

THE ENGINE KILLERS

By Steven Lara-Lee Lumley – technical manager, WearCheck



INTRODUCTION

I have a colleague who believes that engines don't just simply die, they are murdered. A rather dramatic sentiment, I know, but then we take the death of an engine quite seriously at WearCheck.

Being an avid consumer of forensics crime drama television series like CSI (Crime Scene Investigation) I feel that I can confidently explain the procedure that takes place once a murder victim has come to the attention of the authorities.

Firstly, the crime scene is cordoned off. A forensic team (all of whom moonlight as fashion models) examines the evidence, the cause of death is determined (usually in record time) and a murder case is opened based on the strength of the evidence collected (which is usually bizarre in nature and requires the expertise of a socially awkward forensic pathologist).

Similarly, when reviewing oil analysis data, a forensic approach is also required that incorporates a combination of science, experience and gut instinct. There is an explanation for every oil analysis result obtained, but that explanation is not always apparent and requires the abilities of a very special kind of pathologist

– a mechanical pathologist also known as a WearCheck diagnostician.

In this technical bulletin we will take you on a journey through the eyes of a mechanical pathologist tasked with identifying the modus operandi of some of the most lethal engine oil contaminants known to cause premature or even sudden engine failure.



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One of the main functions of oil analysis is to monitor levels of contaminants in the lubricating oil. Contaminants can be classed as being either internal or external. Internal contaminants are generated within the mechanical system such as wear debris or combustion by-products that accumulate in engine oils as a result of burning diesel. External contaminants are substances that exist in the environment that should not be in the oil, like airborne dust or water contamination.

Contaminants can be directly damaging to the mechanical system that is being lubricated. For example, dust is abrasive and can cause components to wear abnormally, but contaminants can also be indirectly damaging as they can cause the lubricating oil to degrade, which in turn may have an adverse effect on a mechanical system being lubricated.

When it comes to the analysis of used engine oils for condition monitoring purposes, certain contaminants are vitally important to monitor as they are often the root causes of premature oil degradation and engine failure.

After lengthy interrogations with several suspected engine oil contaminants we have compiled forensic profiles on what we believe to be the most brutal killers known to the diesel engine.

WARNING: This technical bulletin may contain disturbing and graphic content.

The volatile killer

Let us begin our journey into the mechanically macabre with our first engine killer - fuel dilution AKA "the volatile killer".

This engine killer was responsible for 21% of all engine-related problems detected by WearCheck in the last year.

