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# GUIDELINES FOR DIESEL ENGINE LUBRICATION

# IMPACT OF LOW SULPHUR FUEL ON LUBRICATION OF MARINE ENGINES

The International Council on Combustion Engines

Conseil International des Machines à Combustion

CONSEIL INTERNATIONAL
DES MACHINES A COMBUSTION

INTERNATIONAL COUNCIL
ON COMBUSTION ENGINES

CIMAC is an international organisation, founded in 1950 by a French initiative to promote technical and scientific knowledge in the field of internal combustion engines (piston engines and gas turbines). This is achieved by the organisation of congresses and working groups.

It is supported by engine manufacturers, engine users, technical universitites, research institutes, component suppliers, fuel and lubricating oil suppliers and several other interested parties.

The National Member Associations (NMAs), National Member Groups (NMGs) and Corporate Members (CMs) as well as previous CIMAC Recommendations are listed in the back of this publication.

This document has been elaborated by the CIMAC Working Group “Marine Lubricants“
and approved by CIMAC in May 2007.

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**FOREWORD BY THE PRESIDENT**

In May of 2006, the Baltic Sea became a SECA which requires all vessels to operate on fuels with less than 1.5 % sulphur or to use suitable approved abatement technology. The use of low sulphur heavy fuel oils (LSHFO) is the most effective way to reduce $SO_X$ emissions and will no doubt be the most commonly used technique to meet the environmental legislations on $SO_X$. Sulphuric acid is highly corrosive and should be neutralised by lubricating oil additives in order to prevent corrosion of the cylinder components.

Local legislation was the pacesetter to the maritime environmental regulations that are either in place today, or are being considered for ratification. The shipping industry, the marine diesel engine designers and manufacturers as well as the oil companies are all making preparations to handle the challenges of the stricter legislation.

The present Recommendation on “GUIDELINES FOR DIESEL ENGINE LUBRICATION, Impact of low sulphur fuel on lubrication of marine engines”.

This recommendation describes the key technical issues that marine engine builders, ship-owners and the marine industry as a whole will face by using low sulphur heavy fuel oils.

Everyone with an interest in engine lubrication can find this paper very topical and useful. My sincere thanks to authors and to all those members of the Working Group who made efforts to publish this CIMAC Recommendation.

Matti Kleimola, President
May 2007

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## ABSTRACT

Environmental legislation already in place has impacted the marine industry, and with new legislations on the horizon, engine manufacturers and shipowners are evaluating a number of options to maintain compliance with emissions standards.

Low sulphur fuel operation may not be restricted to SECAs ($SO_X$ Emission Controlled Areas) but may be encountered all over the world, where low sulphur fuels are readily available (e.g. South America).

This paper describes the key technical issues that marine engine builders, shipowners and the marine industry as a whole will face. Although the primary purpose of this paper is to examine the specific aspects of low sulphur fuel on lubrication, it will also examine, albeit in less detail, other emission concerns.

It is not the purpose of this paper to endorse any single method of emissions control or to suggest preference of any particular method.

## 1 INTRODUCTION

Users of this document should be aware of additional information already released by the CIMAC Working Group - “Fuels” on this subject [1].

Shipowners will be faced with increasing regulatory compliance requirements as new and more stringent emission control legislation is enacted. In addition to the shipowner, other impacted parties will be the engine manufacturers, manufacturers of after-treatment devices, and to a certain degree, the lubricant and additive companies.

Diesel engine development work has been underway for some time in the attempt to design the most practical and cost effective means to ensure compliance with both today's and future environmental regulations,. The different methods have their own advantages and disadvantages in terms of cost and effectiveness. It is not within the scope of this document to compare and contrast the various methods in terms of their relative value proposition.

Although European emission regulations are probably the main cause of the current focus on low sulphur fuel operation, low sulphur fuels are supplied in other parts of the world (e.g. Canada, US and South America) as well.

In researching this subject, it soon became clear that the amount of experience that the collective industry has in terms of operation on low sulphur fuel is relatively limited. The area with the most experience, as of the date of this paper, is in the stationary power sector. Some shipowners have run internal evaluations of low sulphur fuel operation, but only a few have developed enough running hours to be able to claim that they have sufficient experience regarding the complex interactions between the lube oil, the diesel engine operation and the fuel.

The primary focus of this paper will be the reduction of $SO_X$ emissions through the use of low sulphur fuel and the implications this may have on engine lubrication.

