



# 50,000 Hour Off-Highway Diesel Engine Rebuilds: They Are Possible!

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**From dozers to graders and loaders to haul trucks, diesel engines are everywhere. For companies who rely on diesel power to make their living, there's no greater emphasis than diesel engine reliability. But when it comes to diesel engines, they also have some of the shortest life expectancies.**

Compared to fixed equipment, where mean-time-between-rebuilds is measured in years, most diesel engine original equipment manufacturers (OEMs) recommend an engine overhaul or rebuild every 12,000 to 15,000 hours. Even with oil analysis, which allows the rebuild interval to be optimized, 20,000 to 25,000 hours is about as good as it gets for engine life in off-highway applications.

So why is it that an engine has such a short life expectancy? The issue is less about maintenance than it is about the operating conditions and environment of a typical engine. With

temperatures close to 200 degrees F, severe duty and shock loads, internal contaminants like soot, acids and wear debris, and the possibility of fuel or glycol leaks, engines have a tough life.

But perhaps the biggest engine killer is external contamination in the form of dust

and dirt, sucked into the engine each minute of operation through the air intake. Particle contamination can be lethal for engines - even microscopic particles no bigger than a red blood cell can result in a significant reduction in an engine's life expectancy. In fact, studies by General Motors, Cummins, Inc., and other engine OEMs have proven that particles in the 0 to 5 and 5 to 10 microns size ranges are three times more likely to cause wear in critical piston rings and bearings than larger particles (Figure 1). To

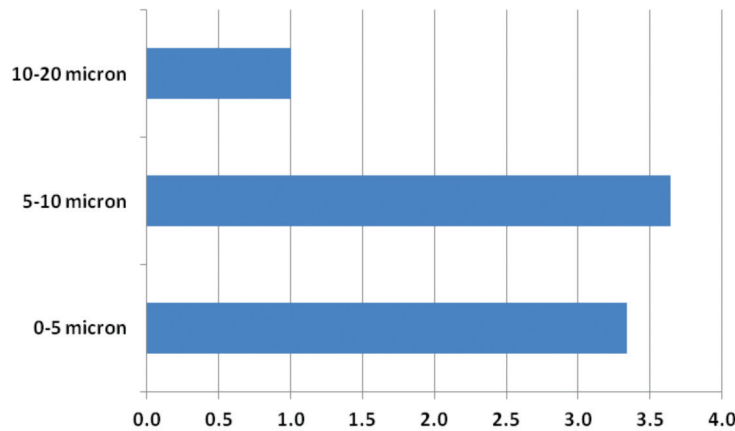


Figure 1: Relative wear rates for engine rings and bearings versus particle size distribution (Ref: Cummins, Inc.).

put that into context, particles that are less than a tenth of the diameter of a human hair are enough to reduce an engine's life expectancy by one half or more! These particles, which are often called silt-sized particles, are so small that a large percentage of those ingested into the engine air intake manifold

pass straight through the air filter, which, by comparison, is really only equipped to take out rocks and boulders.

Armed with these facts - which are widely known by OEMs, lubrication engineers and filter manufacturers alike - why is it that most full-flow engine oil filters are at best 70 percent efficient at removing 10 um particles and are effectively useless at removing silt-sized particles? The answer is largely a question of flow. With any filter, there is always a balance between flow rate and filter efficiency.

With most filters, as the micron rating and filter efficiency improves, the flow rate drops off significantly. This should be fairly obvious: the smaller pore sizes necessary to trap smaller particles create a greater barrier to oil flow. But the problem is exacerbated by simple physics: For most mechanical filters, halving the micron rating, say from 10 to 5 microns, would require a four-fold increase in filter surface area to maintain the same flow rate. Because of this and due in part to the physical limitations in the size of an engine filter, it is almost impossible for filter manufacturers to reduce the micron rating to be more efficient at removing silt-sized particles while maintaining adequate flow rates.

So that's it right? We're stuck with accepting the fact that the most harmful particles to an engine are going to be present in an engine with no hope of removing them? Wrong! By thinking outside the box a little,

silt particles can be removed from engines effectively, with a dramatic impact on engine life. To illustrate the effect, consider the following example:

## Case Study

A maintenance team at a 25,000-acre surface coal mining operation in Montana was seeking to improve profitability by lowering direct maintenance costs and extending the operational life of the engines. They were well aware that the service life of their engines was being cut short by particles that the OEM full-flow filtration was not designed to remove. Starting with their CAT 992G bucket loaders equipped with CAT 3508B engines, the mine developed an approach to reduce silt-sized particles from the engines. Initial oil analysis

data on one 992G in the mine's fleet indicated a particle count of 22/21/18, with copper and iron levels at 118ppm and 53ppm respectively, levels commonly found across the rest of the fleet. Maintenance personnel also indicated that a typical engine "top end" overhaul interval was approximately every 12,000 hours and when engines were torn down, they were typically very "dirty" inside with evidence of scuffing on the cylinders. The team set about lowering in-service contamination levels through an aggressive contamination control strategy.

