

Early Experiences and Future Challenges: Post 2020 Engine Lubricants

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Lubricants

Four stroke engines

In general, four stroke OEMs did not specify significant changes in BN for VLSFO operation. Typically, a reduction by 10 BN has normally been suggested and recommended but is not a mandatory option. It means that continued operation at the BN level used for HSFO is unlikely to result in operational problems. The link between BN and detergency has been the principal concern for four stroke OEMs and hence the reluctance to require and specify lower BN crankcase oils. Currently the major OEMs specify BN levels between 20BN and 30BN but noting that 40BN is also acceptable in most applications.

Two stroke engines

In the recent past, the major change in marine lubricants has been with two stroke cylinder oils. Longer strokes combined with slow steaming - resulted in cold corrosion and a need for a higher BN than the traditional 70 BN. Gulf Oil Marine has developed approved 100 BN and 140BN cylinder oils. As well as the elimination of cold corrosion, the high BN cylinder oils resulted in extremely clean ring packs. In many cases we have virtually no deposits on the first ring land. This is a location in the past where there have been some deposits. Ring grooves and backs of rings also remained clean with minimal deposits.



*Typical piston ring land condition operating with 100BN.
WIN G&D 7RT flex82T - 340cSt & 2.5%S*

The drop from an average fuel sulphur content in bunker from 2.7%S to 0.50%S means it is no longer required to have a high BN for neutralizing acid to any significant extent. In fact, it was not unusual in the 1960s and 1970s for on road diesel fuel to contain 0.4%S. Typical engine oils at that time required only 15BN to neutralize the acids albeit these were four stroke applications.

Noting that the benchmark for liner and ring pack cleanliness performance has been achieved using 100 BN cylinder oils, the industry has chosen reformulated 40 BN cylinder oils for VLSFO.



Figure 1 - Typical SDA reported recently for a 6G80ME-C9.5, Fuel 0.48%S & SFR 1.2g/kWhr

Analysis / Unit No.	1	2	3	4	5	6
BN [mgKOH/g]	30.7	36.0	24.1	31.5	36.5	38.8
Iron [ppm]	23	122	32	23	81	41

Figure 2 -Typical SDA reported recently for a 6RT-flex58T, Fuel 0.44%S & SFR 0.9g/kWhr

Analysis / Unit No.	1	2	3	4	5	6
BN [mgKOH/g]	27.3	30.3	30.1	24.3	29.3	29.3
Iron [ppm]	25	28	29	17	22	31

Figure 3 - Typical SDA reported recently for a 6S60 ME-C-8.2. Fuel 0.30%S & SFR 1.1g/kWhr

Analysis						
BN [mgKOH/g]	33.0	33.1	32.2	29.9	31.4	31.2
KV@40°C [mm²/s]	258.0	251.0	247.2	236.3	238.1	224.9
KV@100°C [mm²/s]	22.50	22.25	22.01	21.59	21.35	20.95

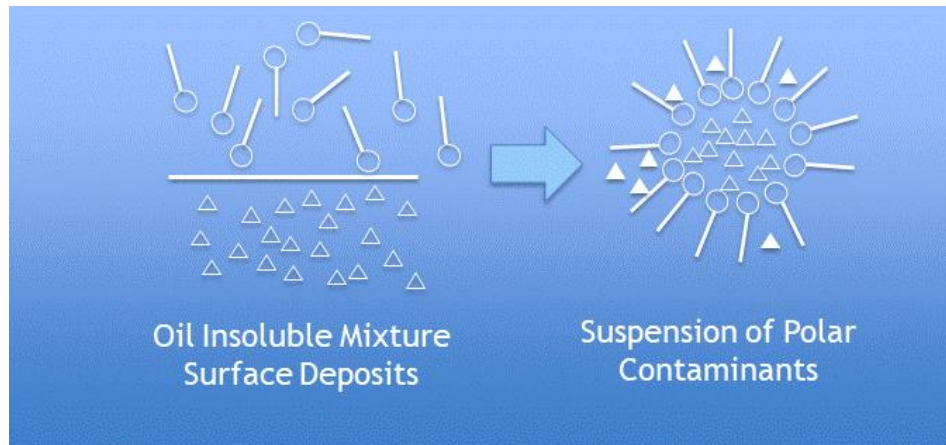
Figure 4 - Typical SDA reported recently for a 6S60 MC-C. Fuel 0.49%S & SFR 0.65g/kWhr

