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Future-proof Crankcase Ventilation Systems

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Alternative fuels offer high decarbonization potential, while increasing power densities and higher oil temperatures improve engine efficiency. However, these trends have massive implications for crankcase ventilation systems, which are exposed to higher aerosol concentrations as well as toxic and potentially explosive gases. UT99 is therefore upgrading its crankcase ventilation systems in terms of performance and flexibility.

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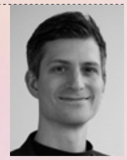

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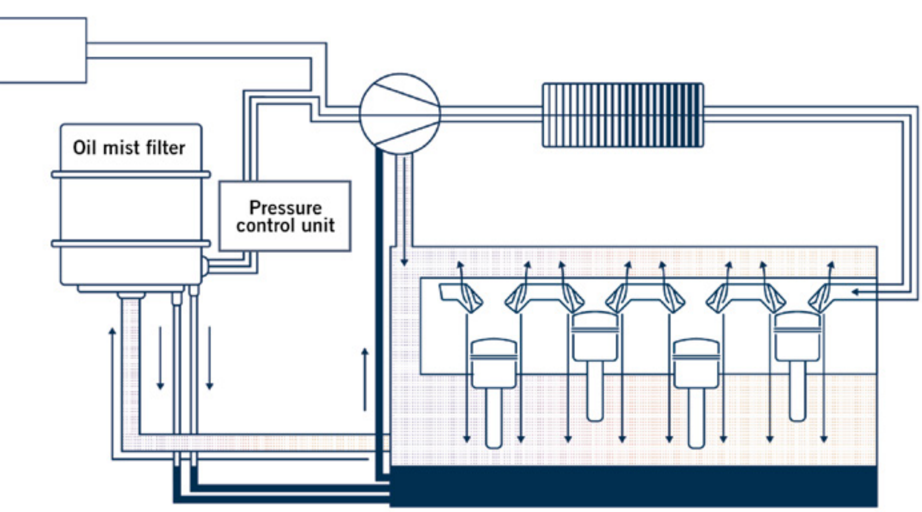
Crankcase ventilation systems separate oil from the aerosol flow and return it to the oil pan. Thus, they make a crucial contribution in reducing oil consumption and particulate matter (PM) emissions. Besides, such systems also regulate the pressure in the crankcase to avoid leakage and reduce wear of seals. **FIGURE 1** shows a schematic of a closed crankcase ventilation (CCV) system consisting of two main components, namely an oil mist filter and a pressure control unit.

In recent years, improvements in aerosol filtration efficiency have made CCV systems the preferable option over open systems [1]. This is especially true for engines running on gaseous fuels, as it not only allows further reducing harmful emissions but also increasing energy efficiency by recirculating unburned fuel into the combustion chamber. Such systems require very high separation efficiencies > 99.5 wt% to avoid fouling of the intake air and ensure reliable turbocharger operation.

It is known from the literature [2] that general trends in engine development include increasing oil temperature, increasing Brake Mean Effective Pressure (BMEP), and increasing power density. These trends have a major influence on crankcase aerosol properties. Ultimately, aerosol concentration increases and the shape of the particle size distribution changes toward sizes near the most penetrating particle size (MPPS) [3, 4]. The MPPS is typically around 0.2 to 0.5 µm and represents the size that is least effectively separated by an aerosol filter. To counteract this development, crankcase ventilation systems are constantly being optimized. In addition, such systems are playing an increasingly important role in achieving compliance with EU, EPA and IMO limits for PM emissions.

FIGURE 1 Closed crankcase ventilation schematics (© UT99)



ALTERNATIVE FUELS

The type of fuel has a direct influence on the composition of the aerosol in the crankcase. While it is not possible to draw a general picture of particle concentration and size for different fuels, as these are highly dependent on engine design and oil properties, changes in gas phase composition are predictable. The main sources of crankcase gases are the gases that flow past the piston rings and the turbocharger bearing. These gases,

FIGURE 2 Engine running on 100 % hydrogen, equipped with an insulated oil mist separator from UT99 (© 2G Energy)

also known as blow-by, contain portions of the actual fuel, fresh air, oil vapor, and combustion products.

Engines running on methanol and ammonia generate crankcase aerosols with high toxicity. This makes CCV systems essential to prevent these gases from being released into the environment without catalytic treatment. They should ensure reliable and precise control of crankcase pressure by maintaining the pressure typically at -1 to -5 mbar below the atmospheric level. In some cases, this may require an auxiliary blower, especially if the crankcase gases are to be returned to the exhaust rather than the intake air, where exhaust backpressure must be overcome. This ventilation setup avoids corrosion in the intake air, which can be particularly relevant with ammonia.

