Poor combustion can hamper engine lubrication

One of the major duties of a diesel engine oil is to keep lubricated parts free of deposits, but this function is often hampered by poor combustion, according to Mr Brid Walker regional manager of Queensland company Fuel Technology Pty Ltd.

For engine cleanliness, an oil's detergency/dispersancy package is called upon to remove and suspend deposits that exist. It must also prevent further deposits from forming on surfaces. These contaminants are suspended until they can be removed by the filter or at the next oil change.

Engine deposits can be caused by many factors, such as fouled injectors, overfuelling, incorrect timing, clogged air filters, overextended oil change intervals, altitude and temperature factors, engine condition and application. Whatever the reason, the result is the same — the oil is called on to work harder.

However, assuming good maintenance and operating practices exist, the fuel itself may not burn properly. With today's diesel fuels it's a greater problem. The slower burning fractions of diesel are associated with black smoke and deposit formations.

Deposits tend to form on combustion surfaces such as cylinder heads, valves, piston crowns, top lands, ring grooves, injectors, etc. This promotes a condition which, in itself (because of reduced cylinder compression, poor oil control, poor fuel spray patterns) causes very poor combustion.

While the oil is trying to remove deposits as they form in ring grooves etc, it is also being rapidly taxed by soot reaching it through exhaust blow-by. Soot is damaging. It's an abrasive just like valve grinding paste, only a bit slower. This reduces the oils cleaning ability, which allows deposits to build up faster, increasing blow-by and soot. Higher levels of maintenance are required and operating efficiency and engine life are reduced quite measurably. According to Mr Walker, "lubrication is a bandaid remedy to a combustion problem".

A major Central Queensland coal mine has provided some recent insight into this. In conjunction with Fuel Technology, a combustion catalyst was introduced into the fuel for the mobile fleet. Mr Walker used data from the mine's research and development laboratory in Mackay to construct wear profiles. Substantial wear reductions were noted (in the range 18-46 per cent). Mr Walker said: "With less soot being produced and reaching the lube oil, abrasive wear can be reduced dramatically. The oil can then cope better with keeping ring grooves cleaner and reducing blow-by.

This was confirmed in the fleet of 12 Cummins-powered coal haulers, which showed an average 58 per cent reduction in oil consumption.

Inspection of a Cat 3412 engine from a Cat 992C loader bore testimony to the benefits of an efficient burn. The engine displayed a complete absence of sludge, with valve covers and sump pan in very clean condition. Cylinder heads, piston crowns exhaust manifolds and turbochargers were coated with a light fluffy layer of soot, which easily wiped off to expose bare metal. Valve part numbers could be clearly read.

Injectors were clean and free of deposits. Inlet and exhaust ports were totally free of any hard deposits. Slight inlet valve stem deposits were noted and these showed signs of erosion. Piston top land deposits were moderate, while rings were free in their grooves and skirts exhibited no varnish.

Overall, the description is one of a very clean engine. But, considering that the engine was overhauled at a programmed change-out, with a total of almost 17,000 hours (original and untouched), its condition can only be described as exceptional. It had burnt catalyst treated fuel for approximately 2400 hours.

The mine has noticed a reduced incidence of carbon related failures during the period of catalyst use. The recent heavy rains in Central Queensland clearly quantified the cost of lost production.

Special lubricants

Blending special lubricants to meet specific requirements is the first priority for Australia's oldest privately owned oil company, Ramsay and Treganowan Ltd.

With 80 years' experience in the industry, the company blends lubricants at Newport, Victoria, where it has a modern oil-blending plant and quality control laboratory.

According to the company's general manager, Mr David Jones, many industrial companies and manufacturers are astonished to find just what our lubricants can do for them at no extra charge.

"While the education system covers all aspects to do with mechanical services, very few syllabuses, if any, cover the importance of lubricants in a specific way. The difference one blend versus another can make to machinery is incredible," he said.

At the company's Newport plant and laboratory, criteria such as specific gravity, neutralisation, moisture content, appearance, viscosity and solids content are all examined under laboratory conditions.

The company has formulated unique blends to suit specific requirements, for industries such as earthmoving, injection moulding, blow moulding, die casting, the transport industry, repetition engineering, general engineering, fork lifts and hydraulic equipment manufacture.

