Blending Cylinder Oil Onboard to Reduce Operational Costs and Particulate Emissions through the Use of SEA-Mate® Technology

Keith P. Saddler
Director, Sales and Marketing
Maersk Fluid Technology, Inc.
Norfolk, Virginia USA

Abstract

The maritime industry continues to be confronted with the dilemma of compliance with emissions regulations while still providing appropriate lubrication to ensure optimum piston and cylinder condition.

To address this issue, Maersk Fluid Technology, Inc. has developed an integrated system consisting of an onboard XRF analyzer and onboard cylinder oil blender. This technology provides the ship owner with the capability to custom blend the required amount of cylinder oil at specific BN levels corresponding to the fuel sulfur level. This technology precludes the requirement to either maintain a supply of two different BN cylinder oils, or to run on a single BN oil that is less than optimum as the fuel sulfur level varies.

The SEA-Mate® blending onboard concept utilizes the used main engine system oil and blends it with a special additive package to produce the required BN cylinder oil.

Additionally, by blending to a lower BN cylinder oil, the heavy metal components from the additive package are reduced, thus reducing deposits on the turbocharger nozzles, and emitting less particulates in the exhaust.

Since the SEA-Mate® blender uses the engine's system oil as the basestock, the engine is consistently being replenished with clean system oil. This results in maintaining the sump lubricant at a consistent level of cleanliness and at the proper viscosity. This results in improved lubrication of the critical bearings, less required filtration and purification, improved cooling of the undercrown and an improved fluid for use as a hydraulic medium for the upper part of the modern electronic engines.

The supporting SEA-Mate® Analyzer provides accurate results in 6 minutes and has a very robust software interface for reporting and historical records. The SEA-Mate® M3000 analyzer allows the user to not only analyze lubricants, but can also be used to analyze fuel for sulfur level confirmation and determination of the level of cat fines which may be present.

Introduction

The current economic downturn in the global economy has had a significant impact on the maritime industry. With, as of the date of this report, over 480 container vessels being laid up, new building orders at an all time low, freight rates continuing to decline, and new emissions regulations continuing to be proposed, today's ship-owner must look to new innovative practices to reduce his net cost of operation and environmental compliance.

Maersk Fluid Technology (MFT-I), in cooperation with our strategic partner, MAN Diesel PrimeServ, are offering two new technologies to the industry to help the ship-owner address the issues mentioned above. MFT-I's SEA-Mate® technology addresses a varied range of products, services and innovative practices, however, the purpose of this paper is to examine only two aspects of the new technology being offered to the industry to help the ship-owner better address today's challenges. Specifically, the author will address the concepts and equipment related to onboard fuel and lube analysis and the onboard blending of optimized cylinder oil.

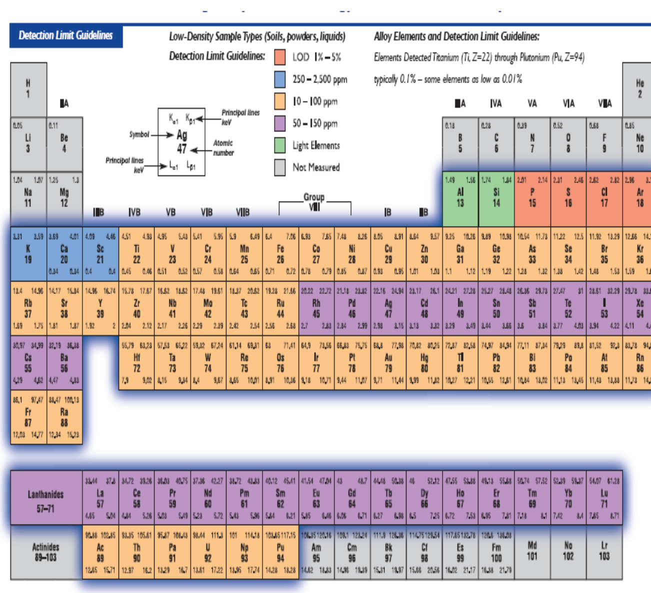
Before continuing, it is worth mentioning that the two specific pieces of equipment discussed in this paper are both mutually exclusive in terms of what they do, however, they also have an interdependency which will be covered in a later section.