## 2 MARINE EMISSION REGULATIONS

Local legislation was the precursor to the maritime environmental regulations that are either in place today, or are being considered for ratification. Leading authorities such as Sweden and Norway as well as the harbour of Hamburg, set up incentives for shipowners to use low sulphur fuels and hence reduce some of the emissions. These local regulations had little true effect as long as marine operation outside the immediate local jurisdiction was still on high sulphur fuel. It was soon determined that a more global approach to the situation was required in order for the regulations to become more effective.

## 2.1. IMO MARPOL legislation [2]

Annex VI of MARPOL 73/78 was ratified on 18 May 2004 specifying that from 19 May 2005 the sulphur content of marine heavy fuel oil used worldwide shall not exceed 4.5 %. At present, this legislation has very little true impact on the marine industry since the majority of the fuels around the world fall below that level. A study conducted by DNV, based on their 2005 worldwide bunker data, showed that only 0.35 % of the fuel sampled from the major ports has a sulphur level greater than 4.5 %. Furthermore, the DNV study indicated that the average fuel sulphur level was 2.8 % worldwide in 2005.

In addition to the MARPOL fuel sulphur and $NO_X$ regulations, MARPOL Annex VI requires detailed record-keeping of the fuel being used. Fuel suppliers also have a responsibility in this process, although the burden will be on the shipowner to ensure compliance. It will also be necessary for the shipowner to maintain records of compliance whenever their main or auxiliary engines undergo significant modifications.

## 2.2. Baltic Sea SECA regulation

In May of 2006, the Baltic Sea became a SECA which requires all vessels to operate on fuels with less than 1.5 % sulphur or to use suitable approved abatement technology.

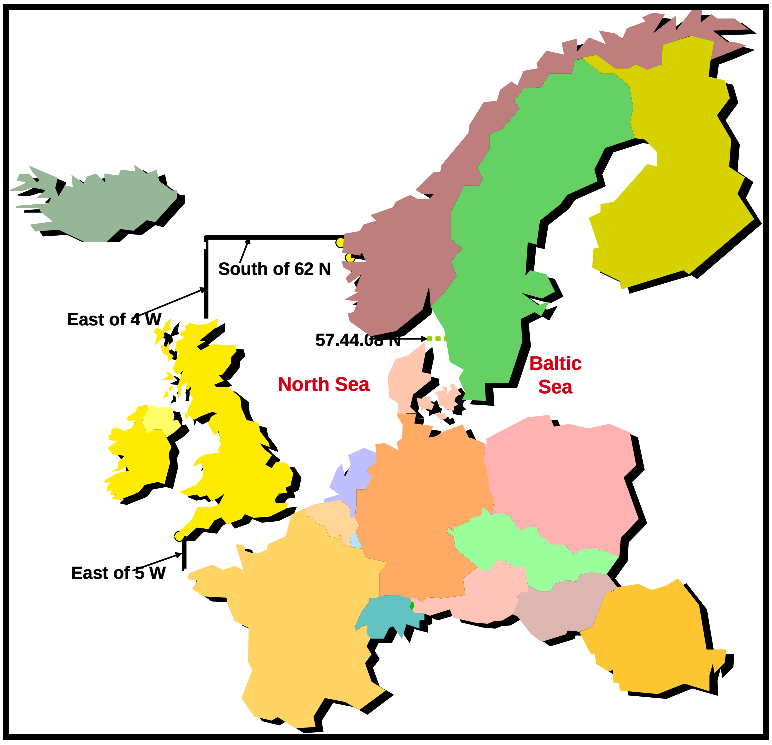



Fig 1: SECAs: Baltic Sea, North Sea and English Channel

## 2.3. North Sea and English Channel SECA regulation

By November 2007 the North Sea and English Channel will become a SECA zone, with regulations the same as outlined for the Baltic Sea.

## 2.4. Other regulations

### 2.4.1. EU Directive 2005/33/EC [3]

The full list of items and exceptions to Directive 2005/33/EC is given in [3]. Some of the conditions for the 2005/33/EC are listed below.

- All ships in the Baltic Sea: Max 1.5 % sulphur as of 11 August 2006
- Passenger ships and cruise ships operating to/from EU ports and in European territorial waters: Max 1.5 % sulphur as of 11 August 2006
- All ships in the North Sea and English Channel: Max 1.5 % sulphur as of 11 August 2007 (Note the IMO legislation for the North Sea and Channel enters into force on the 22 November 2007).
- Sulphur content of MDO in EU waters: Max 1.5 % as of 11 August 2006
- Sulphur content of MGO in EU port and territorial waters. Max 0.2 % until January 2008. After January 2008 max 0.1 % sulphur
- Port and inland waterways operation throughout the EU: Max 0.1 % sulphur fuel except for vessels with short port turn around of less than 2 hours as of 1 January 2010

### 2.4.2. Future SECAs

The Black Sea, Mediterranean, USA, Japan and Hong Kong are being discussed as future SECAs. It is not within the scope of this paper to discuss future SECAs unless their enforcement is imminent.