Analysis						
BN [mgKOH/g]	38.0	38.1	38.1	38.7	39.8	38.0
KV@40°C [mm²/s]	226.3	226.3	248.7	265.2	225.1	210.0
KV@100°C [mm²/s]	20.53	20.80	22.50	24.00	19.98	19.63

This provides more than sufficient acid neutralization performance as well as retaining some detergency from the core additive, which is a metallic over-based soap. However, the core additive at 2/5 the treat rate of the 100 BN cylinder oil does not provide sufficient detergency even for fuels with a lot less residual component and often a fuel that is, or nearly is pure gas oil. Thus all 40 BN VLSFO cylinder oils have had to be reformulated to enhance detergency and dispersancy performance with novel compounds which for economic reasons were previously not used in marine cylinder oils.

Detergents control deposits formed at high temperature as a consequence of thermo-oxidative degradation of fuel, lubricant oil and other extraneous contaminants. These compounds (detergents), are surface active and act to prevent deposit formation on surfaces such as piston ring lands.

Dispersants function to keep the contaminants in suspension preventing them from agglomerating into bigger particles. Dispersants contribute in synergy with detergents to high temperature deposit control, maintaining the overall cleanliness by keeping 'dirt' precursors in solution.



Detergents & dispersants

In general detergents and dispersants are highly polar compounds with a long tails. The electronic charge of the polar end “fixes” to surfaces and to particles whilst the tail enables the compounds to maintain solubility in the cylinder oil

Liner/ ring pack performance requirements

The ULSFO and VLSFO do not necessarily result in improved combustion when compared to HSFO. In all cases marine two stroke diesel engines had been developed to handle the most difficult residual fuels with ease. Combustion performance therefore in nearly all cases of problems varies very slightly at the margins resulting in slightly delayed ignition, slightly late burn, slightly higher incomplete combustion, higher combustion temperatures, higher peak temperatures; effects that cumulatively have the potential to impact liner and ring pack performance. The key performance parameters of concern to the OEMs are

- liner surface deposits – may promote liner surface corrosion
- crown and ring land deposits – indicates poor deposit control
- ring groove deposits – ring stick
- ring back and back of groove deposits – ring jamming

WIN G&D has specified ceramic coated rings for several years. With the advent of engines operating on low sulphur fuels MAN ES noticed an increase in the frequency of the reporting of liner scuffing. MAN ES has concluded and now specifies the use of ceramic coated rings which have a harder surface are much more resistant to micro-seizure (scuffing) under marginal lubrication conditions. Both OEMs have also revised the height of the crown land (so call high land pistons) and both OEMs specify gas tight rings. MAN ES has also recently revised the ring pack ring heights and reduced the number of piston rings to three.

In the case of replacing conventional rings with Cermet coated rings there is a choice of either a three ring configuration or the previous four ring configuration. MAN ES highly recommend the new three ring configuration which if utilised on an older design piston requires the bottom ring groove to remain unused. These design changes have improved the liner/piston ring running conditions and are said by MAN ES to have eliminated scuffing problems when running of VLSFO and ULSFO and 10ppm diesel.



It should be noted that cylinder oil cannot resolve all combustion conditions and all causes of liner and ring pack fouling. If the fuel is unsuitable due to extremely poor combustion characteristics or it contains cat fines or some other unacceptable performance parameter then there will be inevitable consequences for the liner and ring pack. In the case where a cylinder liner problem becomes apparent it is important to take SDA samples immediately and to undertake frequent scavenge port inspections of the liner and piston conditions.

Mild scuffing caused by cat fines can often be recovered. But immediate action is needed to eliminate the cause of the scuffing. Usually this means checking the centrifuge setup to ensure that it is operating and the optimum temperature, flow rate and oil/water interface diameter. To be most effective the day tank fuel should be transferred back to the settling tank leaving a minimum reserve for main propulsion and auxiliary power if operating a Uni fuel ship. To assure that the fuel oil centrifuge is operating correctly, a before and after fuel oil sample should be sent ashore for analysis of cat fines concentration.

