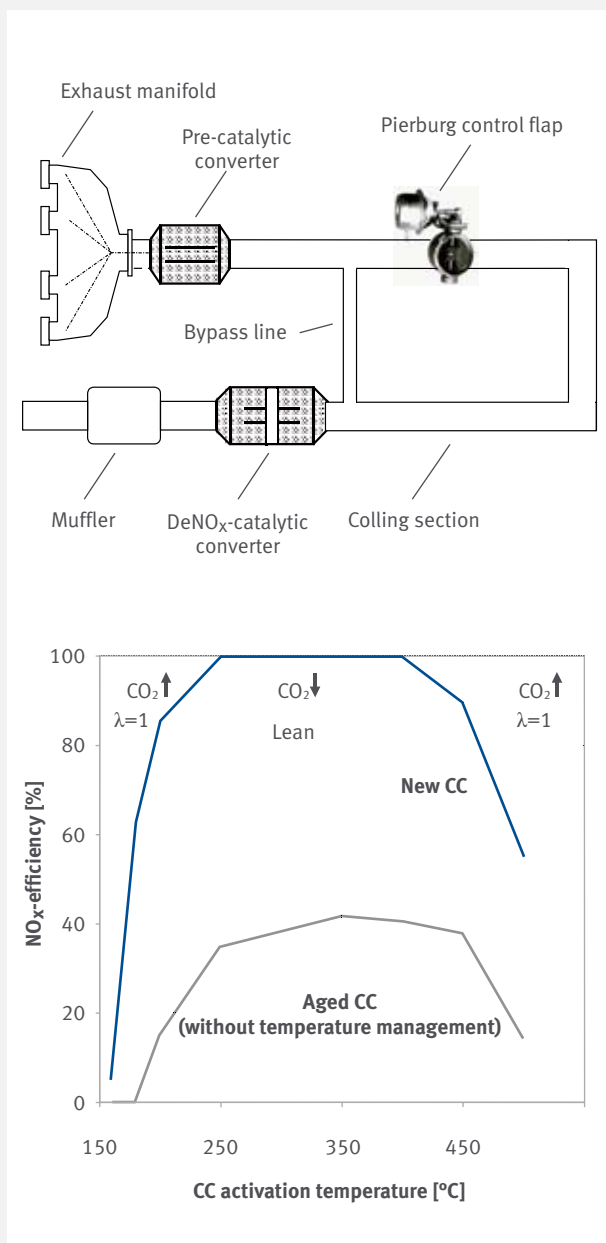


Fig. 1: Temperature management in the DeNO_x catalytic converter

Example of cylinder shut-off (displacement on demand)

In high-volume gasoline engines such as 6- or 8-cylinder engines, fuel consumption can be reduced by up to 15 % using the cylinder shut-off method. In this process, half of the cylinders are shut off in certain load ranges of the engine. This means that no combustion takes place in these cylinders.

However, this technology influences the acoustics of the engine and the entire exhaust system. For instance, an 8-cylinder engine sounds like a 4-cylinder engine during the cylinder shut-off phase. This effect reduces primarily the subjective impression of the vehicle passengers; after all, the engine should sound like a “real” engine in all operating states.

Exhaust flaps are used in order to maintain the engine acoustics of normal operation during cylinder shut-off. To achieve optimum efficiency, they are placed in the exhaust system at a location defined by the exhaust system manufacturer. The flap closes as required and reduces the flow cross-section of the exhaust system. This creates and utilizes effects that make the engine sound just like it does in normal operation with all cylinders active. Pierburg has experience in this field of application and carries such flaps in its product range (see Fig. 2). The exhaust flap can be driven pneumatically (partial vacuum) or electrically via an actuator. The use of an exhaust flap is what facilitates the use of cylinder shut-off technology and thus this potential fuel reduction.