"Over the years, we have formulated approximately 200 different lubricants, some of such a highly specialised nature that many manufacturers swear by the R&T brand above all others," Mr Jones said.

Some engines using R&T blends go back to their first date of manufacture. One such organisation that falls into this category is the Pyramid Hill Pioneer Engine Museum. This organisation, maintained by dedicated enthusiasts, run their historic engines exclusively on R&T blends. Some of these engines date back to the early 1900s.

R&T will, if necessary, provide a back-up service on a regular monthly basis, topping up the oil where necessary.

Maintenance of mine equipment saves downtime

The biggest costs to mine production occur when equipment is not being worked. That's usually during strikes, wet, weather and equipment downtime. The latter is directly in the hands of the mines maintenance people and they need to quantify that cost in terms of dollars per unit per hour.

Consider a large open cut coal mine with daily production valued at $1,000,000 and a 10 piece fleet of coal haulers able to work 20 hours per day. If downtime in these units causes production bottlenecks, it is costing the mine $5000 per truck per hour! If a truck drops a valve and is down for 4½ shifts, that costs the mine $150,000. An engine swap perhaps $350,000-$400,000.

Brid Walker of Fuel Technology, Brisbane, has found that a great deal of equipment downtime is due to combustion problems.

While distillate is widely recognised as the major running cost in diesel fleet operations, it is also the most neglected. Walker says that to the majority of maintenance people, diesel fuel is a "black box item". Yet these same people recognise two facts:

- Diesel fuel has deteriorated in quality over the years.
- The performance of diesel engines has increased substantially.

So what happens when diesel fuel specifications limit the performance of engines?

The evidence of decreased combustion efficiency has been staring us in the face for years.

These days, there is a high incidence of increased — deposit formation, injection fouling, ring sticking, bore polish, high oil consumption, high oil soot, black smoke and valve failures.

There is also decreased fuel efficiency, and engine life.

Many of these symptoms are regularly perceived as oil related, because often higher quality oils and/or more frequent oil changes can reduce the problem. Additional filtration and use of detergent fuels (as offered by most fuel companies) can also reduce the severity of some of these symptoms.

However, Walker says "these are band-daid remedies to a combustion problem. Make no mistake about it, they treat the symptom not the cause.

Walker explained that extending the final boiling point of diesel fuel and increased secondary processing has affected combustion efficiency.

Recent oil analysis studies using the ferrous picrate combustion catalyst (a special type of fuel additive) have quantified reductions in engine wear rates, due to a clearner fuel burn and reduced accumulation of soot in the lube oil. According to Walker, "soot is a good abrasive — it works like valve grinding paste, only a bit slower."

Figure two graphically shows the response to catalyst treatment in a Cummins KTA 38 engine from a fleet of coal haulers. The wear rate is expressed as parts per million of iron per hour, and has been corrected for oil consumption.

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For this mine, the saving of just one valve failure has more than covered the cost of using the ferrous picrate catalyst for a whole year.

