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Cylinder Lube Oil Improvement With New Ashfree Neutralizing Molecules

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1. Introduction

Cylinder Lube Oil (CLO) are increasingly expected to provide more and more basicity and to offer an overall better performance. Lubricants are expected to support new two-stroke engine technologies designed to minimize Specific Fuel Oil Consumption (SFOC) by increasing combustion pressure; whilst at the same time vessels' variable operating conditions are promoting acid condensation, and NO_x Tier III regulation requires additional emission control systems to be in place.

This explains the trend to increase CLO basicity reserve over the past few years, which has seen CLO basicity for engines burning high sulphur Heavy Fuel Oils (HFO) rapidly moving up from BN70 to BN100. But is there any indication that it could stop here?

Users have another option – to increase the Lube Oil Feed Rate (LOFR). This enhances the safety margin, avoiding corrosive wear in engines that are still very sensitive to the notorious phenomenon, cold corrosion. But is the increase of LOFRs really a long-term option for ship operators mindful of the need to reduce vessel running costs?

The time for a new approach in lube technology has arrived. The economic outlook for the shipping industry overall continues to remain negative. The increasing variability of operating conditions and range of fuel mixtures require ever more skill on the part of crews, who are not always sufficiently trained to deal with all the engine management situations they encounter. Engine lubrication is only one of several complex aspects of ship operation, but critical from a risk perspective. According to the Swedish Club, the average cost per claim in cases of lubrication failure is $926,000.

There is currently a need for swift, united action on the part of lube oil suppliers, engine manufacturers and users to create, supply and use simple, flexible lubrication solutions. Reliable engine lubrication, even when administered via modern electronic lubricators requires selection of a fit-for-purpose CLO. The performance of many available products on the market raises questions regarding quality and suitability. There is a great opportunity to bring new solutions to market and a definite need for them – otherwise the environment for end users could quickly become much worse and more confused.

By changing CLO chemistry and substituting a significant proportion of the conventional calcium detergents with new, patented Ashfree Neutralizing Molecules (ANM), we can now provide more efficient basicity, dramatically enhancing thermal resistance and detergency ability, also extending the operating range of the product. With these changes, the risk of corrosive wear is greatly reduced and engine cleanliness significantly increased.
ANM offer the market the ability to lubricate engines using high sulphurized HFO (up to 3.5%) or ultra low sulphur distillate fuels (less than 0.1%), , without requiring higher BN specification and with enough room to minimize the LOFR with sufficient operational safety margins.

2. Advantages of the new chemistry

ANM are pure organic molecules of high basicity – some have over 300 mg KOH/, enabling the formulation of high BN finished lube oils with a reasonable treatment rate of additives. The great interest in substituting the conventional basic species – mainly calcium based detergents including calcium carbonate ($CaCO_3$) by the ANM, is to significantly decrease the risk of deposit build-up. As shown on figure 1 the balance between the mineral components ($CaCO_3$) and the organic components is deeply changed. As an example, the calcium content of BN100 CLO using ANM is lower than the calcium content of conventional BN40 CLO.

As the mineral source of deposits is reduced, so the potential risk of fouling the piston-ring pack or cylinder liner surface is also decreased. This decrease is not only proportional to calcium content but also linked to the extraordinary capability of ANM to maintain engine cleanliness. Hence with ANM we are now talking about low ash content CLO and we can also figure out a wider spectrum of CLO usage when considering the fuel mix for actual shipping operation.

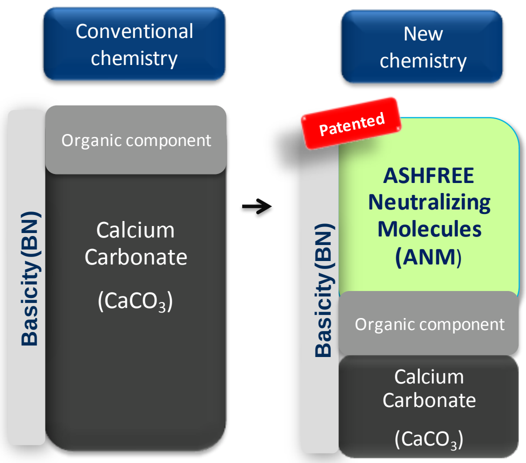

Figure 1 – Structure of formulation for basicity components

3. Laboratory bench testing

To achieve well balanced CLO formulation with improved performance, we had to overcome several challenges, including demonstrating the capability and reliability of new components. A rigorous laboratory bench testing protocol, comparing regular chemistry to ANM chemistry was applied to characterize the most important properties and to optimize the balance of the various additives and base oils formulated.