### 2.4.3 Other Directives / Activities

Although not strictly related to SECA, but likely to impact on fuel sulphur, there are currently significant activities in the USA from the California Air Resources Board (ARB) on particulate matter emission. The following are extracts from Bunkerworld; it reported their proposal:

- applies to all ships within 24 nm from California coastline, except “innocent passage”.
- applies to aux engines and engines for diesel-electric propulsion.

The options are:

- use cleaner (compliant) fuel
- use equally efficient technology
- pay “non-compliance” fees.

In terms of fuels:

- approved fuels (1st January 2007)
  DMA (1.5 %) or DMB with S < 0.5 %.
- approved fuels (1st January 2010)
  MGO (DMA) with S < 0.1 %.

## 3 ENVIRONMENTAL POLLUTANTS FROM MARINE DIESEL ENGINES

There are basically six major emission entities that impact the marine industry. Specifically, and for completeness, they are $NO_X$, $CO_2$, CO, HC, Particulates and $SO_X$, however, only $SO_X$ will be addressed in detail in this paper.

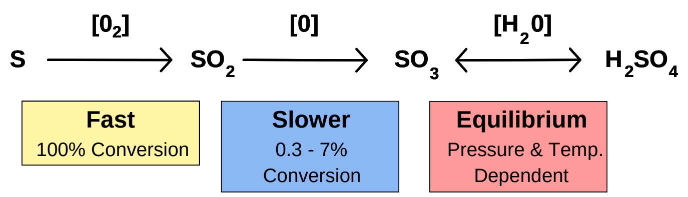
Although $NO_X$ and $SO_X$ have been the principal reduction focus by the industry, regulations pertaining to HC, $CO_2$ and especially particulates are now finding themselves in the spotlight as well.

$NO_X$ $CO_2$, CO, HC and Particulates are products of the combustion process. The degree to which each is formed depends on various factors such as temperature, thermal efficiency, fuel hydrogen to carbon ratio, engine design etc. The engine builders are aware of these factors, however, as reducing one component often induces an increase in another, control measures by means of engine design are limited.

### 3.1. $SO_X$

$SO_X$ is formed during the combustion process from the oxidation of the sulphur in the fuel forming the oxides, $SO_2$ and $SO_3$.

The typical reaction is:




There is a linear relationship between the level of sulphur in the fuel and the amount of $SO_X$ that is produced. Although a small contributor to $SO_X$, lube oils are also a factor. The sulphur level in a 70 BN marine cylinder lubricant is generally between 5000 and 16000ppm. This sulphur comes primarily from the basestock, and to a lesser degree from the additives.

Group I mineral oil basestocks, which are almost exclusively used in marine lube oils, can be in excess of 10000 ppm (1 %) sulphur. Some basestocks, such as synthetics will have no sulphur since they are man made and the unwanted elements can be controlled in the manufacturing process.

The additive contribution to sulphur is very dependent on the type and treat rate of the additives used, but for a 70 BN marine cylinder oil, the additive contribution to the sulphur content of the finished lubricant typically will be between 3,000 and 9,000 ppm sulphur. (Note: In General, the sulphur content of trunk piston engine oils is equal to or lower than that of cylinder oils).

However, to put this into context, calculations for a two-stroke engine with 171 g/kWh SFOC (with a fuel sulphur of 3 %) and 1.3 g/kWhr SLOC (with lube oil sulphur of 1 %), show that 99.8 % of the sulphur comes from the fuel.

## 4 $SO_X$ EMISSION CONTROL TECHNIQUES

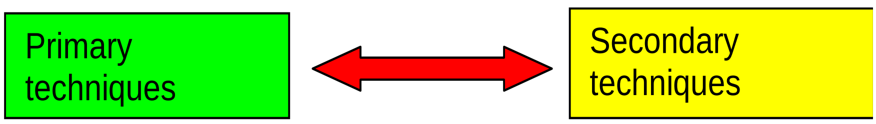
In general, to control $SO_X$ emissions and comply with environmental regulations, the shipowner has the option to operate on:

- low sulphur fuel as purchased
- blends of high and low sulphur fuels available on board. However care must be taken to ensure compatibility of fuels to be blended.