Engine load should be reduced to no more than 50% load and the cylinder oil feed rate increased to maximum (around 1.4g/kWhr). Gulf Oil Marine has assisted in such circumstances and in all cases the liner conditions have been improved and returned to an acceptable condition after about 500 running hours. There is no hard and fast rule on this and in some cases catastrophic wear may occur which will involve replacing all the piston rings in the engine and honing all the liners, or in the worst-case replacing liners.

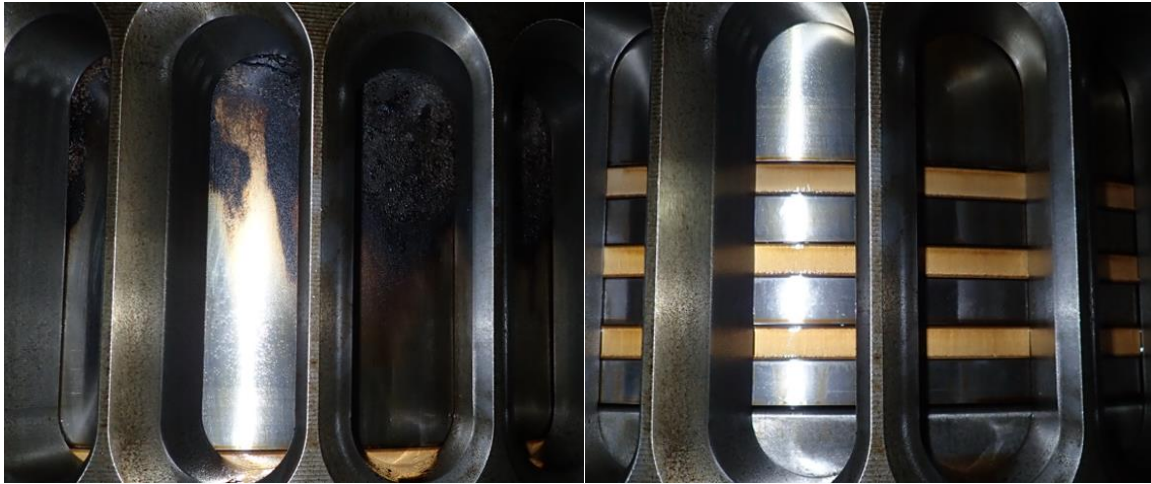
In the case where apparent poor combustion conditions have resulted in piston land and ring groove deposits and possibly black patches on the liner the use of a higher BN cylinder oil can often assist in returning liner conditions to normal. This is not guaranteed and, in some cases, deposits may be of a nature that they cannot be fully removed by this option. In which case careful observation should be practised to assess whether the deposits are affecting the ring pack movement and rapid wearing of the ring coating or ring jamming and breakage.

Future expectation in cylinder oil detergency and dispersancy performance

As the severity of combustion conditions has increased, especially with gas fuelled engines there will be increased demand from the diesel engine OEMs for much higher performance detergency and dispersancy, whilst the neutralisation capability of lubricants will become secondary or almost irrelevant. Traditionally the well-recognised designation of cylinder oils by their viscosity grade and their BN has provided a degree of comfort and some level of understanding as to the suitability and performance of the cylinder oil.

In future the ability to keep the piston and ring pack clean will be the benchmark by which cylinder oils will be deemed suitable. Unfortunately, there is no consistent laboratory test or other measurable parameter that can provide a designation of a cylinder oils cleanliness effectiveness. Currently the only way a cylinder oil performance can be judged is by monitoring how it performs in an engine. The following pictures indicate the best in class performance for piston and ring pack cleanliness. The picture below shows the performance of an average current cylinder oil. The latter will not be an acceptable performance within the next two or three years.

The high performance bench mark product utilise non-metallic detergents with very high surface activity and thermal degradation resistance and more novel high-performance dispersants. All in all, such formulations come at a considerable component cost. Until recently the move to the benchmark product has been resisted as the market is perceived unwilling to take on the additional financial burden of the improved performance. It is forecast that this economic resistance must change, otherwise ships will be sailing with non-approved cylinder oils.



