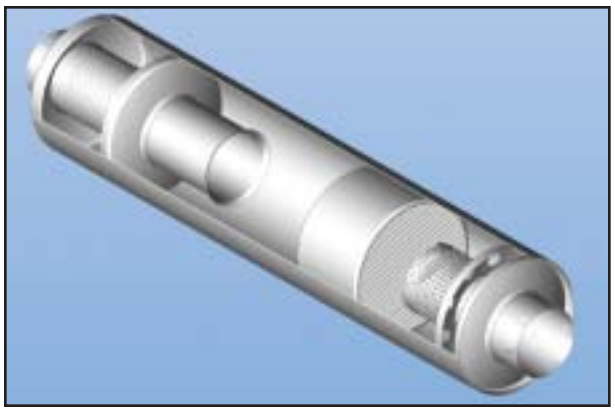
Retrofit System Designed To Reduce Emissions In Trucks, Buses

While up until now, much of the regulatory activity surrounding diesel engine emissions has concentrated on new engines, there is little doubt that as time goes on, the spotlight will be turned

Information for this article was taken from the technical paper "A Sure Way to Cut Emissions from In-Use Diesel Vehicles — A Retrofit System from Donaldson," by Jason Hou and Julian Imes of Donaldson Co. The paper is available by calling 866-484-8329.



Donaldson has developed a retrofit system designed to reduce emissions from heavy-duty trucks and buses. The system combines the diesel oxidation catalyst shown here with the company's new Spiracle closed crankcase filtration system.

New Closed Crankcase Filtration System

Donaldson has developed a new closed crankcase filtration engineered to eliminate engine crankcase emissions and improve the operating efficiency of diesel engines in medium- and heavy-duty trucks and buses, light vehicles such as pick-up trucks, medium- and heavy-duty off-road equipment and light industrial equipment. The Donaldson Spiracle filtration system uses a two-stage coalescing process that is designed to efficiently reduce entrained oil mist while maintaining crankcase pressures.

Mounted between the engine breather port and air intake system, the Spiracle system helps reduce unpleasant in-cab fumes and keeps engine enclosures free from oil film deposits by efficiently filtering and routing blow-by gases back to the air intake. The filtration system also helps lower replacement oil costs by returning coalesced oil to the engine sump, the company said.

The Spiracle system effectively eliminates blow-by particulate matter emissions to meet new on- and off-road environmental regulations, while reducing operating costs, protecting against engine power loss, and with extended service life.

Donaldson's new Spiracle closed crankcase filtration system is designed to eliminate engine crankcase emissions and improve the operating efficiency of diesel engines in medium- and heavy-duty trucks and buses, light vehicles and medium- and heavy-duty off-road equipment.

The heart of the Spiracle filtration system is a high-efficiency coalescing filter produced by a proprietary process of arranging filter media fibers into a first-stage impaction filter. Partially cleaned gases and coalesced oil flow along a coalescing tube on the inside of the cartridge, allowing oil removal at the bottom of the housing. The blow-by gases are then forced through the second stage diffusion filter/coalescing media from the inside of the cartridge where additional coalescing is performed using a proprietary oliophobic filter media that is designed to repel oil. Separated oil is returned to the engine sump, while soot particles remain trapped on the media surface.

Constructed to withstand engine temperatures, vibration and chemical exposure, the Spiracle retrofit filtration system includes two sizes to handle blow-by flows ranging from 110 to 690 lpm. A replaceable two-stage filter offers the highest level of filtration available (90-plus percent efficiency). Filter service life is 500-plus hours or 15,000 to 25,000 miles, depending on the incoming oil mass flow rate.

Donaldson said it is an OEM supplier of Spiracle filtration systems to Scania for use in its new DC16 diesel engines. The DC16 is a 16 L turbocharged V-8 diesel engine with air-to-air charge cooling and individual cylinder heads for higher ratings and easy servicing. ★