Engines running on hydrogen generate crankcase gases that may contain hydrogen concentrations exceeding the lower explosion limit of 4 vol%. Therefore, a ventilation system with a blower may be required to purge the crankcase with filtered air. Additionally, ATEX (Atmosphères Explosibles)-compliant ventilation systems further reduce the risk of explosion. Another challenge arises from the combustion of hydrogen, which forms large quantities of water that must be kept in the gas phase by controlling the temperature in the ventilation system, for example, through insulation. Otherwise, the oil quality would deteriorate, and emulsions could form that eventually clog the filter. **FIGURE 2** shows an engine running on 100 % hydrogen that is equipped with an insulated UT99 filter.

CRANKCASE VENTILATION SYSTEMS

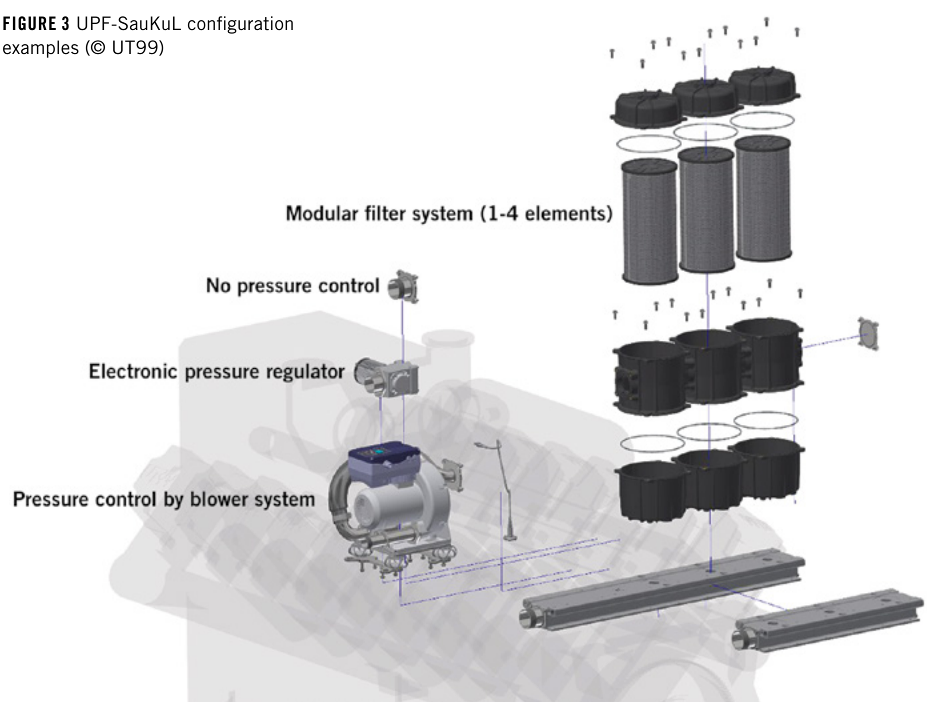
In view of the new challenges posed by alternative fuels, the UT99 filter systems are based on compatible materials such as glass fiber, stainless steel, aluminum and PA66-GF50. Reliable operation is ensured by a high-performance filter media characterized by a steady-state pressure drop < 20 mbar and a separation efficiency > 99.5 %, corresponding to a residual aerosol concentration typically < 5 mg/m³. These characteristics can be adjusted according to the requirements of the specific application by changing the media composition to allow pressure drops < 10 mbar and/or residual aerosol concentrations < 1 mg/m³.

The development of the filter series UPF-SauKuL (Under Pressure Filter-Saubere Kurbelgehäuse Lösung) focused on modularity to ensure maximum flexibility in system design, **FIGURE 3**. This means that the filters can be arrayed in multiple layouts to ensure a compact footprint, optimum performance, and low cost on engine series with different cylinder/power configurations. Besides, the system can be further customized with an auxiliary blower or an Electronic Pressure Regulator (EPR) to control crankcase pressure and enable a purge air system.

Additionally, pressure sensors and a UT99 blow-by flow meter can be installed. These options generate valuable data that enable smart functions such as monitoring, diagnostics, and predictive maintenance. Information is obtained not only on the status of the crankcase ventilation system, but also on engine wear, which can be determined by blow-by flow rate analysis.

In summary, the advantages of the UT99 crankcase ventilation systems are as follows:

FIGURE 3 UPF-SauKuL configuration examples (© UT99)



– ready for alternative fuels in a wide range of applications between 250 to 46.000 kW
– high filtration performance with separation efficiency > 99.5 %,
– pressure drop < 20 mbar, and up to 32.000 h of maintenance free operation
– accurate crankcase pressure regulation within ±1 mbar of setpoint by blower system or EPR
– new benefits through digital status reports of the crankcase ventilation system and blow-by flow rate data.