SEA-Mate® M3000 Onboard Analyzer

The most fundamental component of a predictive maintenance program in the maritime industry is elemental analysis of the lube oil from critical propulsion, auxiliary, and safety equipment. Additionally, the onboard analysis of heavy fuel is also becoming increasingly important as ECA regulations expand and fuel quality becomes an increasing concern. The SEA-Mate® approach is to employ an X-Ray Florescence based onboard analyzer which can analyze virtually any fluid used onboard vessels.

Although XRF is a proven technology that has been utilized for many years in analytical instruments, this is the first application of its type onboard an ocean going vessel. It's functioning is relatively straight forward in that the emitted X-rays excite the atoms in the fluid with a bombardment of X-rays and as a result, the atoms of the individual elements emit X-rays characteristic of the specific elements in the sample. The unit is calibrated to detect, measure the energy signatures and report the results in parts per million (ppm). Commercial XRF spectrometers, like television sets or computer screens, are designed to operate safely without any requirement for radiation certification of the operator. In the SEA-Mate® unit, X-rays are only emitted when the unit is actually running a sample. The unit requires virtually no maintenance, has no moving parts and can be calibrated by the operator using a provided calibration sample.

The Periodic Table below shows the full range of elements and their detection limits capable of being measured by XRF technology.



In the case of the SEA-Mate® M3000 Analyzer used onboard a ship, there is no need to measure the majority of the elements shown above. MFT-I has therefore limited the unit's output, and hence accuracy, to only the following: S, Ca, V, Zn, Cr, Fe, Cu, Pb, Al and Si.

The analyzer itself uses a novel patented duel tube solution where one tube operates at 25 kV (40 Kv max) and 50 – 100 mA, and performs direct excitation of S, Ca, and V, Zn as well as wear metals (Cr, Fe, Ni, Cu, Pb). The second tube uses Mo anode, 20 kV, 1 mA. Mono-chromating optic takes broad energy beam and produces mono-energetic beam of Mo L-lines at 2.3 keV. This beam does not excite S electrons, which can produce significant interference, but is optimal for Al, Si and P excitation. All elements are measured in solid state silicon drift detector.

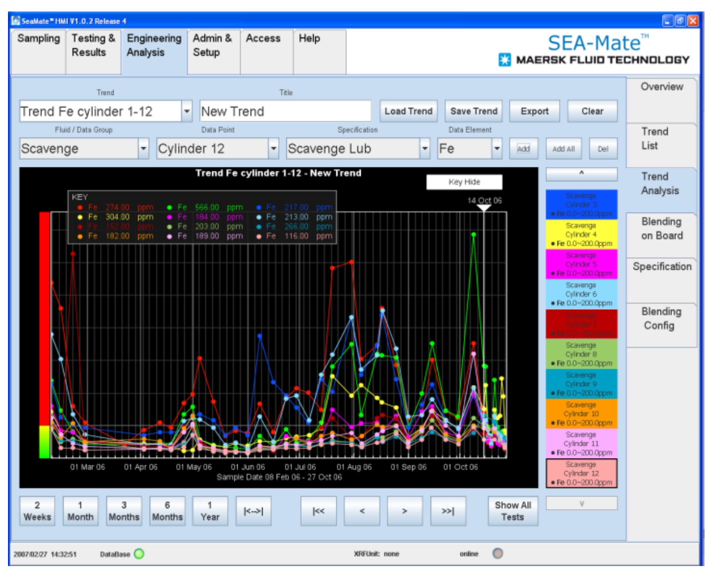
The unit weighs roughly 30 kg and can easily be mounted on a table in the engine control room. Testing is conducted by using bar coded sample data and supplies it to the data processing and historical storage graphics software which can easily generate a paper report or be exported to home office, an OEM or the oil supplier.