The passengers inside the vehicle won't notice whether the engine is operating normally or in cylinder shut-off mode. The engine sounds the same in all operating states; there is no disruptive acoustic change.

Example of noise reduction

The owners of upmarket vehicles in particular have high expectations of their cars, from the design to engine performance to operating noise. With regard to the exhaust system, this means finding solutions that meet the customers' expectations of comfort by combining the lowest possible noise levels with the desire for a sporty-sounding engine.

The exhaust flaps by Pierburg meet increasing demands for upmarket acoustic comfort and fulfill all our customers' wishes for a wide range of sounds from powerful yet whisper-quiet vehicles to elegant sportscar engines. The same or similar physical effects are utilized to achieve noise reduction as well as a sonorous hum.

One of these effects is created by superpositioning of sound waves. These are superpositioned so that they cancel each other, resulting in noise reduction. The sound waves can also be superpositioned in such a way that they amplify each other, thus increasing the volume. In both cases, reduction or enlargement of the space in which the sound is moving facilitates this. For this purpose, the positions of the flaps in the exhaust systems are coordinated with our partners, i.e. various exhaust system manufacturers. The opening and closing of the exhaust flaps thus lengthen or shorten the paths for the sound waves.

Example of low-pressure exhaust gas recirculation

Compliance with increasingly strict laws on pollutant emissions (EU5) calls for correspondingly more complex processes. Diesel engines in particular require effective measures with which to comply with the standards. In the future, this will include low-pressure exhaust gas recirculation systems. These systems require very high rates of exhaust gas return to be efficient, which among other things can be achieved by restricting exhaust system gas flow using a controllable exhaust flap.

During combustion in the combustion chamber of the engine, high combustion temperatures create various harmful substances, including nitrogen oxides. These can be reduced by lowering the combustion temperature during formation of these substances. Targeted recirculation of the exhaust gas in the combustion chamber of the engines facilitates the desired reduction.

For this purpose, Pierburg offers electrically actuated intelligent exhaust valves (see Figs. 5 and 6). Combinations of actuators and valves as well as separately installable units for very high temperatures are available.

Example of two-stage turbo-charging

Sequential turbo-charging for diesel engines is becoming increasingly widespread. In turbo-charged engines, the energy of the exhaust gas is used to drive a compressor. The combustion air is supplied to the engine in pre-compressed form. The engine sucks in the same volume of air, but due to the higher pressure a greater air mass enters the combustion chamber. This means that more fuel can be consumed, so that the performance of the engine increases while the speed and volumetric displacement remain the same.

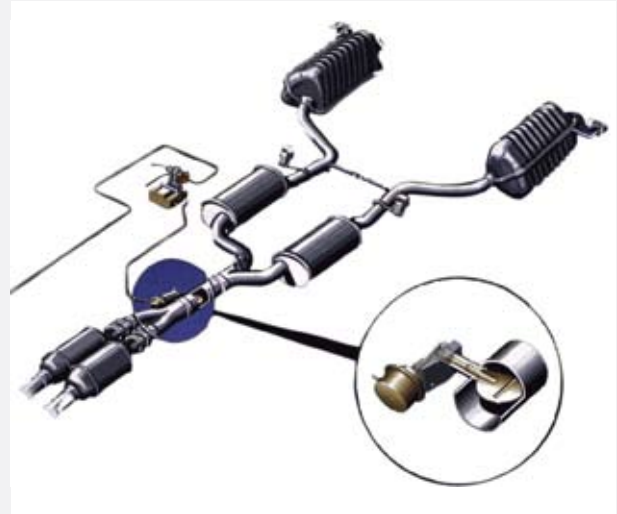


Fig. 2: Example of a pneumatically operated exhaust flap for cylinder shut-off in the exhaust system



Fig. 3 and 4: Examples of pneumatically actuated exhaust flaps



Fig. 5: Example of an electrically actuated exhaust flap for use in low-pressure exhaust gas recirculation



