



Technical Article

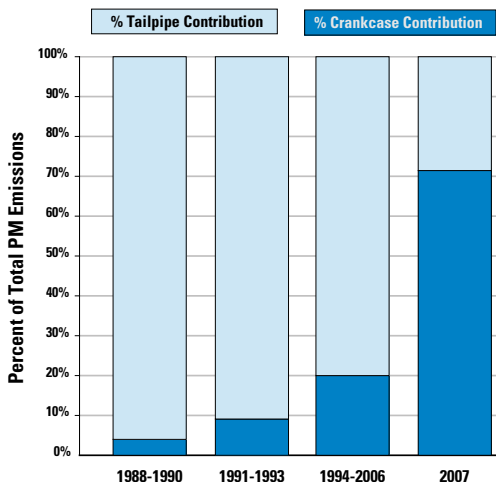
# Spiracle™ Crankcase Filtration Technology

**Author:**

Veli Kalayci  
Spiracle™ Systems Team Leader

For more than 30 years, a focus on environmental air improvement has led original equipment manufacturers (OEMs) to require their manufacturing business partners to design filtration systems that reduce the amount of crankcase blow-by aerosols vented into the atmosphere from diesel engines. This push to reduce diesel emissions and other particulate matter (PM) contaminants from the atmosphere began in the 1970s with the passing of the U.S. Environmental Protection Agency (EPA) Clean Air Act, which regulated on-road diesel emissions and was later amended, in 1990, to include regulations for off-road diesel vehicles. These standards set maximum allowable levels of emissions for new diesel engines and diesel fuel that have been incrementally reducing emissions levels since 1988.

**FIGURE 1**  
**EMISSIONS CONTRIBUTIONS**  
**TAILPIPE & CRANKCASE**



Crankcase emissions levels in diesel engines have remained relatively low compared to tailpipe emissions until 2006. On newer engines, as emissions from tailpipes reduce, crankcase emissions become a greater share of total allowable particulate matter (PM) emissions.

With the significant technology advancements achieved in curbing the exhaust emissions from the engine tailpipe, the relative contribution of the emissions from the crankcase blow-by aerosols started to become an increasing contributor in total engine emissions. Figure 1 shows the increasing relative contribution of crankcase emissions for on-road engines through 2007.

As these regulations evolved in the U.S. and around the world, Donaldson Company, a leading manufacturer of air and liquid filtration systems and replacement parts, led the industry in the development of crankcase filtration technologies with the Spiracle™ Crankcase Filtration Systems (CFS). The engineering advancements of Spiracle™ CFS have continually been used to help meet the EPA's stringent regulatory requirements by providing high efficiency filtration solutions to OEMs and fleet operators around the world.



## Crankcase Ventilation Filtration Systems

Crankcase ventilation filtration systems are designed to be either "open" or "closed" systems.

Open crankcase ventilation filtration systems (OCV) filter engine aerosols, including oil and soot, along with any bulk oil coming out of the valve cover or crankcase vent and discharges filtered air into the atmosphere.

In closed crankcase ventilation filtration systems (CCV), crankcase blow-by aerosols, including oil and soot, are filtered and the filtered crankcase flow is directed back to the intake manifold or to the turbo compressor. Using high efficiency closed crankcase filtration systems, the performance of intake filters, turbochargers, aftercoolers and exhaust system components can be maintained over extended engine usage.