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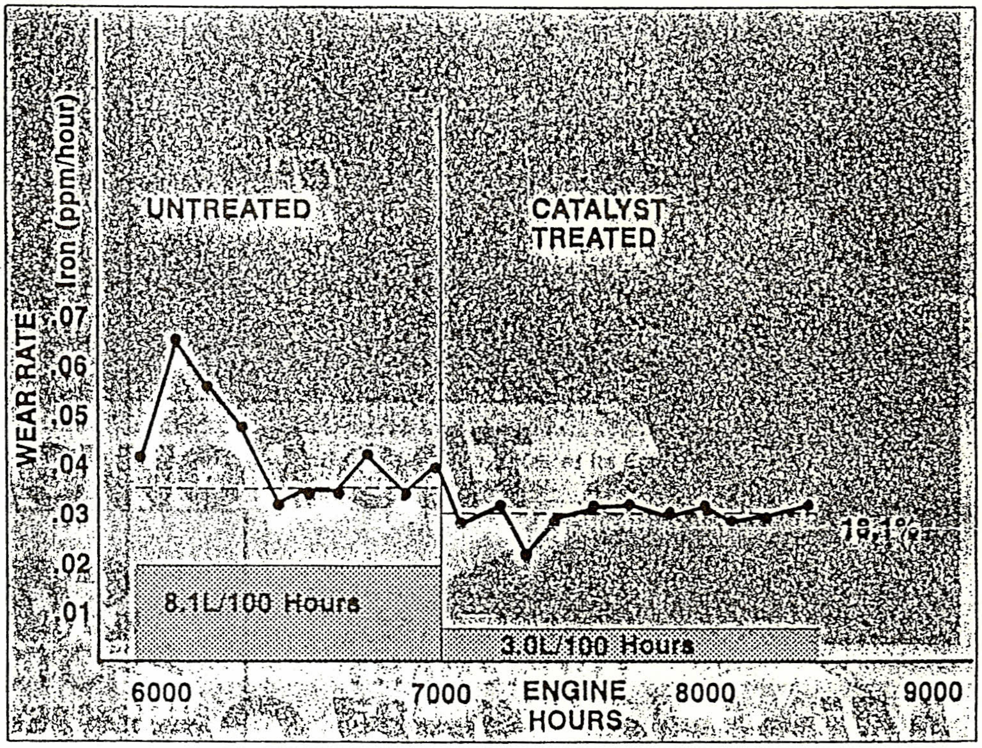

Figure one

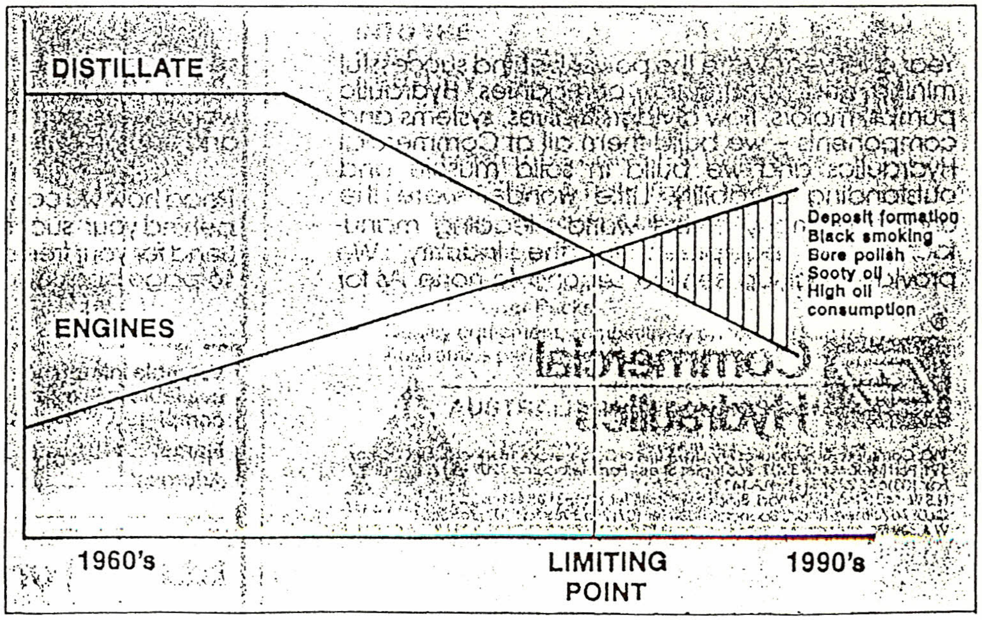

Figure two

Distressing gap between fuel standard required and that produced for modern engines

Brid Walker, of Fuel Technology Pty Ltd presents the second part of a series of three articles on identifying, understanding and correcting problems caused by diesel fuel.

Automotive diesel fuel can be contaminated when we buy it. What we formerly regarded as high-performance distillate may now incorporate various unwanted components. Further contamination occurs with handling and storage — mainly from slack housekeeping. Dirt, moisture, scale and microbes are not uncommon.

With time, fuel breaks down to release further contaminants, the rate of its decay increasing with the level of contamination. Sounds grim, and it is, especially if we're trying to make a profit using machines running on the stuff.

Fortunately, the remedies are mostly cheap and simple. They include better housekeeping practices, improving storage facilities and use of an **effective** fuel additive. If we do nothing the costs can be very high indeed, though the real cause of poor machine life and efficiency can remain well hidden from managers and accountants.

