Low sulphur MGO myth

Ralph Lewis looks at the issues surrounding low sulphur fuels and lubricity

With just five months to go before the 1 January 2010 start-date for the European Union (EU) rule mandating consumption of 0.1% sulphur content marine gasoil (MGO) in port, shipowners are investigating all options to ensure that auxiliary diesel engines and boilers will safely accommodate the new fuel.

Fortunately, the EU mandate is only for vessels at berth. For vessels calling on California ports, the **California Air Resources Board** (**CARB**) now mandates that vessels must operate on a 0.5% sulphur distillate fuel no less than 24 nautical miles (nm) from port, a standard that requires a transition for main engines operating on heavy fuel to the new low sulphur distillate fuel.

To what extent are shipowners ready? Are the precautions and procedures issued to date from engine makers and pump manufacturers sufficient for safe and trouble-free operation? And for vessels that are already consuming the 0.1% sulphur fuel, what problems, if any, have developed?

In this article we will look at these questions and investigate low sulphur MGO, and why the refining process used to produce it, can create serious deficiencies with adverse consequences affecting vessel operation. We will also review widespread misconceptions about the impact of these fuels on proper fuel pump lubrication, and the available remedies. Finally, we will discuss the successful use of low sulphur distillates in the United States the past 20 years, where shipowners and fuel suppliers have been using a proven additive technology for lubricity and performance benefits.

The primary concerns about low sulphur MGO have focused on four areas:

- viscosity: low sulphur distillates have relatively low viscosity, ranging from 1.5 to 3.0 centistokes (cst). Fuel pumps depend upon an appropriate viscosity to meet required volumetric capacity, an especially important consideration in maintaining proper feed rates to boilers
- lubricity: the 0.1 % sulphur MGO has greatly reduced lubricating value for fuel delivery systems. The naturally occurring lubricating components in heavy fuels, and in 1.5% sulphur distillate fuels, simply do not exist in 0.1 % sulphur MGO fuels – exposing pumping systems to damage and potential catastrophic failure
- lubricating oil: engines operating on heavy fuels require a higher total base number (TBN) lubricant to address high sulphur content. Unless the lubricant is changed to a lower TBN, engines operating for extended periods on 0.1% MGO still using a high TBN lubricant run the risk of accumulating excessive calcium salt deposits in the combustion chamber, among other damages
- boiler operation: for vessels with auxiliary boilers, considerable modification to these units must be made, including changes in burners, atomisation, and installation of additional fuel pumping and storage equipment.

Our focus here is strictly with the first two issues: viscosity and lubricity. While engine and fuel pump manufacturers still continue to evaluate these areas, most have now issued minimum standards for fuel viscosity and specific recommendations for the process of changing from heavy fuels to MGO during vessel operations. But many questions remain, and in some discussions, assumptions are still being widely circulated that may possibly put vessels at risk.

One common assumption is that it is sulphur, and sulphur only, that is responsible for providing fuel lubricity. A second assumption is that cooling a fuel to elevate viscosity will provide a thicker, oily film on moving parts that will protect fuel pumps and injection equipment from excessive wear.

With apologies to George Gershwin, 'it ain't necessarily so'.

In the United States, for example, low sulphur diesel fuels have been mandated for automotive use for nearly 20 years, first with a 500 parts per million (ppm) – or 0.05% – sulphur fuel, and now, with a 15 ppm fuel known as ultra low sulphur diesel (ULSD). While low sulphur fuels may be new to international shipping, the operational experience on both high and medium speed diesel engines on these fuels in the US is longstanding.

After the 1990 introduction of 500 ppm sulphur fuel in California, serious problems immediately developed. Some fuel injection

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pumps suffered catastrophic failure. Others experienced excessive wear and severe leakage, with seals shrinking owing to the reduced aromatic content of the fuel.

So petroleum chemists donned lab coats and got busy, eventually amassing a considerable body of evidence about the chemical characteristics of these fuels. Some of the early assumptions about the nature of the fuels proved wholly incorrect.

In 1991, following a spate of fuel pump failures on military vehicles in *Operation Desert Storm*, the **United States Department of Defense** (**DoD**) commissioned a study to determine the cause. Texas-based **Southwest Research Institute** (**SWRI**) conducted wear tests on the fuels, all of which shared identical viscosity under a stringent military specification. As it turned out, viscosity had little to do with lubricating quality. Rather, the capability of a fuel to lubricate was far more the result of the specific refining process from which it was produced.

Then in 2000, researchers for the **Esso Petroleum Company**, the UK-based subsidiary of **Exxon**, confirmed what many had previously suspected: that sulphur itself is not responsible for lubricity. Rather, they identified trace amounts of polar compounds of nitrogen and oxygen as the critical components in providing lubricating benefit. Unfortunately, the severe hydrotreating process that removes sulphur also strips out these key polar compounds.

Today, the lubricity quality of any distillate fuel can be measured with the *High Frequency Reciprocating Rig* (*HFRR*) method. In this test, a steel ball submerged in the fuel is vibrated against a steel plate under pressure for 75 minutes. The scar wear in the steel ball is then measured to determine the extent to which the fuel provides lubrication.