The analyzer has the capability of running a complete analysis in 6 minutes with no need to decant the sample since the measurement is taken through the capped bottle. This non-destructive sampling technique allows the vessel to retain samples for either legal purposes or for further more advanced testing.

The ability to rapidly evaluate samples and evaluate the results vs historical trends offers many, previously unavailable, advantages to the crew. For example:

- Evaluation of cylinder condition through analysis of scrapedown oil at the following events
    - Change in bunker fuel
    - Confirmation of blended oil BN (discussed in blending onboard section)
    - Change in Cylinder oil BN (discussed in blending onboard section)
    - Change in engine load
    - Condition during slow steaming
    - Following maintenance
    - Change in oil supplier
    - Monitoring break-in

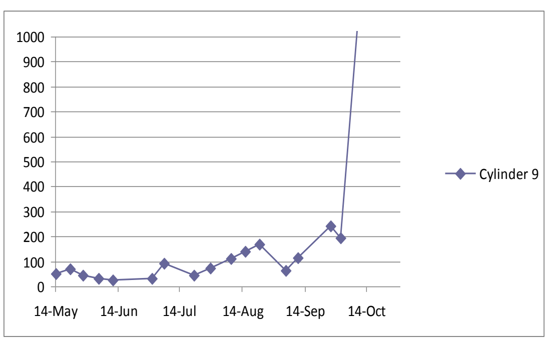
- Evaluation of critical auxiliary equipment
    - Auxiliary engines
    - Deck hydraulics
    - Thrusters
    - Compressors
    - Refrigeration units



In evaluations onboard container ships, the SEA-Mate® Analyzer has proven extremely effective in allowing the crew to identify potentially costly problems in time to take corrective actions before the problem resulted in severe damage. Dependence on a land based analysis program would not have provided the results in time to avoid the associated costs.

Although we have scores of examples where the SEA-Mate® Analyzer has provided early warning of a problem, for the sake of brevity, the author will only discuss two specific cases in this paper.

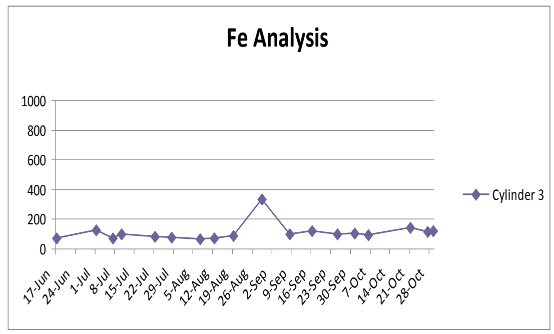
In the data graph below a 12 cylinder engine experienced a rapid increase in iron levels across all cylinders when changing to a new bunker tank. Iron levels of <150 ppm are considered normal operation and in compliance with the OEM recommendation of allowable wear in mm / 1,000 hours.
The analyzer, as shown belo
As you can see, on 10 October, 2008, this engine saw the iron level go from an acceptable level to > 1,000 ppm as soon as the bunker tank was changed over.



In this particular case, the vessel had elected to purchase the SEA-Mate® M2000 analyzer which, unlike the M3000 unit, does not have the capability to measure Al and Si indicating cat fine level. It was subsequently determined that the engine ingested more than 80 ppm cat fines. Had an M3000 unit been onboard, the Chief could have tested the fuel before making the switch. If he had known the cat fine level, he could have increased purifier operation and brought the cat fine concentration down to an acceptable level.

Unfortunately, in this particular case, all 12 liners were lost resulting in a cost of approximately $500,000.

In the example below, the engine was running without problems until 26 August when it experienced a spike in iron of slightly less than 400 ppm in cylinder 3.



