

Low Sulfur Fuel: Impacts on the Marine Industry

International legislation requiring use of low sulfur fuels by ships at sea means significant changes for engine builders, lubricant providers and many ship owners.

Overview

International legislation to decrease pollution from ships at sea includes measures to reduce the amount of sulfur in marine fuels. What exactly are the new requirements, what are the impacts on the operation of crosshead diesel engines, and what are the different lubrication options possible for ship owners? Engine builders have their own requirements, and oil companies have also developed strategies to respond. Each engine must be evaluated based on its own unique operational conditions in order to select the optimum alternative. For its part, ExxonMobil offers a variety of options and recommendations based on years of experience in the marine industry.

Background Issues

The International Maritime Organization's MARPOL Annex VI "Regulations for the Prevention of Air Pollution from Ships" imposed stricter pollution regulations, including limits on sulfur oxide. In some geographic areas (called SOx Emission Control Areas — or SECAs), restrictions on sulfur in fuel are particularly stringent. Those areas include the Baltic Sea and the North Sea. Some regulations have already been implemented. Others are to come.

Here are key deadlines for Heavy Fuel Oil (HFO):

- **May 2005** — A cap of 4.5 percent sulfur in fuel is imposed globally.
- **May 2006** — A cap of 1.5 percent sulfur is imposed in the Baltic Sea.
- **August 2007** — A cap of 1.5 percent is to be imposed in the North Sea.

Three categories of ship owners

Impacts of the new regulations on engine wear and maintenance depend on whether a vessel will be operating in a regulated area (SECA) that requires use of Low Sulfur Heavy Fuel (LSF). Although several engine manufacturers define LSF as being 1.5 percent sulfur or less, the marine industry must still agree on the term's exact definition.



In deciding when it is best to choose the low-TBN cylinder oil option and/or a feed rate reduction, the owner of a slow-speed crosshead diesel engine should first and foremost be guided by the published recommendations of the engine's manufacturer.

For purposes of assessing the impact of LSF on vessels, ships fall into three major categories:

- **Full-time use of LSF:** Ship owners operating primarily in regulated areas will be using LSF full time. This group must decide whether to operate a 70 TBN (Total Base Number) oil at a lower feed rate (operator should refer to OEM (Original Equipment Manufacturer) guidelines for length of time operating on a 70 TBN oil even at reduced feed rates), or run a 40 TBN lubricant.
- **Part-time use of LSF:** Vessels operating only part time in regulated areas need to understand the lubrication issue. This group represents a large portion of the deep sea fleet.
- **No Use of LSF:** Vessels not required to use LSF will operate in their current lubrication regime.

Decisions for ship owners

Ship owners who operate vessels part time in regulated areas must make a choice, dictated in part by the sulfur content of the fuel and how long the engine will run continuously on the fuel.

- 1. Use two lubricants.** When operating in regulated areas they can switch to a lower-TBN cylinder oil (TBN 40) formulated for use with low sulfur fuel, or
- 2. Optimize feed rate.** They can stay with a standard-TBN cylinder oil (TBN 70), but use it at an optimum feed-rate setting while monitoring engine wear.
- 3. Consider a combination.** Under certain circumstances (i.e., very low sulfur fuel), customers may be required to lower rates and switch to 40 TBN.

In all cases, optimizing feed rates is recommended.

Technical Impacts on Crosshead Diesel Operation

For ship owners, the technical implications of the regulations are significant and involve making informed choices about fuels, lubricants and maintenance.

Effects on fuels

For vessels switching back and forth between high and low sulfur fuels, ship owners need to understand the following fuel-related issues:

- Incompatibility of different fuels
- Impact on wear (scuffing)

Impacts on lubricants

From a lubricant standpoint, the major issue in switching back and forth between high and low sulfur fuels is ensuring the lubricant's ability to control corrosion and wear.