Some techniques being discussed/tested but yet to be commercially proven and to enter the market widely are:

- Continue to run on high sulphur HFO and employ abatement techniques such as scrubbers [4 & 5]
- Engage in emissions trading [6]

It is important to note that each method of controlling $SO_X$ has its trade-offs. The overall topic of $SO_X$ control is wide and complex and is not in the scope of this paper. Brief outlines are given below. $SO_X$ emission reduction techniques fall into two major classifications.




### 4.1. Primary techniques for $SO_X$ emission reduction

Primary techniques for $SO_X$ emission reduction could also be described as pre-combustion methods.

$SO_X$ emissions are directly proportional to the amount of sulphur that enters the combustion chamber; so the less sulphur that goes into the combustion chamber, the less $SO_X$ will be generated.

The use of low sulphur heavy fuel oils (LSHFO) is the most effective way to reduce $SO_X$ emissions and will no doubt be the most commonly used technique to meet the environmental legislations on $SO_X$.

The possible drawbacks for using low sulphur fuel are discussed in chapter 5.4.

### 4.2. Secondary techniques for $SO_X$ emission reduction

After-treatment techniques, as the name implies, operate on an extraction principle whereby the pollutant laden exhaust gas is treated, eg by water extraction techniques such as scrubbing.

Although after-treatment techniques such as exhaust gas scrubbing can be very effective, they may present a cost penalty in terms of both the initial cost and ongoing expense, as well as maintenance issues. They may also have additional costs such as increased (electrical) power, require additional space and it is not yet completely clear exactly to what extent IMO will allow the draining of sulphur containing water into the sea/ocean. The environmental impact of scrubbing is still being studied and its commercial viability/practicability has yet to be widely established/reported.

If practicable, its advantages are obvious:

- Independence of fuel sulphur content (hence resulting in improved fuel availability and price)
    - retain option to burn any HFO
- Capability to move to much lower levels of emissions than strictly required. Although currently known technology is falling short of target, scrubbers in general are designed to achieve greater than 95 % removal of sulphur. As a guide for any technology/solutions, the current IMO $SO_X$ limit is 6.0 g/kWh regardless of fuel sulphur content, therefore, this must be the minimum target. If the scrubber technology can deliver its full potential and control $SO_X$ emissions significantly below legislation limit, it:
    - could offer “trade credits” for emission trading
    - could stimulate further emission control regulations ($SO_X$, $NO_X$, particulate matter (PM)) for tighter limits

## 5 LUBRICATION ASPECTS OF OPERATING ON LOW SULPHUR FUEL

As mentioned previously, the combustion process is such that the sulphur in the fuel can result in formation of sulphuric acid in the engine. Sulphuric acid is highly corrosive and should be neutralised in order to prevent corrosion of the cylinder components.

Crosshead diesel operational and design parameters can have a large influence on the degree of corrosive attack for any given sulphur content of the fuel.

Lubricant properties provide the necessary mechanical lubrication. In addition, the lubricant carries base (also called alkalinity) which neutralises any acid formed. The base (BN) consists primarily of calcium carbonate (limestone - $CaCO_3$). After reaction with acid, calcium sulphate (gypsum -$CaSO_4$) is formed.

Unreacted base ($CaCO_3$) can form a very hard type of deposit. In the two-stroke crosshead diesel engine, this deposit can form on the piston crown. If excess deposit is formed, the lubricant film can be disrupted and scuffing or sudden severe wear may take place.

Although neutralisation is important, some engine designers believe that a degree of corrosion is not entirely bad for an engine. A limited degree of corrosion keeps the metal structure of the cylinder liner surface open which enables the lubricating oil to better adhere to the surface ensuring a good oil film.

For the above reasons, it is important that a proper balance is maintained between the base coming from the lube oil and the fuel sulphur level in order to avoid excessive deposit and to keep the cylinder liner metal structure open.

The various two-stroke engine designers have different recommendations on how to balance the cylinder oil characteristics and the fuel sulphur level. The recommendations will be discussed further in this document (chapter 5.2).

The four-stroke engine is less sensitive to deposit formation as the lubricating oil for four-stroke operation contains less base than the two-stroke cylinder oil. Given in Chapter 5.3 are the points to consider for four stroke engines.