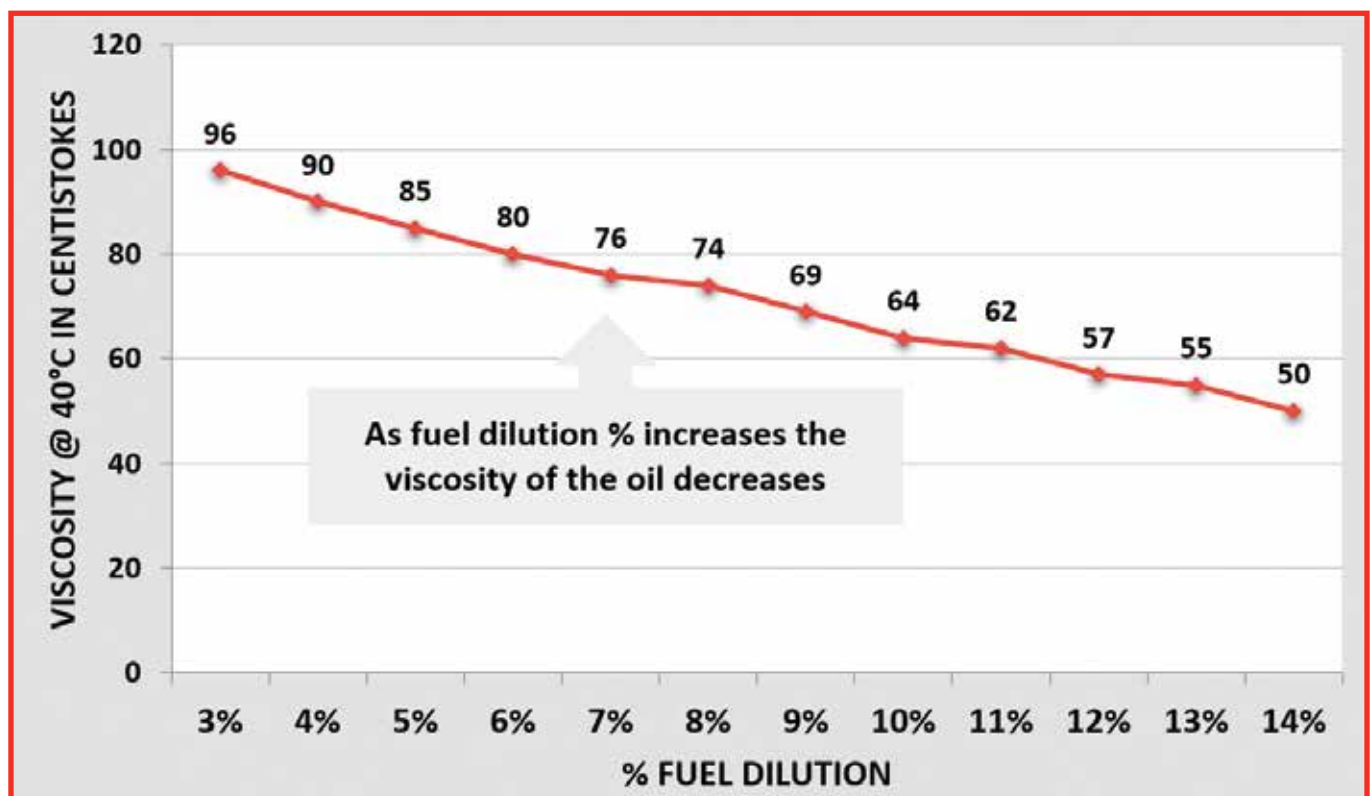
When unburned fuel leaks directly into the sump, the problems caused are twofold - there is a physical and a chemical effect. Let's examine these modes of attack in more detail.

Physical effect

The kinematic viscosity of a fluid is defined as a fluid's resistance to flow under the force of gravity at a particular temperature. Viscosity is considered one of the most important physical properties of a lubricating oil as it determines the thickness of the oil film that prevents contact between metal surfaces. For a mental comparison think of water as having a low viscosity (flows easily) and honey as having a high viscosity (does not flow as easily).

The typical kinematic viscosity of diesel is between 2 to 5 cSt @ 40 °C (think water) and the typical viscosity of a common diesel engine oil, say a SAE 15w/40 is about 100 cSt at 40°C (think honey) so as a result of this difference in viscosities between diesel and engine oil, only a small amount of fuel is required to significantly reduce the viscosity of the engine oil.

Moderate (+/-4%) to large (+/- 8%) amounts of fuel dilution can drop the viscosity of an engine oil by several



grades which can collapse critical oil film thickness. This reduction in viscosity will eventually lead to a reduction in the load-bearing capabilities of the oil and abnormal bearing wear will eventually occur.

Chemical effect

Diesel engine oils are blended with additives that have specific functions to perform e.g. anti-wear, anti-oxidant, dispersant and detergent-type additives, to name a few.

When large amounts of fuel are present in an engine oil, these additives become physically diluted which reduces their effectiveness. Diesel also contains unsaturated aromatic molecules which facilitate oxidation of the engine oil, resulting in a loss of the much-needed detergent additive responsible for neutralising acids generated in the engine oil as a result of the combustion process, extended oil use or high operating temperatures. The loss of this detergency in the oil results in increased corrosion of internal metal surfaces.

To make matters worse, diesel is also made of heavier hydrocarbons that can turn to wax when ambient temperatures drop. If a fuel tank contains summer-grade diesel and temperatures drop significantly, wax crystals can form, causing a blockage in the fuel filter. Similarly, diesel fuel dilution in cold operating temperatures can cause waxing of the engine oil which could result in low oil pressures and oil starvation in severe cases.

Final note in forensic profile: This killer has been known to cause wash-down of oil on cylinder liners, accelerated top-end wear, as well as high blow-by condition and increased oil consumption.

The dirty killer

The second killer in our forensic profile is dust entry, AKA the “the dirty killer”. This engine killer was responsible for

15% of all engine-related problems detected by WearCheck in the last year.