Exactly 931 hours after improving their oil filtration, an oil analysis was conducted to evaluate if any improvements had been made in oil cleanliness. To their surprise, ISO cleanliness levels went from 22/21/18 (c) to

17/16/13 (c), soot levels were maintained at or below 0.1% volume and iron levels dropped from 53ppm to 7ppm. Based on this and the standard life-extension tables (Figure 2), the mine has projected a four-fold life extension, resulting in a savings of \$129K over five years, equivalent to a 216 percent return on their investment (Table 1). This is just one of many examples that demonstrate the effect of improving silt particles in engines.

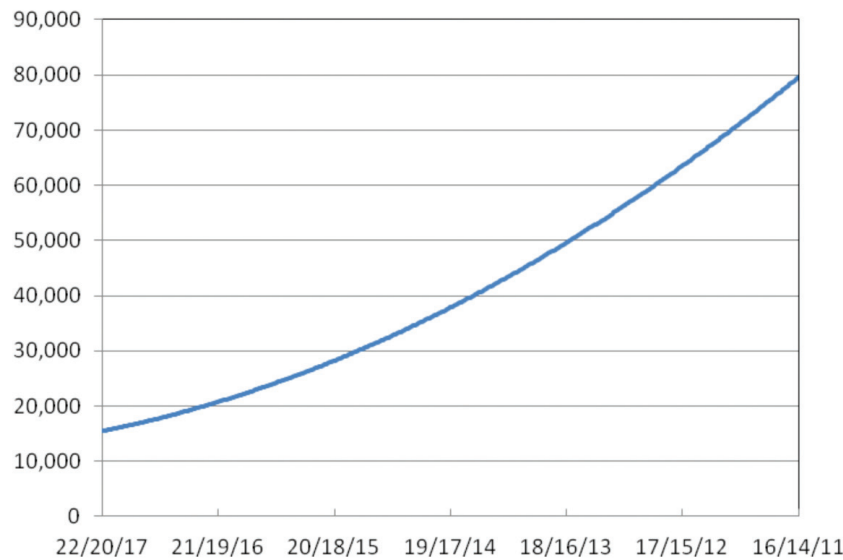
## Bypass Filtration

So how did they do it? The answer is fairly straight forward as illustrated in Figure 3. Without changing the flow of oil within the engine, a small slipstream of oil is taken after the full-flow filter using a flow control valve. By regulating oil flow through the valve, only 10 percent of the total oil flow is removed at any given time, which is not high enough to cause any harm to the engine. This side stream of oil is passed at normal engine oil pressure through a depth media filter with an efficiency rating of 99.9 percent at 3 microns ( $\beta_3(c) > 1000$ ). The oil is then returned to the sump. For safety, a relief valve is included to avoid over pressurization of the bypass filter during start-up.

## Conclusion

Engine overhaul and rebuilds are a significant cost to diesel engine maintenance budgets. With few exceptions, significant improvement in engine life can be achieved by controlling silt-sized contaminants.

### Operating hours



### Oil cleanliness (per ISO 16889)

Figure 2: Projected engine life, with oil analysis.

	Before Standard OEM Filtration	After Secondary Filtration with ENG-2
ISO Cleanliness Code	22/21/18	17/16/13
Hours on oil	306	931
Soot Levels		≤0.1%
Iron Levels	53ppm	7ppm
Life Extension		4x
Annual overhaul costs	\$9,733	\$2,433
5-year Net Present Value (NPV) Savings (6 loaders)		\$129,841
Internal Rate of Return (IRR)		216%

Table 1: Oil analysis data and investment analysis for CAT 992G (3508B engine).

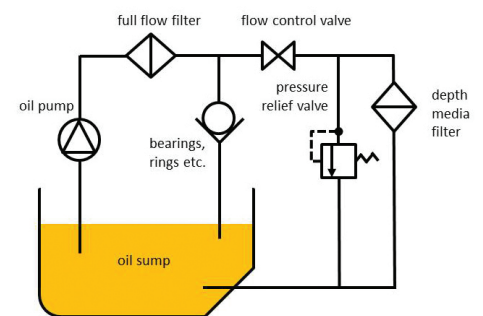


Figure 3: Schematic illustration of engine oil side stream filtration.



Mark Barnes, CMRP, recently joined Des-Case Corporation as Vice President of the newly formed Equipment Reliability Services team. Mark has been an active consultant and educator in the maintenance and reliability field for over 17 years. Mark holds a PhD in Analytical Chemistry. [www.descase.com](http://www.descase.com)