## Crankcase Emissions from Diesel Engines and Emission Control

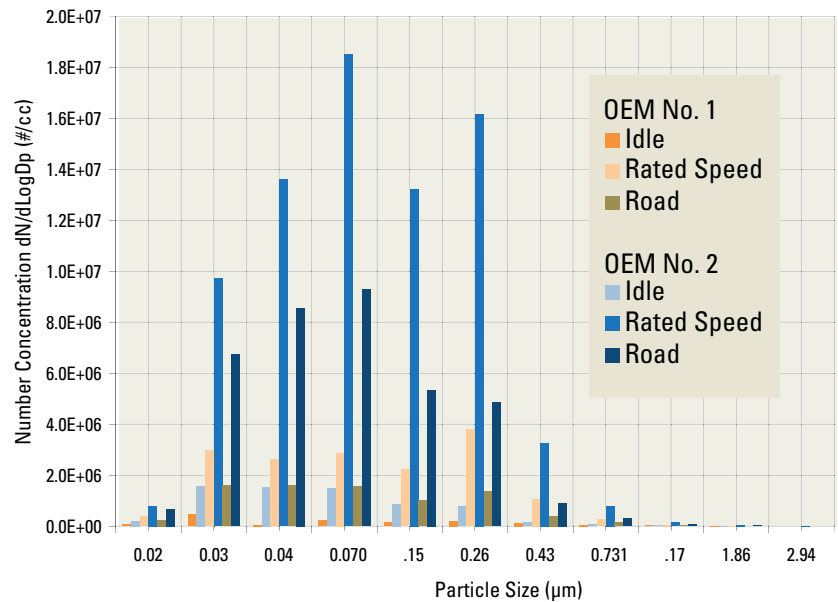
Crankcase emissions are created during the combustion process of reciprocating engines. The primary source of crankcase emissions are combustion gases and particulate matter (PM) that escape past the piston rings and enter the crankcase. Other sources of crankcase emissions include turbocharger shaft seal leaks, valve guides and general movement of parts. These "blow-by" gases must be vented through a tube into the atmosphere to avoid pressurizing and damaging components of the engine. After mixing with oil mists in the crankcase, the gases, PM, and oil aerosols either coalesce and drop out of the vent tube onto the ground, or enter into the atmosphere as pollutants.

Crankcase emissions vary greatly depending on a number of factors. Engine rating, displacement, engine operating conditions such as load, speed and the age of the engine all influence the blow-by volumetric flow rate, mass output rate and particle size

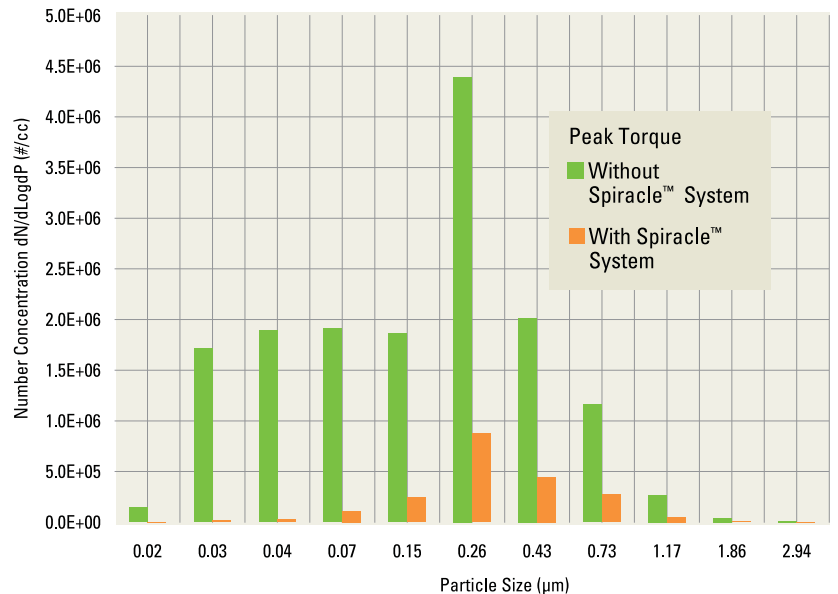
distribution. Just as important, the crankcase emissions can vary depending on the engine design especially the tolerances, materials, turbocharger, wear factors and operating conditions can impact the amount of blow-by escaping past the piston rings.