The use of a high-TBN lubricant in a low sulfur environment can produce excessive hard deposits. This is due to high thermal loads on un-reacted neutralizing additives. These deposits form primarily on the crown land and impact the oil film, leading to scuffing and ultimately to deposits behind the ring and in the ring groove.

An additional consequence is that the high-TBN oil used in a low sulfur fuel environment can reduce corrosion to the point that the liner surface becomes too smooth and unable to hold the oil. This is commonly referred to as a lack of "controlled corrosion." When this happens, wear can take place, and the liner's surface roughness becomes polished and continues to be unable to hold the lubricant. If the condition continues, scuffing can occur due to metal-to-metal contact.

To reduce these problems, ship owners can consider the following:

- **Proper balance.** In order to ensure controlled corrosion and good liner condition, balance both the TBN of the oil, and/or the feed rate.
- **Low-TBN oil.** Use lower-TBN (40 TBN) oil if appropriate.
- **Proper oil formulation.** As TBN is decreased, so is the detergency of the lubricant and hence its ability to minimize piston deposits. The oil formulator must compensate for this loss in detergency by properly re-balancing the formulation with additional and/or other fortifying additives.

Adjusting feed rates

Feed-rate adjustment is another option in dealing with low sulfur fuels. In some cases, in a low sulfur environment, the engine can continue to operate on a standard 70 TBN oil by reducing the net feed rate. The concern is whether the amount of lubricant in the cylinder will be adequate to cover the entire surface and provide enough acid neutralization to ensure that corrosion is kept in check. MAN B&W has conducted significant research on this issue. Development of its Alpha ACC System and feed-rate algorithms based on sulfur levels has proven to be very effective. Wärtsilä, particularly with its Tribo Pack design, has achieved good performance in a load-dependent feed-rate scheme.

Operating with standard 70 TBN oil

The question is frequently asked, "How long can a crosshead engine operate on low sulfur fuel with a standard 70 TBN oil without making feed-rate adjustments to compensate?" This is a difficult question to answer because of the limited experience that the industry has been able to accumulate. As a general rule, feed-rate compensation is essential from the point of switching to a lower sulphur fuel. MAN B&W limits the time of such an operation (i.e., low sulfur fuel and 70 TBN at minimum feed rate) to one to two weeks. It is likely that this general rule may be modified as experience provides the industry with a better understanding of the dynamics of low sulfur operations.

Water separators

It is especially important to ensure satisfactory operation of the water separators when the feed rate has been reduced to compensate for fuel sulfur. The influx of large amounts of water onto a surface with a very thin coating of oil could result in the oil film being washed away, with metal-to-metal contact occurring. It is therefore highly recommended that increased diligence be placed on ensuring proper separator functioning.

Monitoring engine conditions

No two engines/applications are the same. Factors such as operational load, intake air humidity, age, condition of components, feed rate and fuel combustion characteristics, as well as fuel sulfur level, all play a role in determining the wear dynamics of the engine. Therefore, although general recommendations can be made on how to best operate on low sulfur fuel, these recommendations do not preclude the necessity for monitoring the actual condition of the engine.

All OEMs strongly advocate frequent cylinder inspections. This is of particular importance in the early days of low sulfur fuel operation until such time as the industry develops a better knowledge base and can better forecast expected influences of the low sulfur fuel.

Considering storage and logistics

As we move into a low sulfur environment, ship owners must make decisions about whether or not to store two types of fuels and possibly two different types of lubricants onboard. More storage will result in a number of cost, design and space-related issues. A majority of ship owners polled by ExxonMobil about how they plan to address the low sulfur issues say that on existing engines they plan to remain on the 70 TBN cylinder oil and compensate by feed rate reductions. New ship buildings are more likely to have an additional lubricant tank installed at the shipyard during construction, but even with new buildings, the general direction is a preference not to endure the additional cost.

Lubrication Options When Running on Low Sulfur Fuel

The decision on whether to switch to low-TBN cylinder oil or remain on standard 70 TBN oil while adjusting the feed rate can be complicated. In some extreme cases, where the fuel sulfur level is below 0.5 percent, it may be necessary to use low-TBN oil and lower the feed rate. This should be reviewed with the OEM before implementation.