The dire consequences of dust entry are perfectly summed up by Jim Fitch of Noria Corporation, who maintains that the cost of excluding one gram of dirt is only about 10% of what it will cost you once you let it enter the oil.

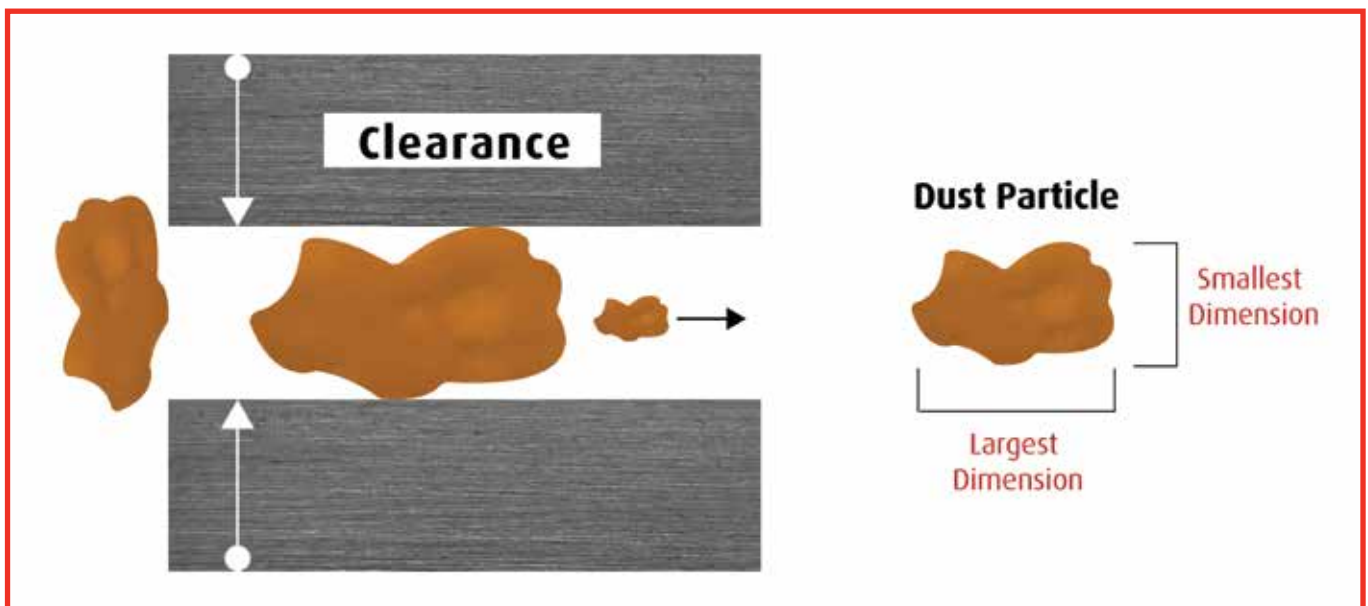
The earth’s crust is made of different types of rocks, (igneous, metamorphic etc.), that contain large amounts of silicon and aluminium oxides which contribute to the composition of natural soil and dust. It is for this reason that silicon and aluminium are used as the main elemental indicators of dust entry in oil analysis.

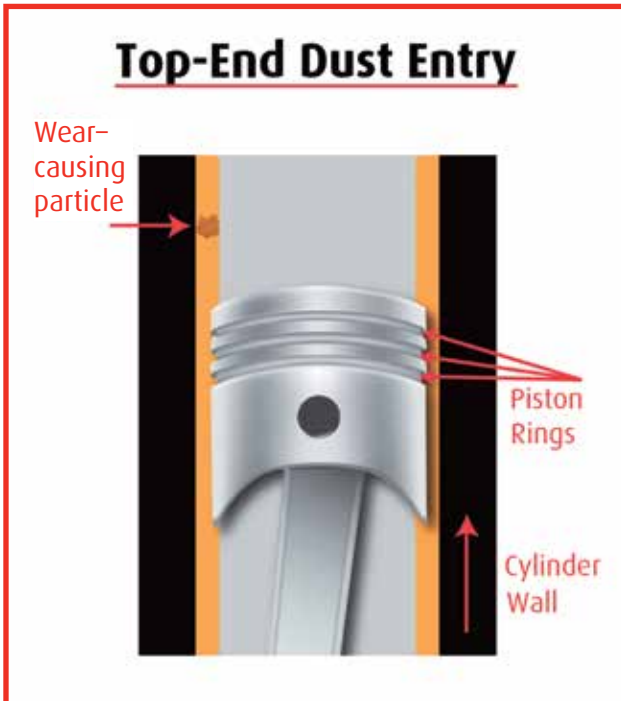
Due to the large volumes of air that engines take in through the induction system they are at high risk of dust entry and the resultant accelerated wear that takes place due to abrasion.