The demonstration of the perfect miscibility and compatibility, in all proportions, of ANM with conventional calcium detergents was the first testing duty completed.

Then it was shown with in-house tests measuring neutralization speed[1], that the ratio between temperature increase and reaction time – also known as the 'neutralization index', when adding sulphuric acid 75% to BN70 CLO, was increased from 100 to 214 when using ANM formulation. This neutralization efficiency also explains another exceptional result obtained from in-house corrosion tests already described[2].

Figure 2 shows the statement of cast iron plates that have been immersed in a heated mixture of BN100 CLO and sulphuric acid 75%. Plates 1 (conventional BN100 CLO) show black color and spots resulting from corrosion, whilst Plates 2 (BN100 CLO using ANM) do

[1] V. DOYEN and Al., Paper n°392, CIMAC Congress 2013, Shanghaï

[2] C. AMBLARD, « New chemistry to protect against cold corrosion in marine cylinder lubricants", Proceedings of the ISME Conference 2013, Harbin

not. The weighting of the plates shown in table 1 clearly demonstrates the efficiency of ANM. The passivation of the surface might be one explanation of such a phenomenon.

 Plates 1

 Plates 2

Figure 2 – Plates after corrosion test with conventional CLO and CLO using ANM

	Lube Oil	Av. weight Loss (mg)
Plate 1	BN100 conventional	730
Plate 2	BN100 with ANM	2

Table 1 – Average weight loss measurement after corrosion test

The potential of ANM chemistry to fight corrosive wear is well established. However the resistance to adhesive wear is also an important target to achieve. Tests on the FALEX machine[3] (2760 N of load applied for 3h) have shown that well balanced BN100 CLO achieved 13 µm wear while the BN100 conventional CLO compared came to 46 µm wear. Considering the high performance obtained, the conclusion is that ANM chemistry is at least as good as the conventional chemistry known to be very efficient to fight against scuffing, thanks to the $CaCO_3$.

Apart from the functionalities presented above, ANM molecules have also revealed high resistance to thermal constraints and good detergency ability in response to in-house coking bench tests, as illustrated by figure 3 and table 2.

 Becher 1

 Becher 2

Figure 3 - Comparison of conventional BN100 CLO and CLO using ANM (Coking Bench Test at 310°C)

	Lube Oil	Deposit after test at 310 °C (mg)	Deposit after ageing procedure(mg)
Becher 1	BN100 conventional	262	149
Becher 2	BN100 with ANM	211	75

Table 2 – Deposit measurement after in-house Coking Bench Tests

[3] JP. ROMAN, “R&D of marine lubricants in Elf Antar France: the relevance of laboratory test in simulating field performance”, Proceedings of the Motorship Marine and Propulsion Conference 2000, Amsterdam

4. Engine bench testing

We performed tests with one MAN 6 S35 ME-B9, Tier II engine built in 2009 to select the final finished CLO formulation before running service tests on-board vessels. For each test, thanks to the split lubrication system, each lubricant has been used in two cylinder units and compared to the others. One reference CLO and two candidate lubricants using ANM were tested each time.

A first test applied sweep test procedure[4] for 120 h with HFO 2.77 % sulphur. Figure 4 shows the statement of one of the units that used ANM based CLO.

Figure 4 – Test result of BN100 CLO with ANM (fuel HFO 2.77% sulphur) on one cyl. unit

Figure 5 reports the evolution of the iron (Fe) content and of the kinematic viscosity at 100 °C (KV100) in the drain oil sampled during the test from each cylinder unit. Even though the Fe content is far from the limit recommended by the OEM (200 ppm), the behavior between the different cylinder units shows the interest of the ANM based CLO (blue and green lines) compared to the conventional calcium based CLO (yellow lines). In the meantime, the exponential increase of KV100 for conventional CLO when the LOFR is decreased, testifies that resistance to oxidation and thermal stress is significantly less compared to that of the CLO based on ANM. One conclusion from this observation is that ANM chemistry provides higher safety margins when reaching extreme operating conditions.