The Chief Engineer realized that this was an unacceptable situation and took corrective actions to reduce the load on cylinder 3 until they reached port. Upon arrival, it was found that cylinder 3 had a broken S Lock Ring. The ring was replaced in port and the next analysis indicated that the cylinder had returned to normal operating levels. The result was a saved liner because of the early detection.

As previously illustrated, a key advantage of onboard analysis is the ability to evaluate bunker fuel to confirm sulfur level and the presence and amount of cat fines.

The ability to confirm the fuel sulfur level is important for determining the correct BN for blending cylinder oil onboard, which will be discussed later in this paper.
The issue of cat fines in fuel, particularly lower sulfur fuel continues

to be an industry concern. Although purifiers are employed to combat this issue, we have found wide variations in purifier efficiency, which, up until now, could not be confirmed onboard. In a recent onboard experience, using the SEA-Mate® M3000 analyzer, we were able to demonstrate to the Chief Engineer that 3 of the 4 fuel purifiers were ineffective in removing cat fines from the fuel. In this case, adjustments were made to the sub-performing purifiers and the fuel was circulated back through the units, and as a result, the cat fine level was brought back down to acceptable levels. Had the Chief not had this analytical capability, significant damage and associated cost would have occurred.

As mentioned earlier, the SEA-Mate® M3000 analyzer is an integral part of the blending onboard process. Not only does it provide confirmation of the fuel sulfur, but is also is used, through scrapedown analysis, to evaluate how the blended oil is performing in each cylinder over a wide range of operational conditions.

Another interesting point is the fact that frequent analysis of the scrapedown oil can provide early warning of a potential problem such as scuffing. In a paper from the 2004 CIMAC conference in Kyoto, written by Diesel United and Ishikawajima-Harima Heavy Industries Co., Ltd., using data from actual engine tests, that the iron content in scrapedown analysis occurs 1 to 2 days before any temperature rise in the cylinder can be detected.

Blending Onboard with the SEA-Mate® B2000 Blender

In the maritime industry today, the ship-owner has to be able to cope with variations in fuel sulfur level. Common practice is to continue to run a 70 BN cylinder oil (in non SECA areas) regardless of fuel sulfur level. Although lower BN products are commercially available, their availability is not always convenient, their price is usually higher than their 70 BN counterpart and it requires the storage of two different cylinder oils onboard.

Almost 12 years ago, the original concept of blending onboard was being worked on by several companies, but, it was not until 2007 that Maersk Fluid Technology was the first to perfect the technology and have it proven as commercially viable. Since then, the SEA-Mate® B2000 blender has been successfully installed on scores of vessels and thoroughly evaluated in cooperation with the major two stroke OEMs. In late 2008, MFT-I and MAN Diesel PrimeServ entered into a strategic alliance to promote this technology in the market.

The blending onboard (BoB) concept is both simplistic and easy to operate. Basically, used system oil is taken from the sump and blended with a specially formulated cylinder oil additive to produce the desired BN cylinder oil for use in the engine.

This is done in a batch process either in a full or semi automatic mode, which will be discussed later. Operating in it's optimum mode, blends are produced in sufficient quantity to last between bunker deliveries.

In designing the SEA-Mate® B2000 blender, the goal was to produce a unit that insured a high degree of blend accuracy to +/- 2 BN, be extremely simple to use and be robust through the used of high quality mass flow meters, pumps and a custom made mixing tube as well as having the necessary safeguards to insure blend consistency.

The blender consists of three major components; the base oil pumping skid, the additive mixing skid and the control panel. All three units are compact enough to fit through standard doorways onboard thus making installation relatively easy.

The photo above shows the additive mixing skid connected to the additive tank and the output line to the holding tank.