Additionally, frequent inspections should be done to ensure that the lesser amount of detergency is not allowing an unacceptable level of deposits to form.



For today's ship owners and their lubricants suppliers, ensuring a cylinder oil's ability to control corrosion and prevent wear — despite the low sulfur fuel environment — is a challenge.

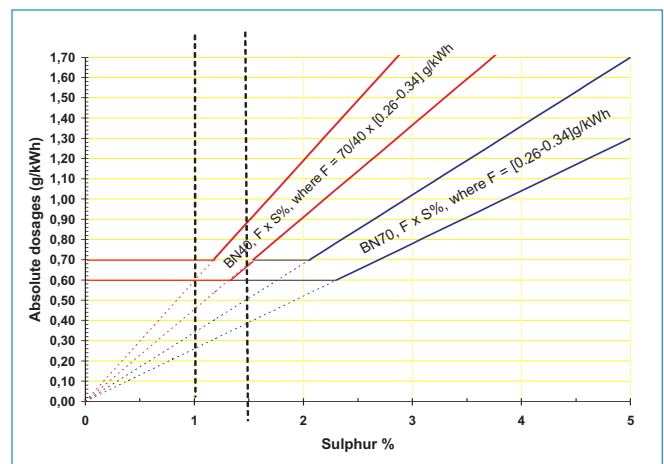
Design differences between engine manufacturers

Crosshead diesel engines manufactured by MAN B&W and Wärtsilä have operational and design differences to consider.

MAN B&W has the following practical approach for operating on different fuel sulfur levels:

The correlation between fuel sulfur level and cylinder oil can be shown as follows:

Sulfur content in fuel oil (%)	Recommended cylinder oil (TBN)
Less than 1	TBN 40/50 recommended, Changeover from TBN 70 to TBN 40/50 only when operating for more than one week on <1% sulfur
1.0 to 1.5	TBN 40/50 and TBN 70 can be used. See Graphic below.
Greater than 1.5	TBN 70 is recommended



Graphic provided by MAN B&W

Wärtsilä engines are basically load-dependent in terms of feed rate. Wärtsilä's published policy for cylinder oil recommendations in varying sulfur environment is provided below:

Sulfur content in fuel oil (%)	Recommended cylinder oil (TBN)
Less than 1.5	40
Below 1	40 ⁽¹⁾
1.0 to 1.5	40 (70) ⁽²⁾
1.5 to 2.0	70 (40) ⁽³⁾
2.0 and above	70

(1) In exceptional circumstance, TBN 70 can be used, then only at low feed rate (approximately 1 g/kWhr).

(2) TBN 40 preferred or TBN 70 at reduced feed rate.

(3) TBN 70 preferred or TBN 40 at higher feed rate.

Two key factors to consider

The decision on whether to use a low-TBN cylinder oil depends on two factors:

- How low the sulfur level of the fuel is.
- How long the engine will run continuously on that fuel.

A general rule is that if the engine is only running on the low sulfur fuel for a period of less than one to two weeks (continuous running), it would probably be acceptable to remain on the 70 TBN cylinder lube oil with an optimized feed rate. If running in this environment, Wärtsilä recommends consideration of reducing the engine load to <80 percent MCR if at all possible. This recommendation is made in order to further reduce any risk to the engine. If the engine is going to be running on low sulfur fuel for more than one to two weeks, a low-TBN cylinder lube oil at optimized feed rate should be used.

Custom blending — a future option?

Another approach, which is being investigated, is custom-blending an optimum TBN lubricant on board the vessel.