Interestingly enough, it is the particle that has its smallest dimension of a similar size to the clearance involved that does the most damage. A particle smaller than the clearance will pass straight through doing little harm and a particle larger than the clearance will be unable to enter and do any damage.

Dust does the most damage at the point of entry, so when an engine has a dust entry problem, the type of wear that takes place is often related to the manner in which the dust enters. For example, an oil sample showing evidence of dust entry and an increase in bottom-end wear indicates that dust is entering the engine oil directly and not passing the pistons and rings. Any dust which is in the oil will usually be pumped through the oil filter before entering the bearings.

However, engine dust ingress takes place predominantly through the air intake. Efficient air filtration removes most





of the dust ingested but the remaining dust that is not removed by the filters or cleaners consists of very small abrasive particles that could be 10 micron to sub-micron in size.

As a result of the small clearances between piston ring and liner bore, it is these small airborne dust particles that pose the biggest threat when leaks occur in the induction system. These dust particles will pass between piston, ring and cylinder and eventually become suspended in the oil.

If that was not bad enough there is also the issue of load distribution. The thin oil film that separates working surfaces prevents direct contact between the surfaces, reducing the amount of friction and the rate of wear. This oil film also absorbs shock loads and helps distribute load over the whole surface. When a dust particle is introduced between the two surfaces it changes the loading of the surfaces from one of even distribution to a point load concentrated on the particle with tremendous pressure.

The dark killer

The third killer in our forensic profile is soot, AKA the "the dark killer". This engine killer was responsible for 6% of all engine-related problems detected by WearCheck in the last year.

Let's face it, burning fossil fuel is a dirty business and due to the inherent impurities and inefficient engine combustion cycles it is not possible to burn fossil fuel with 100% efficiency.

One of the major combustion by-products of burning diesel is soot. Soot is impure carbon particles resulting from the incomplete combustion of diesel. When formed

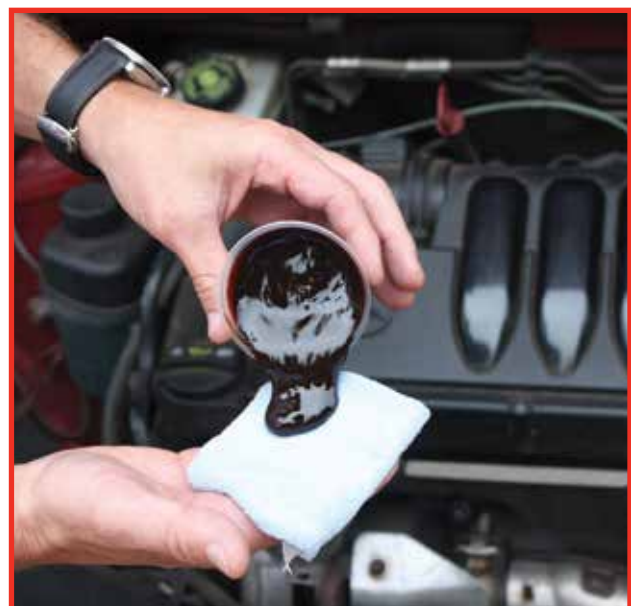
in an engine the soot particles are vanishingly small in size (+/- 0.03 microns), but with progressive fuel usage large quantities of these particles are deposited in the oil and eventually agglomerate to form larger soot particles.

Soot enters the engine oil with exhaust gas in the form of blow-by, or is deposited on the cylinder walls and is then scraped off by the rings and deposited in the sump. Combustion efficiency as well as the sulphur content of the diesel being used is directly related to the soot generation rate. Poor ignition timing, restricted air filter and excessive ring clearances cause high soot load. Engine design, fuel quality and operational environment are also factors that contribute to the rate of soot deposited in the oil.