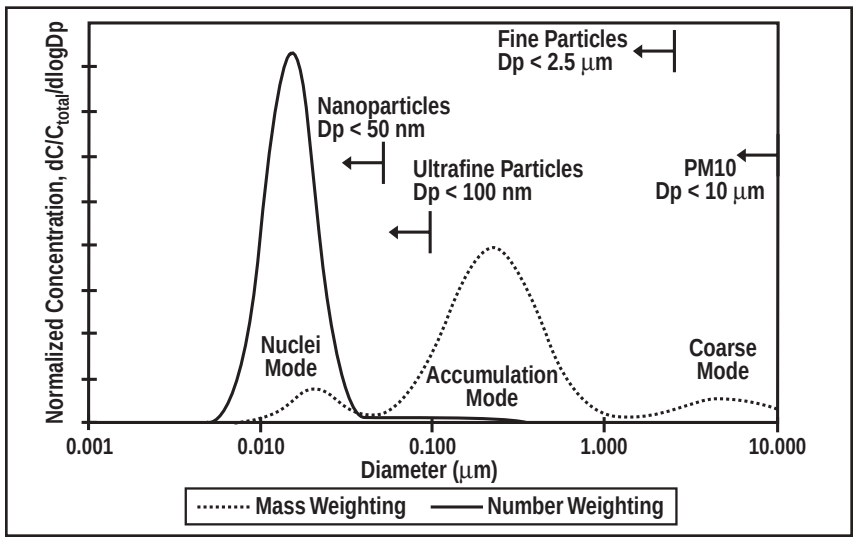


Fig. 2. Typical mass and number-weighted size distributions of diesel PM.

toward engines operating in the real world. Emissions standards scheduled for implementation in 2007 mandate a more than 90 percent reduction in oxides of nitrogen (NO_x) and particulate matter (PM). Yet many diesel engines currently in operation emit far more than even today's standards allow.

For example, there are about 1.2 million diesel engines operating in California alone. These vehicles currently emit 26,000 tons of diesel PM per year, according to estimates. To address this problem, the U.S. EPA has implemented several programs, such as the Urban Bus Retrofit Program and more recently, a Voluntary Diesel Retrofit Program. These and similar programs have a simple goal, to reduce emissions from in-use diesel vehicles.

In California, where air quality is a critical issue, the California Air Resources Board (CARB) is mandating a program through which diesel fleet owners will be required to either install retrofit systems that have been approved by CARB, replace engines with newer emissions-certified models or use alternative fuels.

In an effort to assist engine operators in meeting the California mandates, Donaldson Co., a global filtration solutions provider headquartered in Minneapolis, Minn., has developed a retrofit system that combines a diesel oxidation catalytic (DOC) muffler with the company's new Spiracle closed crankcase filtration system. This combination system was recently verified by CARB for Level I PM reduction (greater than 25 percent).

The DOC technology used in the Donaldson retrofit system has been in service since the mid-1990s, with more than 500,000 units in operation. Donaldson said it has several advantages over diesel particulate filters, including cost, better durability and reduced maintenance, owing to the fact that the unit's flow-through design reduces the potential for plugging because of soot accumulation. In addition, depending on the catalyst formulation chosen, the fuel sulfur content can be as high as 500 ppm. Diesel particulate matter typically is made up primarily of carbon (soot) unburned hydrocarbons (SOF) and sulfate, which is formed by combustion of the sulfur contained in the fuel. The remainder is comprised of trace amounts of ash, etc. According to Donaldson, the DOC muffler assembly is primarily effective in removing the SOF component of diesel PM.

Figure 2 shows typical mass and number-weighted size distributions of diesel exhaust particles. Most of the particle mass exists in the so-called Accumulation Mode in the 0.1 to 1.0 μm diameter range. However, on a number basis, an overwhelmingly large number of particles are concentrated in the Nuclei Mode, which is in the 0.005 to 0.05 μm (or 5 to 50 nm) diameter range, also known as nanoparticles.

Nanoparticles in diesel exhaust typically account for up to 20 percent of the particle mass but more than 90 percent of the particle number. There have been various reports on the adverse health effects caused by nanoparticles.

Research suggests that while the Accumulation Mode is where the larger carbonaceous agglomerates reside, the Nuclei Mode usually consists of volatile organic and sulfuric compounds. A diesel particulate filter (DPF) is most effective at removing the larger Accumulation Mode particles, while DOC technology mainly removes the organic compounds (unburned hydrocarbons) or SOF and nanoparticles that form later in the exhaust stage. Therefore, while removing approximately 25 percent of PM mass, a DOC has the potential to remove more than 90 percent of the total particles by number.