Donaldson has developed engine blow-by characterization methods and tools as part of its standard range of capabilities for crankcase filtration technology and product development. One such piece of equipment is a mobile blow-by characterization system that Donaldson uses to measure the blow-by output of diesel engines. The test bench can quantify the gravimetric and fractional content of the blow-by mass output, volumetric flow rate, pressure and temperature at different engine operating conditions.

**FIGURE 2**  
**CRANKCASE BLOW-BY CHARACTERIZATION AT THREE ENGINE OPERATING MODES**



**FIGURE 3**  
**PEAK ENGINE TORQUE COMPARISON WITH AND WITHOUT SPIRACLE™ FILTRATION SYSTEM**



The mobile blow-by characterization system allows Donaldson to quantitatively assess their customers' crankcase emissions under dynamic conditions (Fig. 2 and Fig. 3) from their diesel engines and tailor filtration systems to address these needs. This cutting-edge technology allows Donaldson a unique capability in the industry and provides the benefit of custom designed products to fit customer needs.

It is imperative that crankcase filtration manufacturers develop products that can handle crankcase emissions that vary significantly over the operating range and life of the engine. In addition, these systems must be designed to operate in the extreme conditions for temperature, shock, and vibration – typical of medium- and heavy-duty applications.

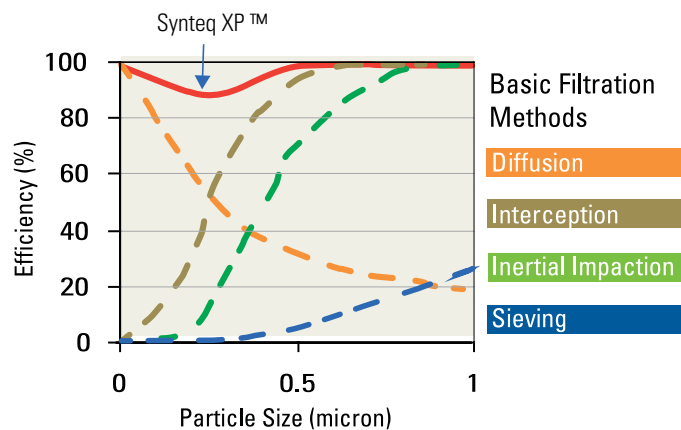
### Spiracle™ Filtration Technology

Donaldson has a long track record of success with its Spiracle CFS technology. In an effort to meet EPA's continued mandates and realizing the health benefits to passengers<sup>(1)</sup>, school bus fleet owners have installed a Spiracle CFS combined with a second emissions reduction technology; i.e., Diesel Oxidation Catalysts (DOC), Diesel Particulate Filters (DPF) or a Diesel Multi-stage Filters (DMF). The combination creates a retrofit solution that delivers maximum emission reduction both inside and outside the bus.

Crankcase filtration manufacturers are challenged to tailor their products to meet a host of manufacturers' applications with differing size, efficiency, pressure loss, and life requirements while delivering high efficiency filtration and reliability.

With the introduction of Donaldson Synteq XP™, a revolutionary, patented filter media, Donaldson engineered the Spiracle CFS creating new open and closed crankcase filtration systems solutions.

**FIGURE 5**  
**PARTICLE SIZES AND FILTRATION PRINCIPALS**



**FIGURE 4**  
**SPIRACLE SYSTEM ON A SCHOOL BUS**



As part of California ARB and US EPA emissions retrofit programs, over 16,000 units have been installed on school buses and trucks across the U.S.

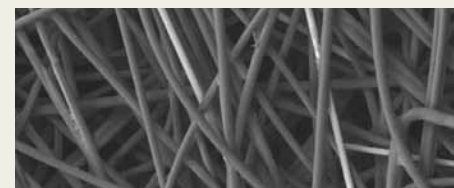
The precise dimensions, shapes and innovative fiber bonding of the Synteq XP media provide the ideal solution for the challenge of balancing high efficiency and low pressure drop, and increased filter life.