## 5.1. Experience with low sulphur fuel in two-stroke engines

Historically, the engine designers report that in the 1970's low sulphur fuels were only available in a few locations. In the 1990's the engine designers, specifically Wärtsilä and MAN Diesel, began to note some problems with engines that had been operating on LSHFO and standard 70 BN cylinder oils. Specifically, instances of liner polishing leading to scuffing were observed.

The proposed mechanism behind the scuffing incidents was two fold:

a. All acid formed during the combustion was neutralised due to excess base being injected into the cylinder. No corrosion was present to keep the graphite structure of the liner wall open, resulting in a bore polished surface. A bore polished surface is mirror-like, which makes it difficult for the lubricant to adhere to the surface, leading to oil film breakdown.

b. Unreacted base (BN additive) formed hard deposits on the piston crown top land and in the ring groove area.



Fig 2: CaCO3 Deposits on piston top    Fig 3: Bore polish of liner

Individually [a] and [b] can result in increased wear; but the combination of oil film break-down and hard deposits on the piston in severe cases can result in scuffing.

Based on the above, it is importance to reduce/control piston deposits. This can be done by reducing the amount of unused BN additives in the cylinder oil, or by the continuous removal of piston top land deposit.

One solution developed by the engine designers was the introduction of the anti-polishing or piston cleaning ring. This innovation was generally successful in removing the hard deposits and preventing the polishing from occurring.

As a result of the problems experienced, lubricant companies also made available low BN cylinder oils to reduce the amount of unused BN additives. At the same time, technical questions with regard to the impact of reduced feed rate began to emerge.

The scuffing incidents gave low sulphur fuel a negative perception; but in terms of engine operating efficiency and fuel consumption there is no debit / no negative impact.

### 5.2. Two-stroke engine designer recommendations

Each of the three major two-stroke engine designers considers <1.5 % sulphur fuel as LSHFO (low sulphur heavy fuel oil) based on today's standards.

It is generally accepted by the major two-stroke engine manufacturers that consideration should be given to the use of a low (40-50) BN cylinder oil when operating on low sulphur fuels. This should not, however, be viewed as an absolute rule, but rather as a guideline. The major engine designers will usually not recommend against the standard 70 BN cylinder oil when the fuel sulphur is between 1.0 % and 1.5 %, if: (i) the feed rate is appropriately optimised or (ii) the amount of time that the engine will be subjected to the LSHFO is relatively short (1-2 weeks).

When an engine is operated with an optimised cylinder oil feed rate, it should be ensured that the amount of lubricant in the cylinder is adequate to cover the entire swept surface area with a satisfactory oil film and to provide enough acid neutralization so that corrosion is controlled. As the feed rate is decreased the level of base (alkalinity) delivered decreases. In additional, the detergency characteristics of the oil are also decreased. Hence, as the volume of the oil present decreases, the risk of dirtier pistons increases.

With the exception of MHI, the other 2-stroke engine designers recommend that lower BN lubricants (BN40-50) should be considered when operating in the LSHFO regime for extended periods. Again, as a general rule, an extended period is considered to be more than 1 to 2 weeks of continuous operation.

Currently MHI has approached low sulphur fuel operation by placing importance on lubricant feed-rate optimisation rather than reducing the BN. Wärtsilä and MAN Diesel recommend either the reduction of the cylinder oil feed rate or the use of low BN lubricants (or a combination of both) depending on the time frame.

When the fuel sulphur is <1.0 %, most engine designers advise the use of a low BN cylinder oil for operation of more than 48 hours.

<table>
<tr><th>Fuel sulphur level</th><th>MHI</th><th>Wärtsilä</th><th>MAN Diesel</th></tr>
<tr><td>< 1 %</td><td rowspan="3">BN 70<br>Operate on optimised feed-rate as guided by MHI.</td><td>BN 40-50</td><td>BN 40-50</td></tr>
<tr><td>1.0-2.0 %</td><td>BN 40-50 or ensure feed-rate is optimised as guided by Wärtsilä</td><td>BN 40-50 or ensure feed-rate is optimised as guided by MAN Diesel</td></tr>
<tr><td>> 2 %</td><td>BN 70<br>Normal optimised feed rate operation</td><td>BN 70<br>Normal optimised feed rate operation</td></tr>
</table>

Table 1: Summary of engine designer recommendations. More specific recommendations can be provided by the engine designers.

### 5.3. Experience with low sulphur fuel in four-stroke engines

Although the issues regarding the use of LSHFO have been shown to have the most pronounced impact on the two-stroke engine, LSHFO will also be used in four-stroke marine diesel engines.