AEROSOL FILTRATION

Detailed knowledge about the properties of the crankcase aerosol is the foundation of filter development. It is known that the blow-by flow contains a very broad oil droplet size distribution ranging from tens of nanometers to hundreds of microns [5]. Typical total crankcase aerosol concentration is around 1000 mg/m³. However, in practice, concentrations ranging from 300 to more than 2000 mg/m³ have been observed. This underlines the need to obtain aerosol data from the actual application to adjust filter properties for the best fit.

UT99 filters are developed on custom test rigs that mimic these conditions to obtain results that are relevant to the actual application. **FIGURE 4** gives an idea of the performance of one standard UT99 UPF-SauKuL filter operating at 80 °C, 500 l/min, and a raw aerosol concentration of 900 mg/m³. The results show that the aerosol concentration downstream of the filter is always < 1 mg/m³ and the pressure drop < 14 mbar, even when reaching steady-state after about 50 h of aerosol exposure. This state is reached when no additional oil accumulates in the filter. In practice, the steady-state is a pseudo-stable-state because ash, soot and viscous organic components reduce the permeability of the filter. These processes must be considered to determine the time frame between filter changes.

PRESSURE REGULATION AND BLOW-BY FLOW MONITORING

UT99 has a long history of providing Open Crankcase Ventilation (OCV) blower systems designed to regulate crankcase pressure. This is accomplished through a robust control unit that uses the crankcase pressure signal to adjust the blower speed. Blower systems used in CCV employ a similar design that takes into account the intake air vacuum provided by the turbocharger.

For applications that do not require a blower, UT99 recently introduced the EPR. The EPR is a maintenance-free mechatronic throttle that was specifically developed to adjust crankcase pressure within ±1 mbar of the setpoint. The device is placed in the crankcase ventilation path between the oil mist separator and the intake air. While the external dimensions always remain the same, the geometry of the throttle body can be customized by selecting one of five versions between DN14 and DN50. This ensures optimum pressure control accuracy for a wide range of flow and pressure conditions [5]. The throttle angle is controlled by the integrated data processing unit. This unit uses the actual crankcase pressure signal obtained directly from a sensor or from the engine control unit. Advanced features are supported, including EPR status reporting via CAN bus communication and blow-by flow monitoring through an optional flow meter connected directly to the EPR, **FIGURE 5**.

The UT99 blow-by flow meter is also available in a stand-alone version with two impeller geometries and a measuring range of 150 to 2500 l/min. Currently, this device is being tested in field trials. **FIGURE 6** shows results of these tests, which focus on the correlation of flow meter speed with actual blow-by flow rate determined with a reference device. Apparently, the measurement accuracy is stable, even after several thousands of hours of operation.

CONCLUSIONS

Crankcase ventilation systems are increasingly coming into focus due to the challenges associated with alternative fuels, high separation targets, and regulatory requirements. UT99 addresses these challenges with crankcase ventilation solutions that are compatible, highly efficient (> 99.5 %), and customizable. There is a wide product portfolio, including crankcase pressure control by

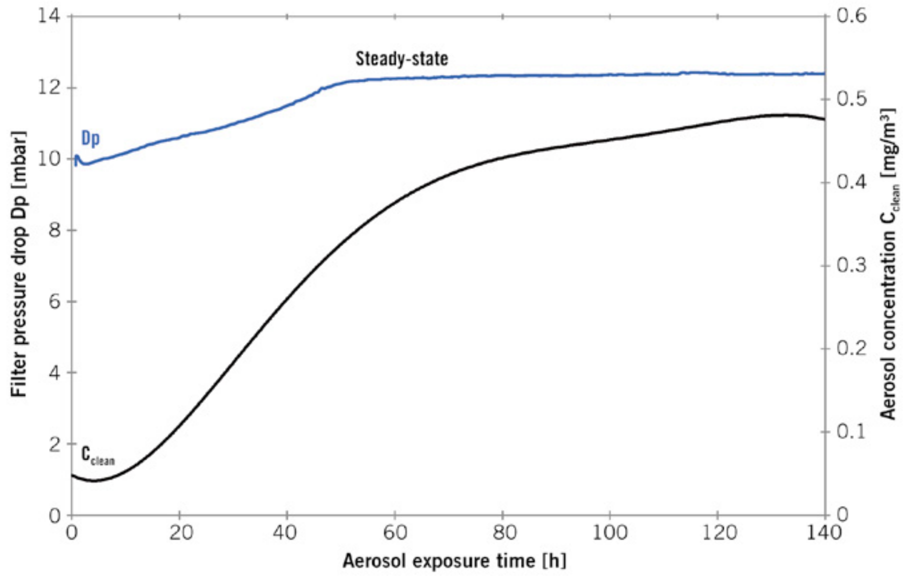


FIGURE 4 Filter pressure drop and clean gas aerosol concentration (© UT99)