The present *ASTM* standard of 520 millimetres (mm) wear is deemed acceptable for fuel pump systems designed for high speed diesel engines operating on ULSD in the United States. But many disagree with the standard. The **Engine Manufacturers Association** (**EMA**) states that a wear of 460 mm is more appropriate, and this is a standard now widely accepted in Europe for high speed automotive diesel engines.

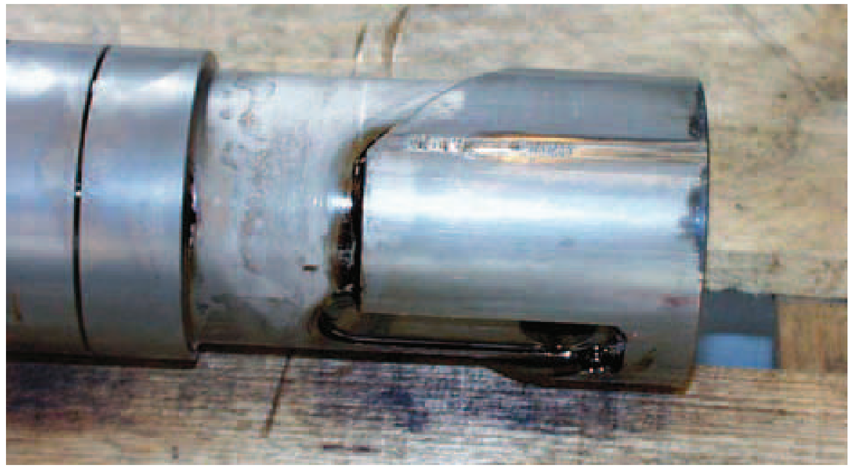
But what of a standard for fuel systems originally designed to handle the much higher lubricating value of heavy fuel oils? **MAN Diesel** is studying the issue, yet to date, has drawn no conclusions.

'We are still working on a correlation between HFRR and actual effects on fuel pumping systems designed for commercial ships,' says Kjell Aabo, a director at MAN Diesel. 'We have the obligation from the **ISO 8217 Working Group** to solve this and report back for the introduction of a standard.'

So the jury is still out. But it does seem likely that a scar wear rate well below that of the 460 mm standard will likely will be more appropriate for systems originally designed for lubricity quality even higher than that found in normal distillate fuels.

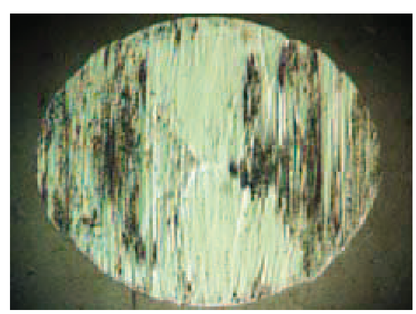
Problems are already occurring. One Greek cruise line owner operating vessels on 0.1% sulphur MGO reports that 'while the engines seem to tolerate this fuel, we have had a lot of headaches with constant fuel pump plunger sticking'. And just a day after the new CARB mandate took effect on 1 July, a US-based cruise ship operator reported fuel pump failures after operating on the CARB mandated fuel for just a few hours. Reports have also surfaced that not all of the fuels supplied in California ports have a 0.5% sulphur content – but rather – are the same 0.0015 % ULSD fuels mandated for onshore use.

CARB's Paul Milkey advises that vessel operators need not suffer. He frequently



Fuel pump plunger sticking can result from the use of a 0.1% MGO with poor lubricating properties. (Photo courtesy of MAN Diesel)

The High Frequency Reciprocating Rig (HFRR) quantifies the extent to which any distillate fuels provide lubricating value



Scar wear in a steel ball subjected to the HFRR test is measured to determine the lubricating property of a given distillate fuel reminds technical managers that both onshore and offshore diesel engine operators have successfully coped with low lubricity fuels in California for almost 20 years by dosing the fuels with appropriate lubricity additives.

In fact, not long after the first low sulphur fuels were introduced in California, fuel suppliers and end users began to make regular use of these specialised fuel treatments.

One proprietary blend, the *PRI-D* lubricity/stability treatment, has been protecting thousands of commercial marine vessels in the United States since it was introduced in 1989. Among them are fleets of oceanographic research vessels, self-propelled semi-submersible drilling rigs, commercial and recreational fishing vessels, harbour equipment for the ports of Los Angeles and Long Beach, and standby generators for San Diego's San Onofre nuclear power plant.

Still thousands more are protected against the ravages of low lubricity, thanks to bulk treatment of marine fuels with PRI-D by commercial fuel distributors throughout the United States. And now shipowners who have been applying the *PRI-RS* heavy fuel oil treatments for many years are dosing MGO tanks with PRI-D on larger commercial vessels to safeguard systems.

Formulated to handle even the most severe ULSD fuels, PRI-D offers a level of protection not available with conventional lubricity treatments. This is well established in HFRR testing with PRI-D treated samples of ULSD taken from various regions across the United States. Reduction in scar wear varies from 30% to 45%, with the average reduction more than 242 mm, a very high rate of protection.