Figure 3 shows the effectiveness of an oxidation catalyst in reducing nanoparticles. The catalyst used here is essentially a small DOC catalyst called a catalytic stripper. Like a DOC, a catalytic stripper removes primarily the volatile SOF in the exhaust. In the figure, the horizontal coordinate represents particle diameter in μm, while the vertical coordinate represents the particle number density over a size increment on a log-scale. As shown, a stripper operated at 564°F (295°C) and 1000 ms residence time reduces the particle number density at 10 μm size by almost 99 percent. It should be noted that a DOC system can increase sulfate, another form of diesel PM. At higher exhaust temperatures, the catalyst can promote the formation of sulfate. One remedy to this is to use Vanadium as a suppressant. Donaldson said very careful and elaborate engineering was done to develop a catalyst formulation where optimal precious-metal-to-Vanadium ratio is achieved. As a result, the Donaldson retrofit system produces little to no sulfate increase.

The Donaldson system also provides significant reduction in emissions of hydrocarbons (HC) and carbon monoxide (CO). According to the compa-

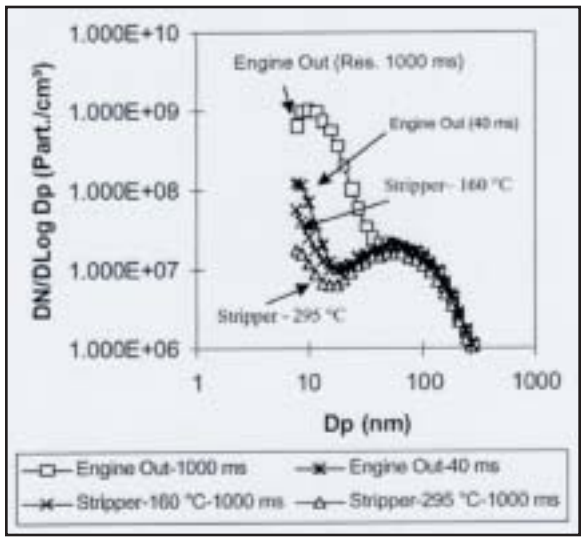
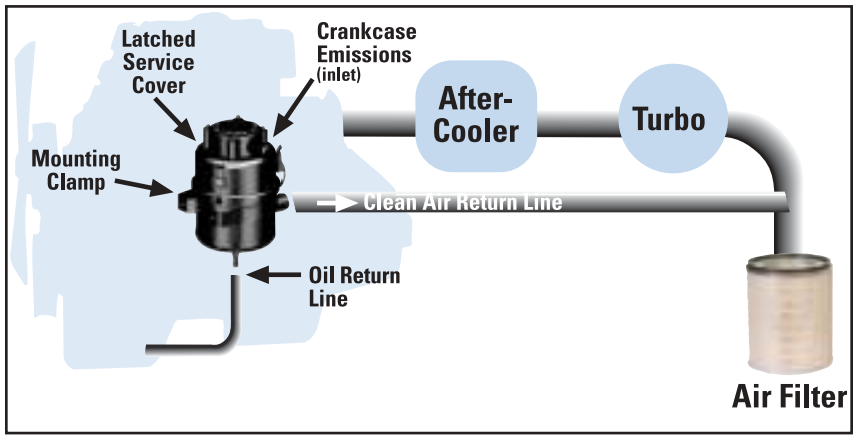


Fig. 3. Particle size distributions from a turbocharged diesel engine with and without a catalyst.



A schematic of the Spiracle system integrated into a diesel engine.

ny, in testing using the U.S. Federal Test Procedure (FTP) heavy-duty transient cycle, the system provides a 20 to 50 percent reduction in PM; a 50 to 85 percent reduction in HC; and a 25 to 50 percent drop in CO.

Another source of emissions that has received greater attention in the last few years are those from the diesel engine's crankcase breather. The emitted blow-by aerosol consists mainly of oil droplets, with some carbon and traces of wear debris and dust. Particle sizes range from 0.03 to 6 µm, which means that the aerosol is highly respirable. Blow-by emissions can be as much as 25 percent of the total emissions (tailpipe and blow-by) over an FTP transient cycle. In addition to aerosol emissions, engine blow-by is also a source of undesirable odors, fumes, engine compartment oil filming and roadway/garage/parking lot drips.

Donaldson's new Spiracle filtration system (*see related story*) is designed to remove more than 90 percent of particle mass across the whole size range.

The Donaldson retrofit system can be used with a wide range of diesel engines used in heavy- and medium-duty trucks and buses.★