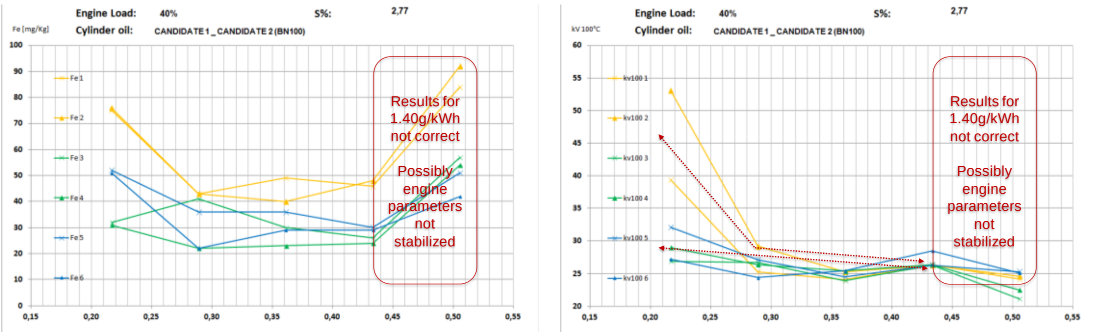

Figure 5 – Fe and KV100 measurement from drain oils (fuel IFO 2.77% sulphur) when changing the ACC factor

A second test was carried out with distillate fuel (MDO 0.08% sulphur) for 200 hours following a procedure involving variable loads from 25% to 75% MCR, simulating a vessel sailing in an Emission Control Area (ECA). The test compared conventional *BN25 CLO* (recommended by MAN when burning MDO) to two candidate lubricants of *BN100 CLO* using ANM. Figure 6 shows no whitish calcium deposits on the piston crowns for BN100 ANM-CLO candidates. Figure 7 shows the cleanliness of the ring packs on the candidate side as well. Figure 8 confirms the high anti-wear performance achieved with ANM chemistry as well.

[4] MAN Service Letter 2014-587/JAP

cyl.#1 (conventional BN25 | cyl.#3 (CLO1 BN100 with ANM) | cyl.#5 (CLO2 BN100 with ANM)

Figure 6 – Piston crown after 200 h test with MDO 0.08% sulphur

cyl.#1 (conventional BN25) | cyl.#3 (CLO1 BN100 with ANM) | cyl.#5 (CLO2 BN100 with ANM)

Figure 7 – Ring pack after 200 h test with MDO 0.08% sulphur

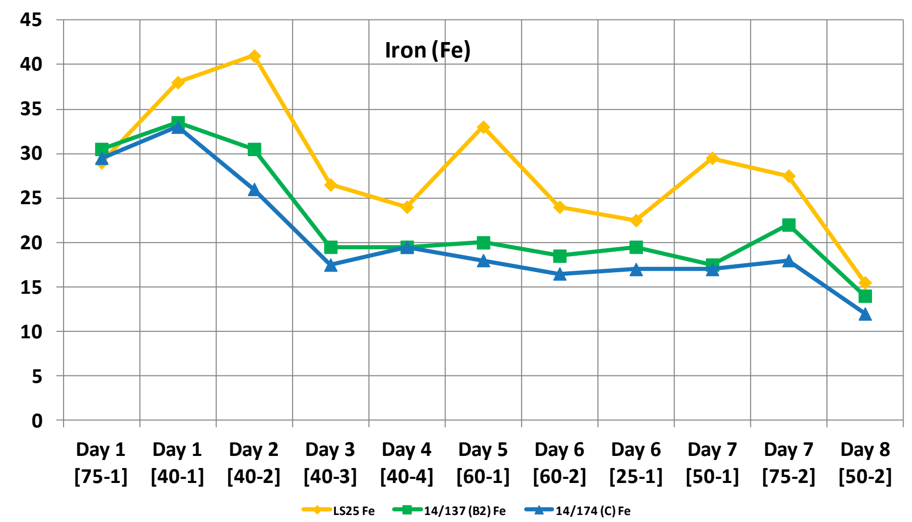

Figure 8 – Fe content from drain oil analysis during 200 h test with MDO 0.08% sulphur

The clear and most important conclusions from the bench testing stage are that the newly formulated BN100 CLO using ANM performs better than conventional reference CLO. Resistance to corrosion is shown by lower iron content in drain oils, coupled with slower BN depletion. The viscosity behavior demonstrates a better resistance to thermal stress and oxidative degradation, which is confirmed by the exceptional cleanliness of the cylinder units testing ANM-CLO candidates.

However the most important finding is that a more reliable performance was obtained with BN100 CLO using ANM when the engine was burning ultra-low sulphur MDO for 200 hours, compared to the recommended conventional BN25 CLO: there were fewer/no calcium deposits on the piston crown; fewer deposits on the piston top lands and a cleaner statement of all the piston ring lands.