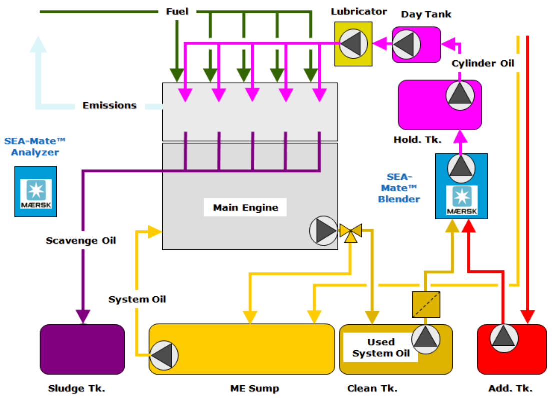
Above is the base oil pumping skid that draws in the used system oil and sends it to the additive blender.
The photo below shows the input screen from the blender's control panel.

In this particular example, you will note that the BN of the base oil is 12 BN, which is higher than the BN specification for new system oil. This indicates that this setting is for an initial (first time) blend using used system oil. After one or two blends, the BN of the system oil will be consistently at the new oil specification.

Once several blends are made, the input for the base oil BN and the additive BN will be constant, therefore, all the Chief Engineer needs to enter is the desired BN of the blend (in this case 70 BN) and the amount of cylinder oil to blend. Once this is completed, the operation is automatic and the Chief can leave the unit and perform other duties.

As was mentioned earlier, the blender can be set to full or semi automatic mode. In full automatic mode the blender with reinstitute another blend, of the same set BN specification and amount, once the holding tank reaches a predetermined level. In the semi-automatic mode, the Chief must institute the blending for each batch.

Although the unit has been proven to blend to an accuracy of +/- 2 BN on a consistent basis, MFT-I recommends that a sample from the blended batch be analyzed using the SEA-Mate® M3000 analyzer just as an additional quality control check. By measuring the calcium in the blended oil, the Chief can confirm that it contains the right amount of additive for the specific BN requested.



The schematic above shows the entire process as installed on vessels today. Although not every ship is configured the same, this basic installation design can be adapted regardless of the ship's configuration.

It is worthy to note that once the necessary piping work is completed, the unit's skids and control panel are designed to simply drop into place, connect the power and operate. A complete installation and commissioning package is available from MAN Diesel PrimeServ.

Operational, Environmental and Financial Benefits from Blending Onboard

The benefits of blending onboard and using onboard analysis are varied and numerous. They range from soft benefits such as increased awareness of the individual cylinder's health and wellbeing, to the very tangible and measurable benefits such as lower net cost of operation and less environmental impact.
Although not a complete listing, the author has elected to simply describe some of the benefits that the ship-owner can expect to achieve by blending onboard.

Optimum Lubrication: As mentioned earlier, the most common practice is to run on 70 BN cylinder oil regardless of fuel sulfur level. Some in the industry believe that having "more than enough" BN in the cylinder oil is not a problem, however, this has been proven not to be the case.

In scrapedown studies conducted in 2007 covering a sample set of 34 bunkerings, with fuel sulfur ranging from a low of 1.3% to a high of 3.2% it was found that the residual BN left over after the cylinder oil has done it's job, was > 40 BN. Residual BN values of between 15 BN – 20 BN is considered ideal and provides a sufficient safety margin.

In the case above, this unused additive was subsequently discarded with the waste oil. When you consider that a large portion of the cost of cylinder oil is the BN additive, this is a tremendous waste of an expensive additive. Equally important however, is the fact that excessive unused calcium additive can actually damage the engine.

Without getting into micro-chemistry, the fact is that un-reacted BN additive can be impacted by the high thermal load in a two stroke engine and cause hard deposits on the ring lands and behind the rings themselves. These deposits, widely believed to be a combination of CaO and CaCo3 tend to be highly abrasive. To further aggravate the situation, the deposits that form behind the rings on the back face and in the ring groove tend to force the rings out against the liner. This results in breaking the oil film barrier and metal to metal contact of the ring face and the liner. The net result is a polishing of the liner surface and ultimately scuffing.

Through blending onboard and controlling the BN appropriately, the amount of un-reacted BN additive can better be managed, and high cost deposit related scuffing incidents avoided.