Fig. 6 and 7: Example of an electrically actuated exhaust flap for use in two-stage sequential turbo-charging

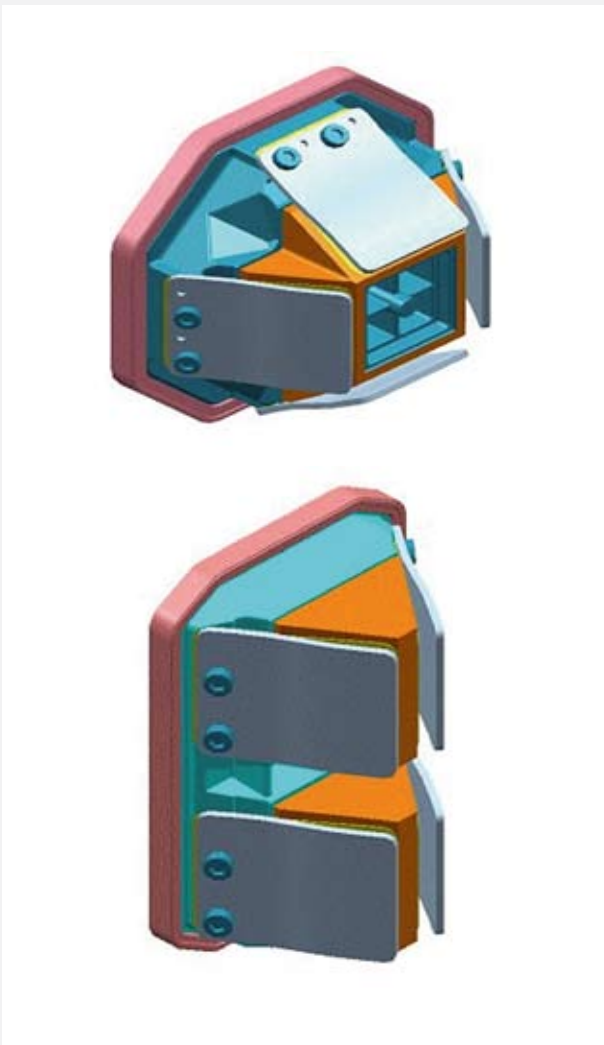


Fig. 8 and 9: Models of reed valves for EGR for commercial vehicles. Both types vary in design only, the performance is the same.

Up to now, the charging resulted in higher power output only at higher engine speeds. At lower speeds, the increase in engine performance was barely noticeable. The goal of sequential charging is to eliminate this disadvantage.

This is achieved by using two turbo-chargers: a small one, which operates with the gas throughputs at lower to medium speeds, and a larger one designed to handle the gas throughput at medium to higher speeds. This requires a targeted supply of exhaust gas to the corresponding turbo-chargers, so that each one can be operated efficiently in its respective range. Suitable valves are used to operate the supply lines. This means that at lower speeds the exhaust gas flows through the small turbo-charger first. If the speed and thus the exhaust gas flow increases, the supply line to the small turbo-charger is closed and the exhaust gas is supplied to the large turbo-charger.

Pierburg offers a high-temperature control valve (see Figs. 6 and 7), which facilitates the continuous distribution of the exhaust gas to the large or small turbo-charger. This results in almost instantaneous accelerator response even at low speeds.

EGR for commercial vehicles Constantly in operation – check valves from Pierburg

Worldwide, check valves from Pierburg make a dynamic contribution to meeting present and future emission limits on trucks and buses. The stainless steel leaf springs are actuated up to 3,750 times per minute*, meeting the toughest demands at temperatures of up to 180°C and maximum pressure increases of 1,300 bar/s, in an environment of corrosive exhaust condensation.

This product, proven many times over, is based on a simple functional principle and longstanding expertise, the benefits of which are highly appreciated by our customers in Europe and the United States!

*: refers to an inline 6-cylinder engine at 2500 RPM

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