In discussions with the major four-stroke engine builders, it is clear that based on their experience, they do not anticipate any significant concerns when LSHFO is used, nor do they require the use of a lower BN engine oil when running on this type of fuel for intermittent periods.

In the case of continuous operation on LSHFO, it may be necessary to use a 20-40 BN lubricating oil (as guided by engine designer) for four-stroke engines (rather than the 40-55 BN oils used with higher sulphur fuel) in order to avoid excessive deposits in the combustion chamber, exhaust gasways and turbocharger. However, more operational experience is required to determine if these pose any problems.

More specific recommendations can be provided by the engine designers.

## 5.4. Other aspects of low sulphur fuel operation

### 5.4.1. Viscosity

Some low sulphur fuels, e.g. MDO or MGO, have a relatively low viscosity. All two-stroke engine builders recommend a minimum viscosity level of 2 cSt in order to avoid operational problems to the fuel equipment. The viscosity can be adjusted by temperature control.

The four-stroke manufacturers recommend that the fuel at engine inlet does not fall below 1.8 - 2.8 cSt (depending on engine make and type).

See also Reference [1] for more information and specifics for switching from heavy fuel oil to distillate fuel

### 5.4.2. Tank installation

As low sulphur fuel (distillate or residual) is possibly both more expensive and less available than high sulphur fuel, it is believed that most ships will carry the low sulphur fuel for use when entering SECA areas. In open sea, most engines will probably operate on high sulphur fuel.

The required engine operation on different fuels of various sulphur levels demands that the ship's tank layout design must accommodate both low and high sulphur fuels, as well as low and high BN cylinder oils. It is, however, outside the scope of this document to discuss this in detail.

### 5.4.3. Lubricity

Fuel lubricity is related to the chemical composition of the fuel. Sulphur is one of the compounds in the fuel that imparts lubricity characteristics [7, 8, 9]. Therefore, one might fear that a very low sulphur level reduces the fuels' lubricity and leads to fuel equipment durability problems.

Lubricity issues of low sulphur distillate in large two- and four-stroke diesel engines are relatively unknown as these engines traditionally have operated on MGO, MDO or HFO with higher sulphur levels.

Automotive diesel fuels which are very low on sulphur (< 50ppm) contain additives which enhance lubricity. Lubricity for extremely low sulphur fuel has been well studied by the inland market such that today there are additives, established tests and specifications. The lubricity of the automotive diesel fuels is tested using ISO12156 [10]. If marine diesel fuels fulfill the limits of this method, there is a high probability that these fuels will not cause lubricity problems. There is a good possibility the fuel additive technology from the inland market can be replicated for marine. However, due to the limited experience with such very low sulphur fuels in marine applications, this still remains to be seen.

5.4.4. Liner lacquering

Liner lacquering has been observed on four-stroke engines operating on low sulphur fuel (mainly on MDO or MGO). The lacquer fills in the honing grooves of the liner which results in difficulties in maintaining a good oil film. This can result in high lubricating oil consumption.

Whether the same phenomenon can be expected to occur with two-stroke engines remains to be seen. This should be clarified when more experience with low sulphur fuel is gained on these engines.

## 6 FUTURE ASPECTS

It is highly likely that the future will bring more severe legislation to protect the environment with increased control of exhaust emissions from marine diesel engines. Already more SECAs are being discussed and stricter regulations are pending in European and US inland/coastal waters.

Low sulphur fuel operation of two-stroke diesel engines has put increased focus on cylinder lubrication and how the various mechanisms – mechanical and chemical – influence the cylinder liner condition. Much has been learned about the complicated mechanisms to ensure a good cylinder condition.

The shipping industry, the marine diesel engine designers and manufacturers as well as the oil companies are all making preparations to handle the challenges of the stricter legislation. The full extent of how engine operations will be influenced by low sulphur fuel is still to be established; future wider experience to be gained will enhance the industry understanding and enable further recommendations.

## 7 REFERENCES

[1] CIMAC FUEL WORKING GROUP. Bulletin 1. Use of Low Sulphur Diesel Fuels in Coastal Waters.

[2] IMO MARPOL ANNEX VI

[3] EU Directive 2005/33/EC

[4] [GREGORY, D M. “Expectations and Uneasiness of Low Sulphur Fuel”. Japan Internal Combustion Engine Federation Symposium, Tokyo, Japan. 8th March 2005

[5] GREGORY D M & TRIVETT A. “Using Seawater for scrubbing $SO_X$ and PM from the
exhaust of a marine heavy-fuel engine”. Motorship Conference. 2002

[6] HIRST, D.R. Emissions reductions Trading for Shipping? www.seaat.org/unemit. 2002

[7] BERNASCONI, C. et al. “Lubricity Properties of Diesel Fuels and Their Improvements by Using Lubricity Additives”. IASH 2000, the 7th International Conference on Stability and Handling of Liquid Fuels . Graz, Áustria. 2000.