Another aspect of optimized lubrication through blending onboard is the ability to maintain the system oil at near new oil condition. Since the sump is consistently being replenished, the cumulative build up of combustion by-products is kept in check. This has an obvious positive impact on the main bearings, but also improves the performance of the system oil when used as an hydraulic medium for the newer electronically controlled engines. Clean system oil is much less likely to cause servo valve problems and thus insure smooth operation of the hydraulically operated components.

It also provides improved cooling and deposit control for the piston undercrowns.

The above photograph, from a vessel that is 10 years old, shows how the replenishment system oil into the crankcase results in a significantly cleaner condition. In this particular case, the engine had only been blending onboard for three months.

As stated earlier, being able to blend to the lowest acceptable BN has cylinder performance benefits, but, it also is advantageous for turbochargers exhaust gas boilers as well. In both cases there is a direct correlation to the BN level and deposit build-up either on the turbocharger nozzles or in the case of the exhaust gas boiler, in the heat exchangers. In the latter case, this has been known to lead to fires. When the ship-owner is able to lubricate the engine using a 60 BN, 55 BN or 50 BN cylinder oil instead of the traditional 70 BN commercial product, there is a linear relationship in the development of harmful deposits in these two critical components.

Supply Continuity: On August 29, 2005, Hurricane Katarina caused a force majeure situation in the oil industry which had a huge impact on the shipping industry. Ship-owners were either put on cylinder oil allocation or told they could only purchase a low BN product. Although no one can predict when the next hurricane will again hit the U.S. Gulf Coast, it is enviable that it will happen.

Through blending onboard, the ship-owner can carry sufficient additive to ensure supply during the hurricane season and beyond. We have seen many ships that take on a single delivery of additive capable of allowing the vessel to blend for 6 to 8 months, or even longer if they lower their BN requirement.

Environmental Benefits: It is estimated that roughly 12% of the total particulates emitted from a two stroke engine come from the heavy metal additives in the standard 70 BN cylinder oil. Although it has not yet been scientifically measured by MFT-I, it reasonable to expect that the lube oil's 12% contribution in particulate emissions can be reduced by the same percentage as the reduction in BN from 70 BN to the lower level in the blended oil.

Additionally, the constant replenishment of system oil in the blending onboard process should eliminate both partial change outs to control contamination and viscosity levels, and complete sump change outs. This results in the elimination of system oil disposal costs and reduces the ship's overall hydrocarbon footprint.

Before continuing with a discussion regarding the next possible environmental benefit, the author is obligated to divulge that the following argument is based on tribological theory, and has not been proven in actual field trials. Additionally, it is important to state that until such time as the necessary analytical testing and due diligence is applied, that it can not be officially endorsed by our strategic partner, PrimeServ.

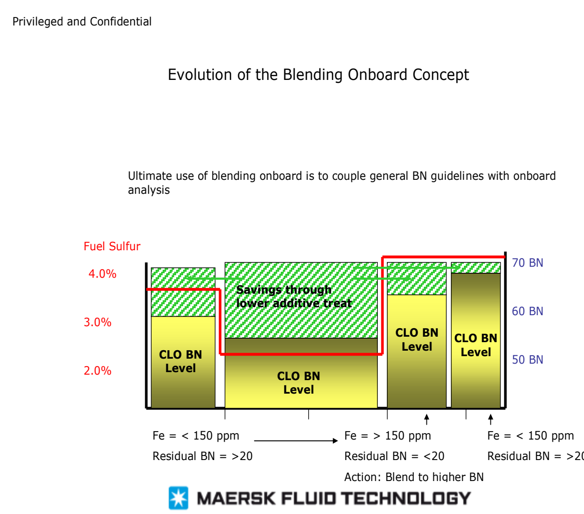
It is MFT-I's belief that that maintaining the system oil to the specification of new product can potentially result in an improvement in overall engine efficiency which could have fuel economy implications. This belief is based on two factors. First, a test conducted on a 7S50 MC engine by A.P. Moller in 2003 using an ABB Cylmate Unit where efficiency gains were indicated using clean vs dirty/used system oil, and secondly, the fact that from a tribology standpoint, as oil thickens up, the internal shear planes within the oil itself creates internal friction or "a drag factor" which must be overcome. By eliminating the amount of internal friction through optimized viscometics, it seems most logical that the net efficiency should be positively influenced.