5. Service testing

A first approval test was carried out with BN74 CLO using ANM on one large container vessel fitted with a Wärtsilä 14 RT-flex 96C-B engine. The reference lubricant used for comparison in half of the engine was TALUSIA HR70, the Total Lubmarine conventional BN70 CLO. The test was run for 4420 hours with a load pattern between 20% and 50% MCR, using HFO 1% to 3.5% sulphur. Then the BN74 CLO candidate was used for additional 85 hours when the vessel sailed in ECAs.

After the completion of the test, the engine condition was found to be very good, as illustrated by the cleanliness of the ring grooves shown in Figure 9 (BN74-CLO test unit). The maximum liner wear measured was only 0.20 mm/1000 h. Consequently, Wärtsilä delivered a No Objection Letter[5] recognizing the reliability of high BN CLO using ANM chemistry.

Figure 9 – End of 4420 h test on 14 RT-flex 96C-B engine (piston unit 2)

A second container vessel was used to run an MAN approval test on a 8 S60 ME-C7 engine. The load applied was around 40% on average with frequent changes and the HFO used with 1% to 2.9% of sulphur. After 4238 hours the engine condition was found to be good (see Figure 10) and the test cylinder units gave a maximum wear rate of 0.022 mm/1000 h. MAN delivered a No Objection Letter[6], also recognizing the reliability of the new CLO using ANM chemistry.

Figure 10 – End of 4238 h test on MAN 8 S60 ME-C7 engine (cylinder unit 1)

6. Final development stage

Final formulation of the new CLO using ANM chemistry is specified with BN100 to fulfill OEM requirements.

Thanks to the huge experience accumulated in the laboratory, on the bench engine and in real service operations, TALUSIA OPTIMA is the first and only BN100 CLO designed to lubricate existing, as well as the latest and most demanding Tier III two-stroke engines, burning high sulphur heavy fuel oils and, when sailing in Emission Control Areas, ultra-low sulphur distillate fuels. This flexibility results from the low ash content of formulation using

[5] NOL Wärtsilä for BN74 TOTAL Talusia OPTIMA B7, dated 17 December 2014
[6] NOL MAN referenced LDF1/JUSV/CEN/3338-2015 dated 19 January 2015

ANM molecules with high neutralization efficiency and wide capability in deposit handling and control. TALUSIA OPTIMA ensures unrivalled cleanliness of engines, whatever the fuel used.

A first approval test with TALUSIA OPTIMA was completed a few weeks ago on a Wärtsilä 14 RT-flex 96C-B engine. The vessel concerned has gathered close to 4500 hours of testing time, sailing four times in ECAs and accumulating near 400 hours of operation with TALUSIA OPTIMA (BN100) when burning ultra-low sulphur distillate fuel. The result is in line with expectations (see figure 11).

Figure 11 – Piston pulled out at the end of test of TALUSIA OPTIMA in Wärtsilä engine

A second test is in progress on a MAN 11 S90 ME-C10.2 engine. After about 1000 hours accumulated and two sailing legs in ECAs the engine statement is perfect, as shown by figure 12.

Figure 17 – Statement of one reference cylinder unit (intermediate inspection) during TALUSIA OPTIMA test on MAN engine

7. Conclusion

ANM chemistry is a viable alternative to formulate high BN CLO with significantly improved overall performance. It is necessary to make this chemistry available to users to support them in a sustainable way in handling the great challenges they face.

TALUSIA OPTIMA is the low ash BN100 CLO resulting from in-depth development extended over several years. This CLO enables the lubrication of the most modern engines burning either high sulphur HFO or, temporarily when sailing in ECAs, ultra-low sulphur distillate fuels. Such flexibility with demonstrated reliability cannot be achieved by conventional BN100 CLOs.

With the exceptional potential of ANM chemistry, TALUSIA OPTIMA also provides simplicity, avoiding CLO switches when changing fuel entering and exiting ECAs, enabling easier lube oil management.

TALUSIA OPTIMA outperforms conventional CLOs in many aspects, with faster and more efficient neutralization, better engine cleanliness and deposit control capability that gives greater tolerance to actual lubrication variations. It also provides higher safety margins thanks to reduced operating risk.

All in all, TALUSIA OPTIMA opens the door to additional improvements in reducing the LOFR.

TALUSIA OPTIMA and ANM chemistry offer long-term benefits for vessel operators.