Consumption up

It's just as well the remedies are cheap: problems resulting from low quality fuel are increasing as production of Australian crude declines. To cope with our increased use of fuel, particularly diesel, more crude is being imported. The imported crude is not nearly as good for making quality diesel as the local crude.

Australia is using more diesel fuel than ever before. In 1960, diesel engines were much less common than they are now. There were still plenty of trucks and tractors running on petrol. In 1960 the ratio of petrol:diesel consumption was 5.5:1. By 1985 it was down to 1.9:1.

Today, the ratio is estimated at less than 1.7:1 and still falling. The ratio will continue to fall because of increased diesel consumption by transport, mining and other industrial activities, coupled with a strong trend to diesel-powered cars and light commercials.

Figures just released by the Australian Institute of Petroleum show diesel consumption is increasing by 4% annually; an alarming statistic, twice the figure predicted only 12 months ago.

Australia's level of crude oil self-sufficiency peaked at around 80% in the mid-1980s and is now declining. The Australian Minerals and Energy Council estimates that by 1990/1991 we will only be 55% self-sufficient. Australian refining and marketing companies expect a 45% increase in diesel fuel sales over the next 10 years.

But unless **major** new fields are found — and this is acknowledged as unlikely — domestic production in 1998 will be sufficient to supply only the Sydney and Melbourne metropolitan areas.

Some Australian-produced crude is exported. Since January 1, 1988 when the Federal Government deregulated the crude oil market, producers may also sell offshore. (Australian refiners may also sell their products overseas, but competition is fierce.)

Although the increased export is balanced by increased import, the net result is Australian machines must burn even more diesel derived from imported crude.

It's a sad situation, because our crude is one of the best for producing diesel without having to resort to secondary treatments. Our crude has an average 30% yield. Compare this to the 21% typical of imported stocks, which Ampol's research manager, Dr A J Clark, says are generally heavier, higher in sulphur and less suited to production of diesel. (The corrosive effects of burning high sulphur fuel were discussed in part one.)

How is Australia's increased demand for diesel fuel to be met? Refiners are today in an increasingly difficult position. They have two options if they are to meet today's demand for diesel: refine more crude; or attempt to squeeze more diesel from each barrel processed.

Refining more and more crude does nothing to improve production efficiency. It also ignores another of the refiners' problems. Having separated off the easily marketable products, refiners have to do something with the remainder.

Unfortunately for them, the market for residual products has decreased since 1984 (eg demand for fuel oil has dropped 30%), and this trend is expected to continue, leaving refiners with an excess at the heavier end.

Refiners can increase the yield from each barrel of crude by including in the fuel extra products obtained (a) by relaxing the fuel specifications, for example by extending the distillation temperature range, or (b) from secondary processing methods which convert some heavily residual components into forms suitable for including with distillate.

Extending distillation range

The traditional way to produce diesel fuel was by distilling the desirable fractions from crude oil. Thus the name distillate. Increasing the distillation temperature range increases the yield by including in the distillate some less desirable, heavier fractions.

Although a less homogeneous fuel is produced, some degree of balance is achieved through inclusion of LCOs (see below). At a recent conference of the Australian Institute of Petroleum, BP researchers AED Gunn in Australia and CJS Bartlett in the UK said extending the final boiling point just 30°C will increase diesel yield substantially.

Greater yield has a price. The heavier fractions include waxes which can raise the cold filter plugging point (CFPP) — the filter is clogged prematurely, at a higher minimum temperature than before. Also, substantial increases in density and viscosity may occur.

At the same conference, a service engineer at Caterpillar Australia, Marshall McKelson, said viscosity and density of diesel fuel can have important effects on engine operation. Since fuel is metered through injection systems on a volume basis, and density reflects the heat value, such variations alter the power output. Injection timing depends on fuel viscosity, which can affect the advance and hydraulic governor mechanisms.

Low viscosity causes leakage and excess wear, while high viscosity causes filter damage and pump wear (because of increased resistance). The higher the viscosity the worse the injector spray pattern, leading to reduced power and economy. Poor spray patterns also tend to wash cylinder walls, removing the oil film and causing excessive wear and dilution of the lube oil with fuel.