MFT-I is currently discussing the testing of this theory with a third party and will provide scientific support data to the market as soon as it becomes available.

Optimal use of onboard analyzer and blender: Now that we have discussed the SEA-Mate® analyzer and blender, and reviewed how they function and the benefits they provide, the author would like to review exactly how these two pieces of equipment work in tandem to produce savings for the ship-owner.

The graphic below provides a simple illustration of the optimum use of the analyzer and blender. This example is strictly for illustrative purposes and is not intended to be a guideline for the relationship between fuel sulfur and specific BN levels.

The base assumption is that the vessel was previously using a 70 BN cylinder oil. This model also assumes that the same feed rate used as was used previously with the 70 BN product. Obviously further savings could be generated by adjusting both BN and feed rate and monitoring the scrapedown oil onboard.



The red line indicates the change in fuel sulfur at three different bunkerings.

Just below the X axis is indicated two analytical measurements (iron wear and residual BN) taken during the time period that the specific bunker was being used. This data is needed for decision-making purposes and to insure satisfactory protection of the engine. As a general rule, as long as the scrapedown analysis for each cylinder shows iron <150 ppm and residual BN >20 BN, that the cylinder is operating well within the OEM standard for mm wear / 1,000 hrs.

The green crosshatched area represents the net savings from the lower additive usage vs the 70 BN reference.

At the first bunkering, the 60 BN blended oil is showing very acceptable performance as indicated by the iron level and residual BN.

At the second bunkering, the fuel sulfur level is considerably lower than what was used previously, and therefore the required BN is less. The oil is now blended to 55 BN. Using the onboard analyzer it is again confirmed that the wear rate is fully acceptable.

At the third bunkering, the fuel sulfur is measured by the onboard analyzer to be in excess of 4.2%, and the Chief Engineer elects to blend the cylinder oil to roughly a 62 BN level. (Normally BN blends are increased in increments of 5 BN). In this case the Chief felt that based on experience a 60 BN would be sufficient; however, he decided to build in a +2 BN cushion. After several hours of operation the scrapedown samples are analyzed onboard and the results exceed recommended levels. These results indicated to the Chief that he needed to either re-blend the current batch to a higher BN or blend a smaller new batch at a significantly higher BN level and put it on top of the existing oil in the tank.

In this example, once the BN was adjusted from 62 BN to 68 BN, the iron wear returned to acceptable level.

Through this sort of use of the analyzer and the blender, the ship-owner should expect to see a decrease in the vessel's net cost of operation through a combination of lower cylinder lube cost and increased time between overhaul for the cylinders. As mentioned earlier, if feed rate adjustments are included in the overall process, even more savings could be achieved.

Financial Benefit from Blending Onboard: There are many variables that impact the specific cost savings that SEA-Mate® analyzers and blenders can generate for a fleet. Items such as current price being paid for system and cylinder oil, engine size, typical vessel operation characteristics, hours of operation per year, degree of variation in fuel sulfur levels and number of SEA-Mate® units purchased, all have an impact on the net savings.

In actual calculations done by MFT-I for perspective customers we have seen payback periods for the equipment and installation costs that ranged from 1.5 years to 3+ years depending on the variables mentioned above.

Conclusion

The combination of the SEA-Mate® onboard analyzer and blender represent a step change for the industry. This equipment now allows for a much improved capability to optimize of two stroke engine lubrication, insure engine reliability, reduce environmental impact and substantially reduce the overall net cost of vessel operation.

It is the firm belief of Maersk Fluid Technology that it is time to move beyond the old practices of the past 50+ years and for the industry to embrace new technology.