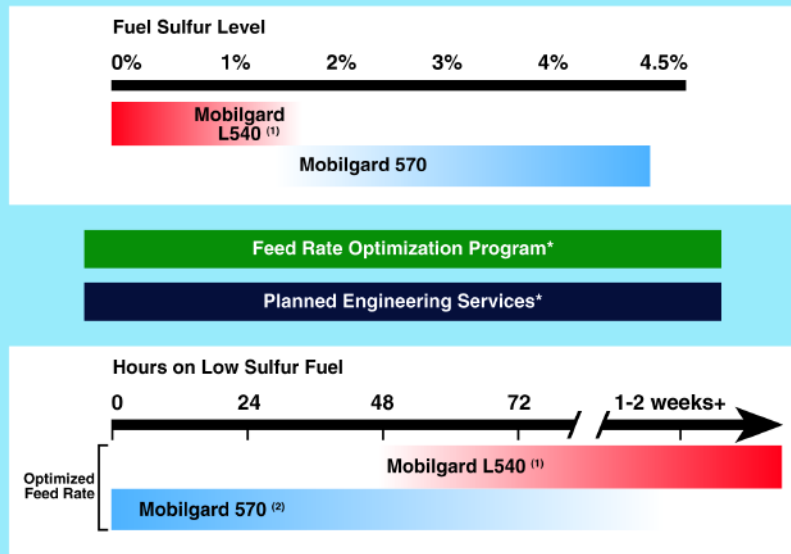
Other considerations for choosing the low-TBN option

In deciding when it is best to choose the low-TBN option versus the feed rate reduction option, a ship owner should first and foremost be guided by the published recommendations of the OEM.

This decision also depends on logistics. If the vessel can handle the additional storage of low-TBN oil, its use would be the preferable method. In this scenario, the ship operator can usually maintain existing feed rate while ensuring appropriate corrosion protection.

The age of the engine can also be a factor. In some older engines, with standard lubricators, the feed rate adjustment process can be somewhat labor intensive. Ship owners who have manual adjusting lubricators may want to consider having a supply of low-TBN cylinder lube oil onboard for short-term operations on low sulfur fuel. Owners with more modern engines, with computer-controlled feed rate adjustment capability, may find that varying the feed rate is their best option. In extreme cases, where the sulfur level is very low (less than 0.5 percent sulfur), reducing the feed rate may not be the best option because it may subject the cylinder to localized oil starvation and increase the likelihood of wear. In this case, the owner should contact the OEM and ExxonMobil for guidance.

Lubricants Guidance from ExxonMobil for Crosshead Engines on Low Sulfur Fuel



⁽¹⁾ If running under 0.5% sulfur fuel, it may be necessary to also reduce the feed rate as well as consult the engine OEM and ExxonMobil.

⁽²⁾ Wärtsilä recommends also reducing load.

* Per Feed Rate Optimization and Planned Engineering Services program guidelines recommended by ExxonMobil Marine Lubricants.

In all cases, optimizing feed rates is recommended.

A decision to use a low-TBN cylinder lubricant often depends on how low the sulfur content of the fuel is and how long the engine will run continuously on the fuel. Generally, if the engine in question runs on LSF for less than one to two weeks, it may be acceptable to remain on the 70 TBN cylinder lubricant with an optimized feed rate. Any decision should be guided by the published OEM recommendations on LSF operation.

ExxonMobil's Position on Low Sulfur Fuel Operations

ExxonMobil has worked closely with ship owners and engine builders throughout its history to ensure the best possible service as technology changes and the industry faces new demands. It supports ship owners and operators as they transition into compliance with impending legislation.

ExxonMobil and the engine builders

ExxonMobil maintains technical alignments with the two-stroke OEMs regarding the issue of operation on low sulfur fuel. As more marine experience is gained by ExxonMobil and the builders, any substantial changes regarding lubrication in a low sulfur environment will be communicated to customers accordingly.

Policy on oil for older engines

Since feed-rate adjustment on some older engines can be labor intensive, some operators may consider maintaining a supply of both a 70 TBN and 40 TBN oil. In modern engines where feed-rate adjustments can be more easily implemented, it may be more effective to lower feed rate when operating on low sulfur fuel, provided that the OEMs minimum feed rate is not exceeded.