Larger particles, typically from 1 to 10 microns are efficiently separated by interception and inertial impaction. Sub-micron particles, often the most harmful for compressor blades, are efficiently separated by diffusion. Donaldson's Synteq XP media is specifically designed to combine interception, inertial impaction and diffusion, thereby offering high efficiency for all particle sizes (see Fig. 5).

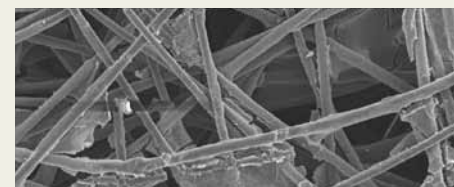
After the oil mist particles are captured, they are coalesced into larger droplets and drained from the media. The drainage within the media pack is also optimized. Pressure drop across the self-draining filter is kept low and stable over time, and no engine downtime is required to drain the oil out of the media pack.

The large pore size of Synteq XP media (Fig. 6) reduces the pressure drop across the filter. Multiple layers of the media allows custom design flexibility for a wide range of filtration efficiencies and field life depending on the needs and requirements of OEMs.

**FIGURE 6**  
**SCANNING ELECTRON MICROGRAPHS OF SYNTEQ XP™ MEDIA @ 200X**



Close-up of Synteq XP media (clean)

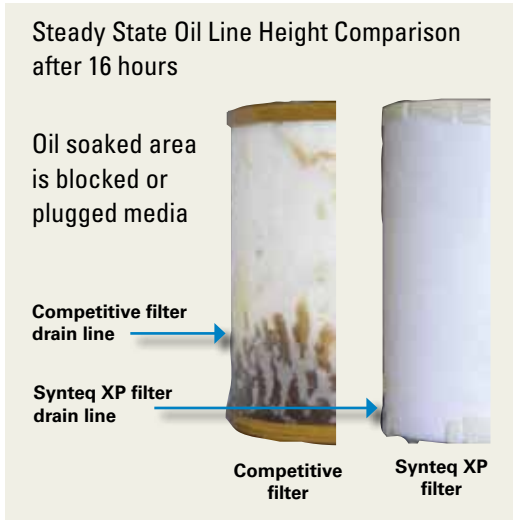


Close-up of Synteq XP media after 1200 hours of field use. The open areas that are free of contaminant offer additional filter service life.

One of the unique features of Synteq XP filtration technology is its exceptional ability to coalesce oil and then drain.

Oil that is held in the filter will increase pressure drop and reduce efficiency, resulting in shorter filter life. In Fig. 7, there is no wet line on the Spiracle filter shown on the right after 16 hours of operation. Better drainage means less pressure drop, better efficiency and improved life.

**FIGURE 7  
FILTER OIL LINE COMPARISON  
AFTER 16 HOURS**

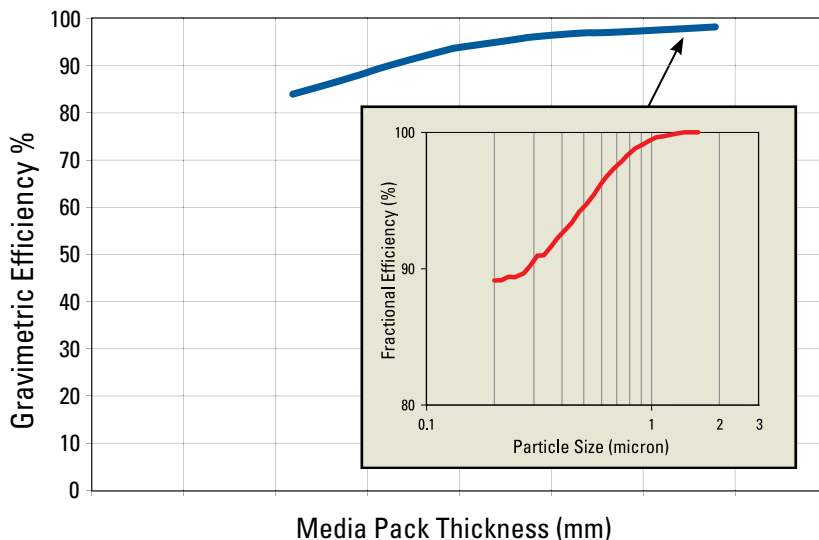


Better oil drainage means less pressure drop, improved efficiency and filter life.