All engine oils contain detergent and dispersant-type additives which control the effects of soot. The detergent additive keeps metal surfaces free of deposits while neutralising compounds that can form sludge and varnish. The dispersant additive works by keeping insoluble contaminants (like soot) dispersed in the lubricant and prevent them from coating metal surfaces. However, these additives, like all oil additives, are sacrificial in nature and once used up they will not be able to protect the oil from degradation and continued soot accumulation or agglomeration.

The most dramatic effect of excessive soot is the viscosity increase which results in higher operating temperatures and accelerated wear. The oil might still be able to flow and provide sufficient lubrication at operating temperatures of 90 °C but when it cools down to 10°C during the night the oil can solidify. Under these adverse conditions, when the engine is started, the oil pump will not be able to pump this solid mass leading to oil starvation.

But wait, it gets worse! EGR (Exhaust Gas Recirculation) units on diesel engines amplify the amount and abrasivity



of soot production as the device channels the emissions back to the combustion chamber, creating a multi-pass opportunity for soot to deposit in the oil.

Final note in forensic profile: This killer has been known to cause plugging of oil filters and galleries, additive mortality, increased operating temperatures and bearing seizure due to oil starvation.

The cool killer

Finally, the pièce de résistance of engine killers - the internal coolant leak, AKA “the cool killer”.

This engine killer was responsible for 13% of all engine-related problems detected by WearCheck in the last year.

This is the most brutal engine killer of them all, and a testament to this is the fact that major diesel engine manufacturers estimate that 53% of all catastrophic engine failures are due to cooling system problems.

So, what is the modus operandi of this coolest of engine killers you might ask? Well, the answer lies in a Hannibal Lecter quote “Of each particular thing, ask what is it in itself? What is its nature?”.

Generally, most coolants are a mixture of water, glycol and additives. The water acts as the heat transfer medium while the glycol component of the coolant raises the boiling point and lowers the freezing point of the water it is mixed with. The additive portion of the coolant is there to protect metals in the cooling system from corrosion, cavitation, scale formation etc.

Internal coolant leaks can sometimes be confusing as there is often no physical water present in the oil. This is due to the operating temperatures and pressures in the engine, which ensure that the water evaporates off. However, the additives in the coolant will contribute to elemental concentrations of sodium, boron, potassium and silicon in the oil, and it is this elemental family from the coolant additive system that serves as a marker to confirm coolant contamination of the oil.

Coolant can leak into engine oil in a variety of ways e.g. from a defective seal, blown head gasket, damaged or corroded cooler core, or water pump seal failure, but one of the most common causes of an internal coolant leak is liner perforation.

Liner perforation occurs when the liners vibrate to the rhythm of the piston movement during the compression and combustion stroke. This movement causes pressure waves to form negative pressure regions that nucleate vapour bubbles. As the combustion chamber fires, these vapour bubbles implode and can literally blast small holes in the liner wall.

The introduction of coolant into lubricating oil can expose your machine to a dangerous mixture of chemicals that can progress to engine failure in a short period of time.

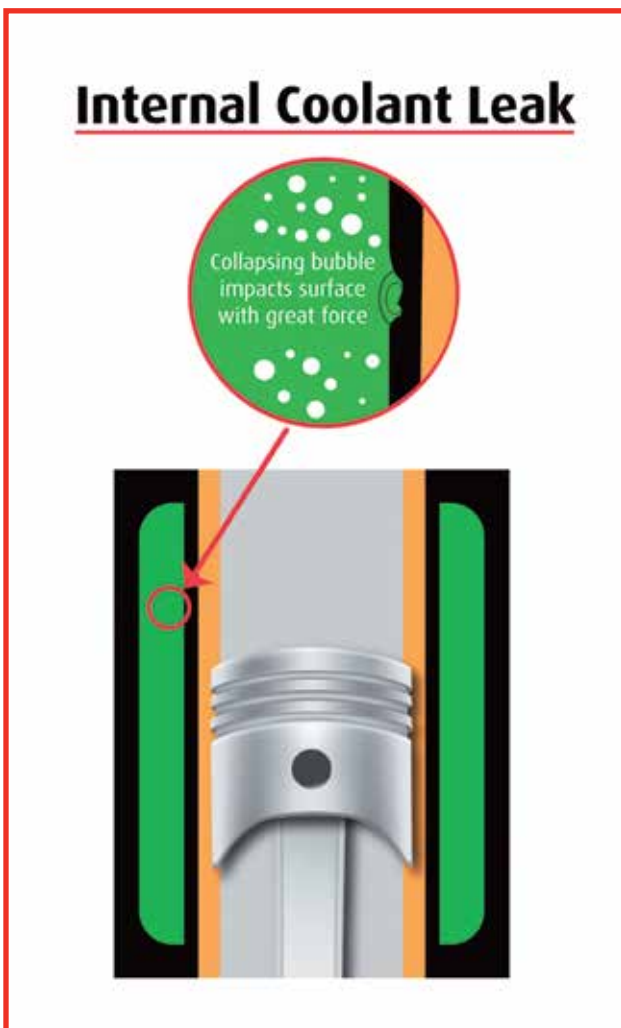
Below are just some of the known modes of attack this engine killer has displayed in past murder cases.