Shipowners should also be aware that the specific chemical type of lubricity additive used can have far reaching implications for safe, long-term engine operation. PRI-D technology, for example, incorporates a safe and highly effective aliphatic ester chemistry. But many lubricity additives employ a carboxylic acid type material that can have far-reaching consequences.

In 2001, **Exxon Chemical Ltd** conducted an extensive study of various lubricity additive technologies. Results are available in a **Society of Automotive Engineers** (**SAE**) paper authored by Rinaldo Caprotti, and an online summary is available at: www.sae.org/automag/harmfree/index.htm.

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Caprotti found that while lubricity additives can be beneficial in providing lubrication benefits, some of the carboxylic acid chemistries can produce adverse long-term effects, including; fuel filter plugging, increased levels of engine bore polish, and 'deactivation' of other additives designed to improve fuel performance. Fortunately, these negative effects do not occur with the advanced technology of PRI-D.

Improved lubricity, an extremely vital benefit, is only one of the primary functions of PRI-D. The second capability, enhanced thermal stability, is also mission critical for all hydrotreated, low sulphur fuels.

Wärtsilä, for example, warns of reduced thermal stability with low sulphur MGO. Poor thermal stability, after all, can result in excessive smoke, particularly at reduced engine load ranges. **Det Norske Veritas Petroleum Services** (**DNVPS**) has also issued statements cautioning vessel owners that these fuels may offer increased problems with instability, incompatibility and reduced ignition quality. MAN Diesel recommends that vessel operators should consider conducting a compatibility test on heavy fuels and the MGO to be blended before changing over to the MGO at sea, warning that 'when switching from HFO to a distillate fuel with a low aromatic hydrocarbon content, there is a risk of incompatibility between the two products'.

Again, these problems are the direct result of the hydro-desulphurisation process, which not only greatly reduces the aromatic content responsible for ignition quality and physical stability, but also removes many of the natural anti-oxidants responsible for maintaining thermal stability for better deposit and particulate emissions control.

Thermal stability may also be compromised in many low sulphur distillates when a refiner chooses to introduce 2-ethyl-hexyl-nitrate (2-EHN), a nitrate-based cetane improver, used to compensate for the poor ignition quality associated with hydro-treatment. Lacing fuels with 2-EHN is a universal practice among US refiners manufacturing ULSD, and will likely be used in many cases to upgrade reduced cetane value in 0.1% MGO.

Yet when 2-EHN treated low sulphur diesels were introduced in the US in 1990, some automotive diesel operators observed increased fuel filter fouling and, over time, excessive exhaust stack smoke. Studies conducted by John D. Bacha and D. G. Lesnini of **Chevron Products Co.** soon discovered that in many distillate fuels, the addition of a nitrate-based cetane improvement additive actually accelerates degradation of thermal stability, resulting in the associated problems of increased smoke, fuel filter plugging and reduced performance.

Internationally, PRI-D has been successful in greatly improving thermal stability in a wide range of distillate fuels, from on-road diesel fuels in China, to petroleum naphthas in Korea, as well as conventional diesel fuels in India and Vietnam. Standard *ASTM D2274* stability tests show substantial improvement in thermal stability in all distillate fuels treated with PRI-D, regardless of initial fuel quality or source. And with these enhancements come other proven benefits in the areas of fuel performance and emissions reductions.

Environmental Protection Agency (**EPA**) heavy duty diesel transient test cycle studies at SWRI on low sulphur distillates confirm that PRI-D not only reduces particulate emissions, but also provides an improvement in fuel efficiency and horsepower as measured by grams per brake horsepower hour. These same tests have also verified PRI-D chemistry capability to effect reductions in NOx and unburned hydrocarbon emissions.

In the field, studies at a **Southern California Edison** power plant equipped with a state mandated continuous emissions monitoring system showed an average 8.8% nitrous oxide (NOx) reduction with the use of PRI-D. Similar levels of NOx and unburned hydrocarbon reductions with PRI-D were again verified in a year-long study conducted on a semi-submersible drilling rig based in the Gulf of Mexico. In high speed diesel engines, results are almost identical, with CARB 13-mode testing verifying the products capability to reduce NOx and carbon monoxide (CO).

In summary, the issues of poor lubricity and degraded thermal stability associated with low sulphur distillate fuels have been successfully addressed in thousands of marine applications with PRI-D since 1989, protecting fuel pump systems from excessive wear and failure, while providing superior deposit control and emissions reductions benefit. So ship operators need not worry. The experience base is vast, and the benefits of PR-D are well documented.

But I must add one note of caution. Refiners are not permitted to inject lubricity additives into fuels. Aircraft engine manufacturers have objected to this practice, recognising that lubricity chemistry leaves trace amounts of residue in pipelines that are shared for transportation of aviation and all other distillate fuels. Hence, lubricity treatment is either injected at onshore fuel distribution terminals, or end users conduct their own treatment programmes. Since most marine fuel suppliers to large commercial ships receive fuels directly from the refinery, it will be incumbent on shipowners to dose MGO tanks when bunkering to ensure adequate protection.

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