Synteq XP media offers great flexibility to Donaldson engineers in customizing crankcase solutions. Spiracle CFS can be developed to any target gravimetric and fractional efficiency depending on the requirements of the customer and the diesel engine crankcase blow-by characteristics. This media technology offers the best combination of high efficiency with low pressure drop.

Synteq XP media in combination with a Spiracle housing for OCV or CCV applications allows increased engineering design flexibility (see Fig. 8) for custom fit solutions. This design flexibility translates into improved serviceability including mounting location and direction and aligning the filter service interval with other maintenance intervals to reduce downtime and maintenance costs.

**FIGURE 8  
CRANKCASE FILTRATION PERFORMANCE DESIGN  
FLEXIBILITY WITH SYNTEQ XP MEDIA**



## A Better Product and Technology to Control Diesel Engine Crankcase Emissions

Donaldson Spiracle CFS is a serviceable unit. Its benefits include lower cost, higher efficiency, and reliability over a wide range of engine conditions and longer filter life creating less demand on the diesel engine.

### Benefits of Spiracle CFS with Synteq XP Media include:

- ◆ Lower operating pressure drop
- ◆ Continuous oil drainage even at low pressure differentials
- ◆ Higher gravimetric and fractional efficiency including the sub-micron particle size range
- ◆ Longer filter life compared to traditional media

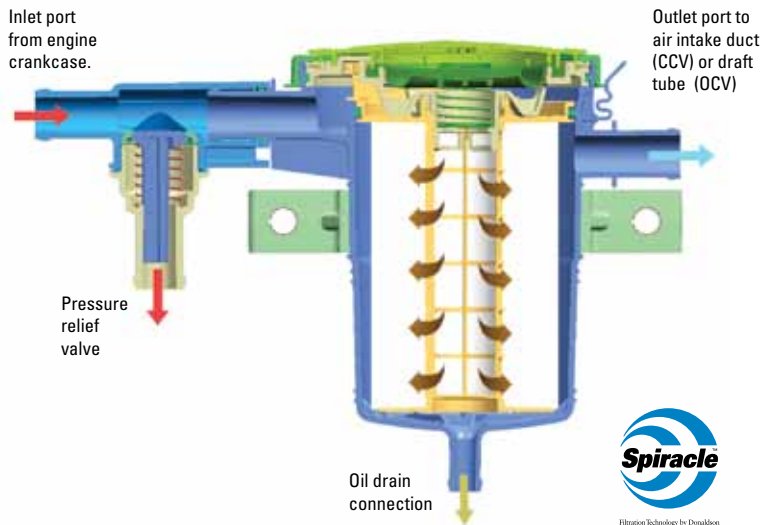
Donaldson Synteq XP media provides continuous drainage at low pressure differentials. Just as importantly, a Spiracle CFS provides high gravimetric efficiency at broad flow ranges in a dynamic engine operating environment where consistency is required no matter the duty cycle of the engine. The Spiracle CFS also provides high fractional efficiency on sub-micron particles. Sub-micron particles along with larger aerosol contaminants contribute to wear and damage to the air intake system components on diesel engines. Typical manifestation of such damage is wear on compressor blades and the housing of the turbocharger system, or a reduction in aftercooler efficiency which negatively impacts engine performance. This outstanding performance of the Spiracle filtration technology over any contaminant size range including sub-micron particles, clearly sets it apart from other methods of filtering crankcase blow-by



contaminants. The technology offers the added advantage of providing optimum filtration performance in low and high temperature extremes.

The Spiracle CFS does not have any moving parts and does not require any electric or hydraulic power to function; therefore, it does not require engine power to operate, which may otherwise cause parasitic losses and decrease fuel efficiency.