Viscosity change

Glycol contamination of engine oil can increase the oil’s viscosity, and this can lead to insufficient flow of the oil to critical metal surfaces. Added to this, glycol and its reaction by-products can also aggressively promote oxidation of the base oil which will further thicken the oil. Remember - if it’s too thick...it can’t flow...if it can’t flow...it can’t cool - so any dramatic increase in the oil’s viscosity will have an adverse effect on the oil’s cooling ability.

Oil filter plugging

The acids and water that form in engine oil as a result of coolant contamination can disrupt soot dispersancy. A prominent oil filter manufacturer claims that 75% of filter plugging complaints in engine oil filters involve coolant in the crankcase, and that just 0.4% coolant in engine oil is enough to coagulate soot and cause dump-out, leading to sludge, deposits, oil flow restriction and filter blockage.



Abnormal wear

Glycol oxidises into corrosive acids which can cause a rapid drop in the oil's alkalinity (Total Base Number), resulting in an unprotected corrosive environment which can increase corrosive wear of engine bearings and other internal metal surfaces.

Additive precipitation

Glycol can react with oil additives causing precipitation. ZDDP (Zinc dialkyldithiophosphate) is an important anti-wear and anti-oxidant additive found in almost all diesel engine oils. When the engine oil is contaminated with glycol, ZDDP will form reaction products and this leads to a loss of anti-wear and anti-oxidant performance.

Oil balls

Oil balls are abrasive spherical contaminants that form from the reaction of the detergent additives in the oil and glycol contamination. Oil balls are a known cause of damage to crankcase bearings and other frictional metal surfaces in the engine.

Forensic profile close-out

The time taken for engine failure progression can vary significantly for the contaminants profiled in this technical bulletin. There are also several aggravating factors that can drastically shorten the failure development period, such as deficient maintenance practices, oil quality and filtration. Sudden-death engine failures from moderate concentrations of contaminants are usually accompanied by one or more of these aggravating factors, whereas high concentration of contaminants in an engine oil can result in sudden-death

failure irrespective of any aggravating circumstances. What is most commonly seen, however, is when the moderate scenario is unattended to by the engine operator and escalates over time until engine failure eventually occurs. Unfortunately, many engine operators are unaware of the danger engine oil contaminants create and what inevitable fate they can lead to in terms of equipment availability and lifecycle. Protecting your engines and ultimately your equipment from the harmful effects of contamination and lubricant degradation begins with a proactive mind-set.

An efficiently-run oil analysis programme can generate benefits in two distinct modes – namely the predictive maintenance and proactive maintenance modes.

In the predictive mode an oil analysis programme can reduce the failure severity, maintenance costs and allow the user to plan maintenance activities.

In the proactive mode an oil analysis programme can be utilised to identify the root cause of failure as well as reduce the failure rate. The value of proactive maintenance lies in its ability to extend component life by controlling the root cause that can lead to engine failure.

Hopefully from this technical bulletin it can be seen that the cumulative effect of oil contamination on engine reliability, fuel economy, exhaust emissions and maintenance cost can be considerable. Therefore, proactive maintenance techniques such as oil analysis are vital to mitigate the risk of engine failure.

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