Chart provided by ExxonMobil Marine Lubricants

Predictive maintenance techniques

Multiple influences can impact corrosion, the development of deposits and subsequent wear in two-stroke engines. Factors such as the initial TBN of the cylinder lube, the fuel sulfur level, feed rates, engine load and the quality of the intake charge air all can play a role in the reliability of the engine. It is therefore ExxonMobil's firm position that when a ship owner makes a change from the normal operating conditions — either by using a low-TBN cylinder oil or adjusting the feed rate — particular attention needs to be paid to predictive maintenance techniques.

Feed Rate Optimization Program

ExxonMobil recommends frequent scavenge port inspections at a minimum. To enhance condition monitoring, these inspections can be supplemented by analysis of the scavenge space drain oil, either by land-based laboratory, as well as accompanied by onboard devices. ExxonMobil's Feed Rate Optimization program offers the tools that enable a ship owner to assess scrapedown oil samples from each individual cylinder. The ship owner should establish a baseline understanding of the engine's wear dynamics under normal operating conditions. This baseline can then be compared to the operating conditions when low-TBN cylinder oil or adjusted feed rates is in place.

The key parameters that the ship owners should evaluate are the iron and the residual TBN of the drain oil. If the amount of iron in the drain oil is increasing while operating at a lowered feed rate, it may be advisable to increase the feed rate in increments of 0.05 g/kWh. This should also be done in the event that the residual TBN of the drain oil falls below a value of 10 TBN. In cases where the residual TBN is adequate (greater than 20 TBN) yet the iron level is increasing, the ship owner should inspect the engine for possible abrasive wear conditions.



ExxonMobil's Feed Rate Optimization program is designed to help the ship owner safely optimize slow-speed diesel engines' cylinder oil feed rates. It includes land-based laboratory analysis and the Mobilgard Scrapedown Analyzer, an onboard testing tool that allows shipboard personnel to quickly detect substantive changes in cylinder condition.

ExxonMobil also recommends that a scavenge drain sample, compared against baseline data, be taken after one or more of the following events occur:

- After changing to lower or higher sulfur fuel.
- After feed rate has been lowered, regardless of amount.
- When engine loading increased by 10 percent.

Marine cylinder oils from ExxonMobil

ExxonMobil markets two cylinder oils for crosshead diesel engines:

- **Mobilgard 570.** Mobilgard 570 (70 TBN) was formulated in response to engine design evolution that increased combustion chamber pressures and stroke/bore ratios, imposing greater stress on the lubricant. Laboratory tests, field trials and ongoing customer experience have demonstrated satisfactory performance even with sulfur content below 1.5 percent.
- **Mobilgard L540.** Mobilgard L540 (40 TBN) is required for some applications in which HFO with low sulfur content is burned. Formulated with the same technology as for Mobilgard 570, it was rebalanced to deliver optimum corrosion control while maintaining excellent detergency. The oil is effective in reducing cylinder liner scuffing, which some engine builders have associated with use of 70 TBN cylinder oils and LSF.

Summary

ExxonMobil's position on crosshead engines operating on lower sulfur fuel:

- Constant operation on fuel >1.5 percent sulfur — Use Mobilgard 570.
- Constant operation of fuel <1.5 percent sulfur — Use Mobilgard L540.
- Intermittent operation on fuel <1.5 percent sulfur (less than one to two weeks) — Use Mobilgard 570 or Mobilgard L540 at an optimized feed rate. Under this condition with a Wärtsilä engine, it may be advisable to run at reduced engine load.
- In all cases, optimizing feed rates is recommended.

The ship owner should keep in mind that these are basic guiding principles, and each engine must be evaluated on its own unique operational conditions in order to select the most optimum alternative in accordance with engine builder recommendations.

Exxon Mobil Corporation has been serving the lubrication needs of the marine industry since the 1880s. Its global marine lubricants organization delivers a complete range of mineral and synthetic products and provides unsurpassed technical expertise and service for customers worldwide.