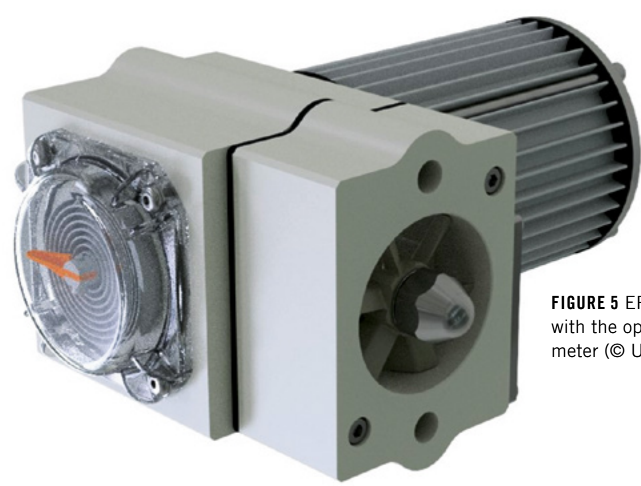


FIGURE 5 EPR equipped with the optional blow-by meter (© UT99)

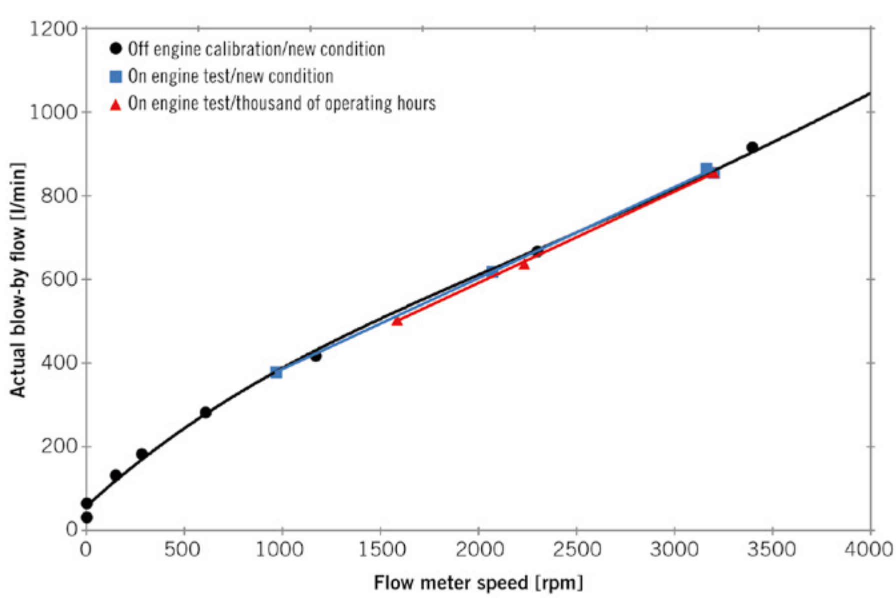


FIGURE 6 Actual blow-by flow rate plotted against the flow meter frequency (© UT99)

a blower system or an EPR that also provides digital data on the status of the ventilation system. Valuable data is also provided by the UT99 blow-by flow meter, which can be used not only for predictive replacement of filter elements but also for analysis of engine wear. With this customizable ventilation system and further developments in close cooperation with OEMs, solutions are found that meet the requirements of the respective application.

REFERENCES

[1] Oppliger, R.; Stieler, C.: Advantages of Closed Crankcase Ventilation for Large Engines In: MTZworldwide 11/2020, pp. 66-71

[2] Figer, G.; Schmidleitner, K.; Schönbacher, M; et al.: 300 bar Peak Firing pressure for a New Generation of Diesel and Gas engines. In: MTZworldwide 6/2019, pp. 70-75

[3] Scheiber, K.; Nowak, N.; Lorenz, M.; et al.: Comparison of four diesel engines with regard to blow-by aerosol properties as a basis for reduction strategies based on engine design and operation. In: Automotive and Engine Technology 6/2021, pp. 79-90

[4] Nowak, N.; Sinn, T.; Scheiber, K.; et al.: On aerosol formation by condensation of oil vapor in the crankcase of combustion engines, In: Aerosol Science and Technology 2/2022, pp. 101-116

[5] Nowak, N.; Sirtl, C.; Rymann, O.; et al.: Aerosol Separation and Pressure Control of a Smart Crankcase Ventilation System. In: Proceedings of the ASME 2022 ICE Forward Conference, Indianapolis, 2022

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