[8] HADLEY, J.W. and MILLS, B. “The Influence of Composition on the Lubricity of Diesel Fuels. Fourth International Symposium on the Performance Evaluation of Automotive Fuels and Lubricants”. Birmingham, United Kingdom. 1993.

[9] MITCHELL, K. “Diesel Fuel Lubricity – Base Fuel Effects”. SAE SP 1628 . Flórida, Miami, 2001.

[10] ISO12156-1 - “Diesel Fuel - Assessment of lubricity using the high-frequency reciprocating rig (HFRR) - Test method”

# 8 GLOSSARIES

| | |
|---|---|
| **Acid** | Any substance containing hydrogen in combination with a non-metallic element(s) and capable of producing hydrogen ions in solution. An acid is capable of neutralising or being neutralised by a base. |
| **Additives** | A chemical compound or compounds added to a lubricating oil for the purpose of imparting new properties or enhancing existing properties. |
| **Base** | A compound which reacts with an acid to produce a salt plus water. |
| **Base Number (BN)** | A measure of the acid-neutralising power in a lubricating oil, also known as Total Base Number. |
| **Base Stock(Base Oil)** | Refined petroleum oil used in the production of lubricants and other products. The base stock may be used alone or blended with other base stocks and/or additives, to manufacture a finished lubricant. |
| **Centistoke (cSt)** | See Stoke |
| **CO** | Carbon monoxide |
| **$CO_2$** | Carbon dioxide |
| **Crosshead Diesel Engine** | Slow-speed marine diesel engine with separate lubrication systems for cylinders and crankcase. Invariably operating on the 2-stroke cycle these engines derive their name from the crosshead bearing which couples the piston rod and the connecting rod. |
| **Crown** | The top of the piston of an internal combustion engine above the firing ring which is exposed to direct flame impingement. |
| **Cylinder Oil** | Lubricating oil having a high BN for the lubrication of the cylinders of crosshead marine diesel engines and some types of trunk piston engines. |
| **Detergent** | A substance added to a lubricant to keep engine parts clean. In engine oil formulations, the detergents most commonly used are metallic soaps with a reserve of basicity to neutralise acids formed during combustion. |
| **Gas Oil** | A petroleum distillate having a viscosity and distillation range between those of kerosene and light lubricating oil. The distillation range of gas oils usually extends from 200°C to 380°C. Gas oil is used as a fuel in medium and high speed diesel engines and as a burner fuel in heating installations. |
| **Hydrocarbons** | Chemical compounds which consist entirely of carbon and hydrogen. They form the basic composition of all fuels and lubricants derived from petroleum. |
| **IMO** | International maritime organization |
| **Kinematic Viscosity** | Measure of a fluid's resistance to flow under gravity at a specific temperature (usually 40°C or 100°C). Engine oils are classed under SAE, which refers to oil viscosity at 100°C. For fuels, viscosity at 50°C is used. |
| **Liner Lacquers** | Hard resin like coatings formed on the surface of liners filling the honing grooves. Such lacquers may lead to increased oil consumption. |
| **LSHFO** | Low sulphur heavy fuel oil. |
| **Lubricant** | Any substance reducing friction between moving surfaces. |
| **MARPOL** | MARPOL: “Marine Pollution”. It is related to the International Convention 1973 and modified by the protocol of 1978, which includes Annex Vi covering air pollution. |
| **MDO** | Marine Diesel oil is a general purpose fuel which may contain a trace amount of residue and is referred to as distillate MDO ( DB (CIMAC), DMB (ISO8217)), or may contain a significant proportion of residual component in which case it is referred to as blended MDO (DC (CIMAC), DMC (ISO8217)) |
| **MGO** | Marine gas oil – see “Gas Oil” |
| **Neutralisation Number** | A measure of the acidity or alkalinity of an oil. The number is the mass in milligrams of the amount of acid (HCl) or base (KOH) required to neutralise one gram of oil. |
| **$NO_X$** | Oxides of nitrogen |
| **PM** | Particulate matter e.g. in exhaust gas |
| **Scuffing** | Abnormal wear occurring in engines due to localised metal to metal contact. It can be prevented through the use of antiwear, extreme pressure and friction modifier additives. |
| **SECA** | $SO_X$ emission controlled area |
| **SFOC** | Specific fuel oil consumption, based on g/KWh or g/bhph |
| **SLOC** | Specific lube oil consumption, based on g/kWh or g/bhph |
| **$SO_X$** | Oxides of sulphur |
| **Stoke (St)** | The unit of kinematic viscosity, ie, the measurement of a fluid's resistance to flow defined by the ratio |