The benchmark cleanliness standard expected by OEMs for piston ring and piston condition



Typical appearance of current cylinder oil operated under the same conditions as the candidate

Approval of 40 BN VLSFO cylinder lubricants

Gulf Oil Marine commenced OEM approval trials of 40 BN cylinder oils in 2019. Like other marine lubricant marketers' trials were conducted on ships operating cabotage trade in China. China had imposed a 0.5%S fuel requirement for their local fleet on the 1st January 2019.

Approval trials run for 4000 hours with periodic visual inspections, periodic SDA sampling and pre and post-trial liner and piston inspections.



MAN ES cylinder oil approval trial

Trial vessel operating on cabotage service in the waters of the Peoples Republic of China

The trial engine a 6S50 ME-C had a total operating hours since start of trial of 1,293 running hours



WIN G&D cylinder oil approval trial

Trial vessel operating on cabotage service in the waters of the Peoples Republic of China

The trial engine a 6 RT Flex 48T-D had a total operating hours since start of trial of 4,128 running hours



DE side



fuel side



exh side



free end side



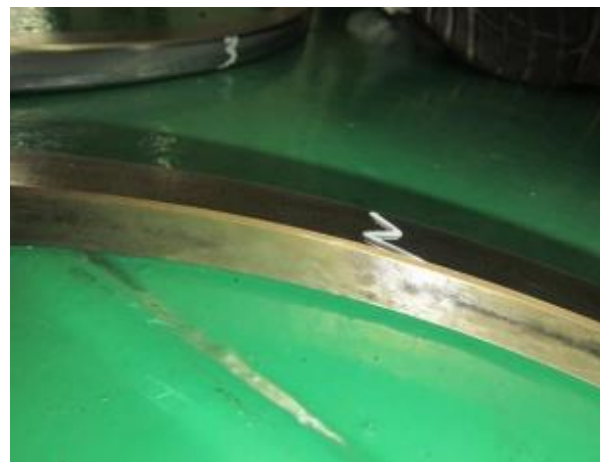
A&B grooves: upper half deposit EXH-FE side



C groove: almost no deposit



Deposit behind A ring: minor



No deposit behind B ring

Gulf Oil Marine now has approvals from all 2 stroke OEMs for GulfSea Cylcare 5040. The reformulated GulfSea Cylcare 5040 is now available on a global basis in all key ports.

Future outlook for cylinder oils

In the current global situation, almost certainly short-term fuel prices will drive different decisions on blending VLSFO. In fact, the glut of clean products may result in declining financial incentives to blend VLSFO and instead straight gas oils may be supplied. Gas oils may be more consistent in properties than VLSFO blends, however if they are not trouble free. Continued use of the ship's SIP to manage bunker procurement, on-board storage and handling is essential. Gas oils are equally capable of causing piston deposits and high performing cylinder oils will be required.

Two stroke engine development continues apace albeit new ship-building orders are currently very low. At least 50% of new engines are being ordered NOx Tier III compliant. This means they are fitted with SCR or EGR. Both systems have sensitivities to exhaust gas constituents' such as metal ash, oxidized and part oxidized hydrocarbons. This is a further and new performance requirement that cylinder evolution will have to take into account in future



formulation development. In general exhaust gas after-treatment will become an increasingly important requirement to address air quality concerns.

IMO EEDI targets continue to force more efficiency. The two-stroke engine design will see even higher peak and mean effective pressures in the combustion space as well as other design changes to reduce friction and improve overall thermal efficiency.

The range of fuels being trialed, and in some cases becoming established, will continue. It will require cylinder oils to be specially formulated for phenomenon such as ash/deposit control which is very prevalent in gas engines, high temperature performance, also prevalent in gas engines, high alkaline conditions, such as when using ammonia as a fuel, etc.

There is no such thing as a "clean fuel". The act of combustion creates a myriad of compounds and effects which have to be managed by the engine and cylinder oil design. Gulf Oil Marine recognizes these future challenges and is currently working on them through our product development programs.

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