The Standards Association of Australia says that fuel of high distillation temperatures promotes increased deposit formations, wear and exhaust smoke. Full load tests on heavy duty direct injection engines have shown significant increases in black smoke for fuels with 90% distillations above 338°C. It is worth noting that current (1988) Australian Standards exceed this temperature (a 357°C maximum is allowed).

Secondary processing

Light cycle oils (LCOs) are made by splitting some of the heavier residual products by a process known as "catalytic cracking". LCOs have a few problems. They are carbon-rich compounds, highly aromatic with many single, double and multi-ring structures. They are also relatively unstable and do not burn well, so refiners limit the amount they include.

The cetane number of LCOs is of the order of 20–30, that is they have a long ignition delay. We've been fortunate to enjoy fuel of cetane numbers 50–55 in recent times and the new Australian Standard for diesel announced last year allows for a minimum of 45.

All Australian refineries now have facilities for mild hydrotreatment of LCOs, which is a process of adding hydrogen atoms to break most of the double and multi-ring molecules to give single-ring molecules. This process helps stabilise the mixture and removes a deal of sulphur, replaced in the molecule with hydrogen.

Unfortunately, mild hydrotreating has little effect on the cetane rating. It is possible, through a process of severe hydrotreating, to fully saturate these compounds and raise the cetane number to that of specification diesel. At this stage the cost is prohibitive, although this clearly remains an option for the future.

Even when hydrotreated, LCOs are still quite carbon-rich. Carbon-rich fuels are strongly associated with deposit formations and their degradation can lead to filter blockage, injector fouling and further loss of combustion performance.

The higher aromaticity due to LCO inclusion is associated with increased black smoking. Also, LCOs are one of the main contributors to production of gums and insoluble particles, through a variety of reactions (eg oxidation, polymerisation and esterification).

Modern engines

Modern diesel engines need high-quality fuel. Engine manufacturers aim for high fuel efficiency, high reliability and extended maintenance intervals. They also have to meet new levels of exhaust emissions. Most engines built today for the mining and transport industries are turbocharged and intercooled, with a trend to electronically controlled fuel injection, much higher injection pressures and faster delivery of fuel.

Injector orifice sizes will probably become even smaller to aid misting. Turbocompounding and the use of ceramics are also likely to be considered by engine manufacturers seeking improvements in engine design.

All very impressive, but why pay for the last word in engine technology unless you can take advantage of it with good fuel.

The very best diesel engines today are about 44% efficient. Theoretically, 50% efficiency is obtainable but this needs a high performance fuel.

The fuel must also burn fully and cleanly, and part three of this article covers a somewhat neglected area of technological development — fuel combustion and the truly exciting headway made in combustion technology.

A striking example

In the name of engine efficiency, some engine manufacturers have repositioned the top compression ring closer to the piston crown, thus reducing combustion space. The build up of carbon on the top land and ring grooves can be rapid.

Contact of these deposits with the cylinder wall causes areas of "bore polish" as the abrasive deposits wear away the cylinder cross-hatch. The problem worsens with ring sticking, increased oil consumption, blow-by, further deposits and thickening of the lube oil with soot, which rapidly exhausts the oil's cleaning effect and increases abrasive wear.

These are classic symptoms of a combustion problem. Despite this, it is a fair bet that in 95% of cases, the lube oil is the first thing to be blamed for the problems! Changing to an oil with better detergency/dispersancy qualities will help, but is a band-aid remedy.

The future

We can expect our fuel to suffer the following changes: amount of LCO inclusion, cold filter plugging point, distillating range, sulphur, viscosity, particulate matter, and density all to increase, and cetane number to decrease.

Not one of these changes is beneficial to users.

We can expect increased use of imported crudes, with more products of catalytic cracking and extended distillation temperatures included to increase the yield of diesel from each barrel.

The fuel companies will continue to do their best, but there seems to be a widening gap between the fuel standard required by modern engines, and that being produced. Fuel contamination and degradation during user handling and storage further aggravates the problem.

Our company believes it would be eminently intelligent for equipment users, engine manufacturers and fuel producers to work together, accepting compromises where necessary. Is this likely to happen?