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|---|---|
| | of the fluid's dynamic viscosity to its density; usually quoted as centistokes (cSt). |
| **Tribology** | The science of lubrication, friction and wear. |
| **Trunk Piston Diesel Engine** | Medium-Speed, or High-speed engine generally using the same oil for both cylinder and crankcase lubrication, and utilising connecting rods to transmit piston power directly to the crankshaft rather than through a crosshead. |
| **Viscosity** | That property of a liquid by virtue of which it offers resistance to motion or flow.  It is commonly regarded as the 'thickness' of the liquid.  Viscosity decreases with increasing temperature. |

## 9 ACKNOWLEDGEMENT

By endorsing this document, CIMAC acknowledges the work accomplished by the CIMAC Working Group "Lubricants" through its worldwide membership. A detailed listing of participating companies, institutions and associations is given on the inside of the back cover.

*The document does not replace the recommendations of engine builders, equipment manufacturers and oil suppliers, which may vary with designs and applications and take precedence over any CIMAC guidance. Users must evaluate whether the guidance in this document is appropriate for their purpose.*

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## Other CIMAC Recommendations

(all available in the CIMAC Technical Paper Database)

| | |
|---|---|
| No. 1 | Recommendations for Diesel Engine Acceptance Tests, 1968 |
| No. 2 | Recommendations for Gas Turbine Acceptance Test, 1968 |
| No. 3 | Recommendations of Measurement for the Overall Noise of Reciprocating Engines, 1970 |
| No. 4 | Recommendations for SI Units for Diesel Engines and Gas Turbines, 1975 |
| No. 5 | Recommendations for Supercharged Diesel Engines, 1971<br>Part I: Engine De-rating on Account of Ambient Conditions<br>Part II: Engine Acceptance Tests |
| No. 6 | Lexicon on Combustion Engines, Technical Terms of the IC Engine and Gas Turbine Industries, 1977 |
| No. 7 | Recommendations regarding Liability – Assured Properties, Publications and Fuels for Diesel Engines, 1985 |
| No. 8 | Recommendations regarding Requirements for Heavy Fuels for Diesel Engines, 1986 (superseded by No. 11) |
| No. 9 | Recommendations concerning the Design of Heavy Fuel Treatment Plants for Diesel Engines, 1987 (superseded by No. 25) |
| No. 10 | Recommendations regarding Liability - Assured Properties, Publications and Fuels for Gas Turbines, 1985 |
| No. 11 | Recommendations regarding Fuel Requirements for Diesel Engines, 1990 |
| No. 12 | Exhaust Emission Measurement - Recommendations for Reciprocating Engines and Gas Turbines, 1991 |
| No. 13 | Guidelines for the Lubrication of Medium Speed Diesel Engines, 1994 |
| No. 14 | Standard Method for the Determination of Structure Borne Noise from Engines, 1994 |
| No. 15 | Guidelines for the Lubrication of two-stroke Crosshead Diesel Engines, 1997 |
| No. 16 | Guidelines for operation and/or maintenance contracts, 1999 |
| No. 17 | Guidelines for Diesel Engines lubrication – Oil consumption of Medium Speed Diesel Engines |
| No. 18 | Guidelines for diesel engines lubrication – Impact of Fuel on Lubrication, 2000 |
| No. 19 | Recommendations for the lubrication of gas engines |
| No. 20 | Guidelines for diesel engines lubrication – Lubrication of large high speed diesel engines, 2002 |
| No. 21 | Recommendations regarding fuel quality for diesel engines, 2003 |
| No. 22 | Guidelines for diesel engines lubrication – Oil degradation, 2004 |
| No. 23 | Standards and methods for sampling and analysing emission components in non-automotive diesel and gas engine exhaust gases - Marine and land based power plant sources, 2005 |
| No. 24 | Treatment of the System Oil in Medium Speed and Crosshead Diesel Engine Installations, 2005 |
| No. 25 | Recommendations concerning the design of heavy fuel treatment plants for diesel engines, 2006 |

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