**FIGURE 9  
SPIRACLE SYSTEM SCHEMATIC**



Due to its reliability over the life of the engine, Spiracle CFS is the ideal solution for controlling crankcase emissions whether in open or closed crankcase ventilation systems. As the soot and other contaminants build up on the Spiracle filters after extended engine use, typically over 1,500 hours, the end user simply replaces an

inexpensive, easily accessible filter. This can be accomplished quickly (typically under 1 minute), thus resulting in minimal downtime servicing the engine and more vehicle uptime. Periodic replacement of the filter returns the system to a known performance level each and every time.

Donaldson Spiracle Systems deliver high performance crankcase filtration over all engine operating conditions. Figure 10 and 11 show examples of Spiracle CFS on engines.

### "Green" Benefits

At Donaldson, we protect our customers' engines by cleaning the air going into the engine, all the fluids around and throughout the engine, and the exhaust gases coming out of the engine. In turn, our filtration systems are improving the sustainability of the environments in which they are used.

Spiracle CFS offers the following green benefits:

- ◆ reduces or eliminates crankcase emissions
- ◆ improves cabin air quality <sup>(1)</sup>
- ◆ reduces engine oil consumption; and
- ◆ maintains a cleaner engine compartment

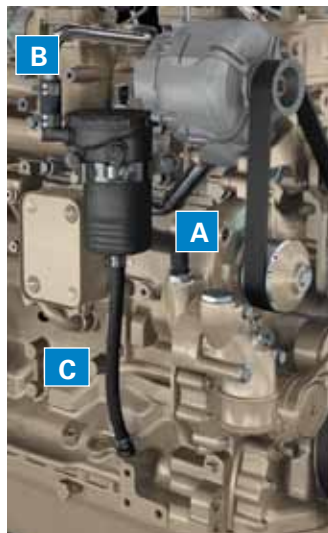
### SPIRACLE FILTRATION SYSTEMS ON ENGINES

A - Outlet B - Inlet C - Oil Drain

**FIGURE 10**



**FIGURE 11**



### Conclusion

Donaldson's diesel engine know-how combined with its cutting edge crankcase blow-by characterization technology and Synteq XP media based Spiracle Systems offer the emissions reduction solutions that are needed by the diesel engine OEMs to meet worldwide emissions regulations.

**Reference:**

- (1) Three independent studies concluded Spiracle CFS improves in-cab air quality. Links to studies can be found on Donaldson Emissions Resource Center at [www.donaldson.com/en/erc](http://www.donaldson.com/en/erc)

**Acronyms**

- OCV Open Crankcase Vent /Ventilation
- CCV Closed Crankcase Vent/Ventilation
- CFS Crankcase Filtration System
- OE Original Equipment
- OEM Original Equipment Manufacturer
- EPA Environmental Protection Agency
- ARB Air Resources Board; California Air Resources Board
- PM Particulate Matter

**Internet Resources:**

[www.donaldson.com/en/engine/crank/](http://www.donaldson.com/en/engine/crank/)

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<b>Donaldson Company, Inc.</b> <b>PO Box 1299</b> <b>Minneapolis, MN</b> <b>55440-1299</b>  <b><a href="http://www.donaldson.com">www.donaldson.com</a></b>	<b>North America</b> 866-511-7610 <b>Mexico</b> +52-449-910-6150 <b>Latin Am. &amp; Caribbean</b> +52-449-910-6150 <b>Brazil</b> +55-11-2119-1604 <b>Europe</b> +32-16-38-3811 <b>South Africa</b> +27-11-997-6000	<b>South East Asia</b> 65-6311-7373 <b>Greater China</b> 852-2405-8388 <b>Japan</b> 81-42-540-4112 <b>Australia</b> 61-02-4350-2033 <b>India</b> +91-124-2290060
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**Brochure No. F113025 (01/11)**  
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