Perhaps it doesn't matter, since developments in combustion technology have provided another solution able to satisfy the aims of all three parties. This will be discussed in part three.

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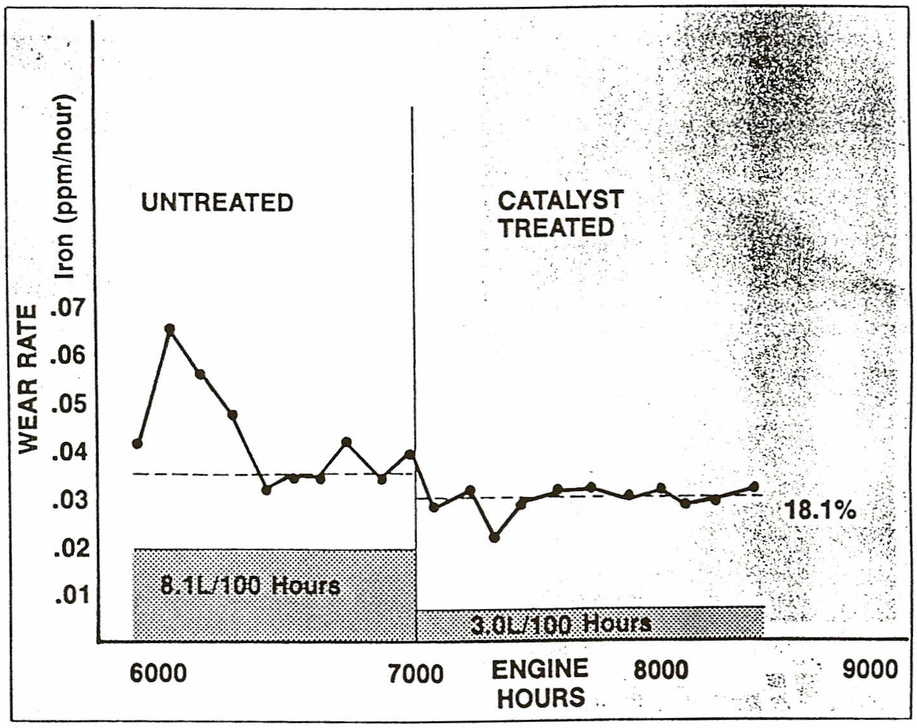
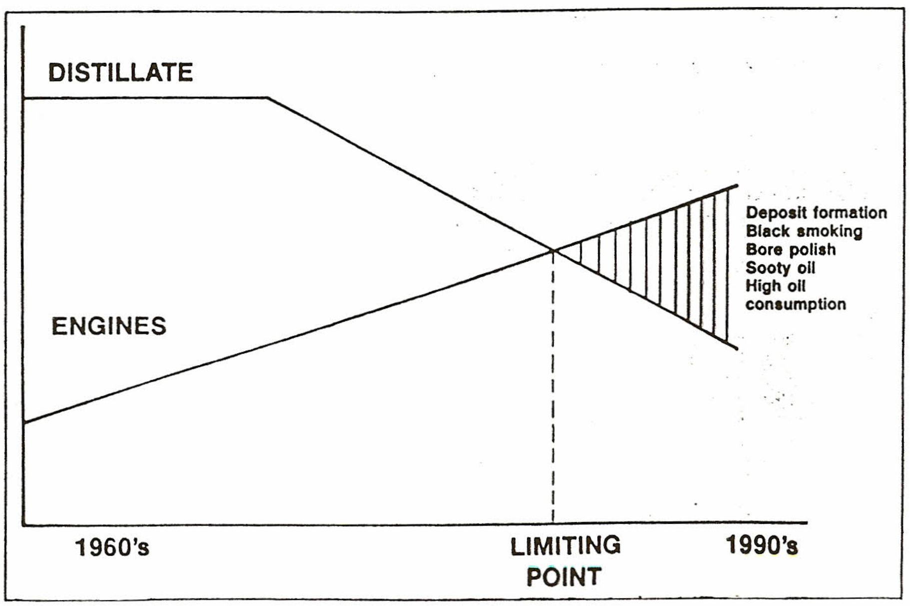


Figure one



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